Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	(1) Accumulation of contaminated water (Storage Tanks, etc.) (2) Treatment of contaminated water (Tritium, etc.) (3) Removal of radioactive materials from the seawater in the harbor (4) Management of contaminated water inside the buildings
Title	Hydrotalcite-based radionuclide removal technology for fresh and saline waters
Submitted by	Dr Grant Douglas, Senior Principal Research Scientist, CSIRO, Australia

2. Overview of Technologies (features, specification, functions, owners, etc.)

Radionuclide-contaminated waters produced from the damaged Fukushima nuclear reactors present a unique remediation challenge given the diverse suite of elements and chemical species present. Effective removal of radionuclides from these waters is further complicated by the presence of both fresh and saline waters within storage tanks and reactor infrastructure.

CSIRO has developed considerable expertise in contaminant remediation, principally to treat wastewaters generated by the uranium industry. In particular, patented CSIRO research known as the "Virtual Curtain" technology has exploited the *in-situ* formation of hydrotalcites, a layered Mg-Al mineral, to simultaneously remove a suite of cationic and anionic contaminants. Images of hydrotalcites formed in-situ from a uranium mining wastewater are shown in Figure 1.

Significantly, the Virtual Curtain technology is generally a one-step, broad spectrum process that requires little infrastructure and thus can be quickly and easily applied to decontaminate affected waters. Importantly, this hydrotalcite-based remediation technique also offers an alternative to conventional lime dosing or ferric iron precipitation with the additional downstream advantage of lower solids generation that is more readily de-watered, enhancing the entire remediation/water recovery cycle. The small volumes of hydrotalcites produced can also be calcined or silicified to produce a stable material suitable for long-term disposal within a containment cell.

The Virtual Curtain technology is distinct from other radionuclide removal technologies: it is simple to implement, it rapidly and simultaneously removes a range of radionuclides, and is inexpensive.

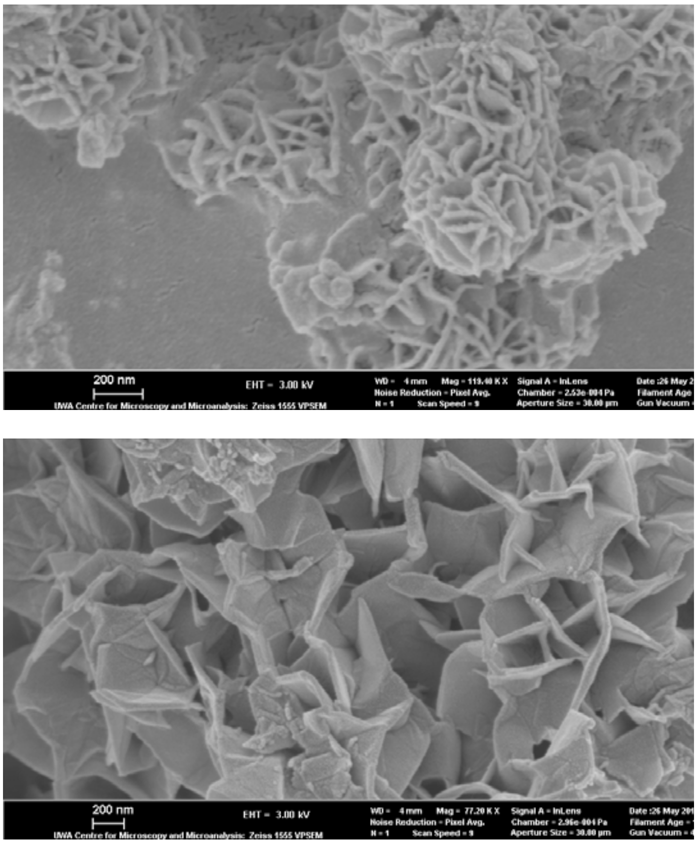

Figure 1. Hydrotalcite (HT) aggregates and detail of HT aggregates. Scale bars are 200 nm.

Importantly, hydrotalcites synthesised in-situ in uranium mine wastewaters have been demonstrated to be able to quantitatively remove a wide variety of radionuclides such as those present in contaminated waters at Fukushima. A study of barren lixiviant (wastewater) decontamination at an in-situ uranium mine in Australia has already demonstrated the capability to remove a range of U-series daughter radionuclides similar to that present in contaminated waters at Fukushima (Table 1). In addition, a wide range of other elements, many of which also represent major radionuclide contaminants at Fukushima, can also be effectively removed (Figure 2) including ^{90}Y, ^{91}Y, ^{113}Cd, ^{115}Cd, ^{95}Zr, ^{60}Co, ^{58}Co, ^{242}Am, ^{242}Cm, in addition to partial removal of ^{135}Cs, ^{137}Cs, ^{89}Sr, and ^{90}Sr. The full range of elements that can be effectively removed from contaminated waters is shown in Figure 1. Thus, the Virtual Curtain technology constitutes a simple, generally one-step broad spectrum tool to deal with the complexity of radionuclide contaminated waters at Fukushima that may complement or augment existing radionuclide removal technologies. Two internationally peer-reviewed manuscripts demonstrating the efficacy of the Virtual Curtain technology as applied to the removal of contaminants from two uranium mine wastewaters with a similar suite of trace element contaminants to those present at Fukushima are contained in Appendix 1.

Table 1. Radionuclide activities for barren and treated lixiviant, hydrotalcite (HT)-based precipitate and percentage removal produced during neutralisation of Beverley North barren lixiviant.

Radionuclide	Barren lixiviant (Bq/L)	Treated lixiviant (Bq/L)	Percent removal	HT precipitate (Bq/kg)
^{238}U	225	2	99.1	67194
^{234}Th	557	0.3	99.9	120986
^{230}Th	8683	66	99.2	1955469
^{226}Ra	324	26	92.0	55282
^{214}Pb	326	26	92.1	53822
^{214}Bi	322	26	92.0	57013
^{210}Pb	2193	4	99.8	488302

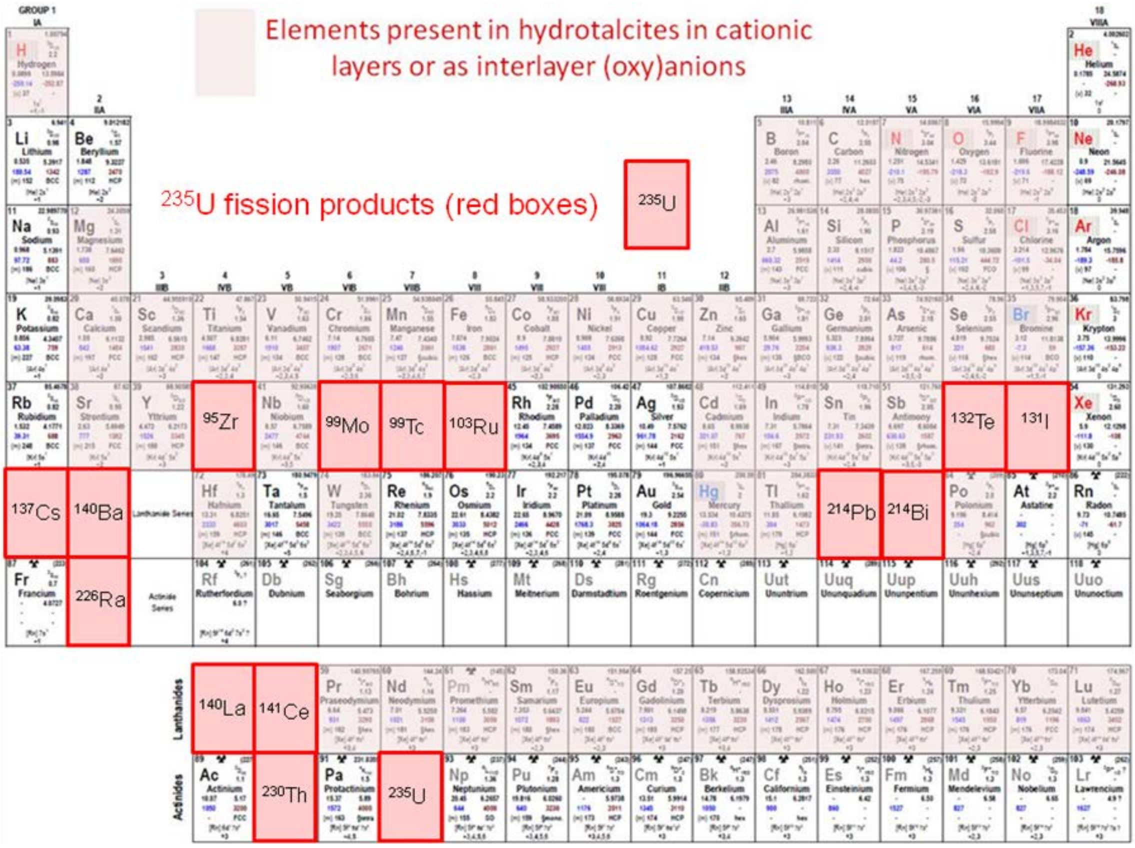

Figure 2. Elements removed by hydrotalcites (pink) and 235U fission products (radionuclides) present at Fukushima.

Table 2. Summary of major (mg/L), trace element (µg/L) and rare earth element (REE) of Beverley North Barren Lixiviant (BL), and post treatment solution compositions.

Analyte	Barren lixiviant (BL)	Treated lixiviant
Major elements (mg/L)		
Na	699	4721
K	46	39
Ca	303	206
Mg	96	33
S	2498	2135
Cl	1129	2779
Total Alkalinity	2.5	19
Trace elements (µg/L)		
Al	323400	300
As	2390	13
Ba	60	7.6
Cd	193	0.1
Co	750	0.5
Cr	900	50
Cs	84	61
Cu	2900	50
F	4200	2400
Fe	335100	100
Ga	204	2.5
Ge	50	0.5
Hf	2	0.025
Li	640	563
Mn	800	50
Mo	44	26
Ni	1600	50
Pb	220	2.5
Rb	562	460
Sb	3	0.4
Sc	200	50
Si	169900	1600
Sn	20	0.5
Sr	4406	2917
Th	1286	0.025
Ti	200	50
Tl	210	11
U	11900	4
V	26000	500
W	13	4.1
Zn	52900	50
Zr	8	0.1
Rare Earth Elements (REE) + Y (µg/L)		
La	976	0.01
Ce	2502	0.01
Pr	345	0.005
Nd	1368	0.01
Sm	344	0.03
Eu	37	0.005
Gd	388	0.02
Tb	68	0.005
Dy	371	0.01
Ho	71	0.005
Er	190	0.005
Tm	25	0.005
Yb	152	0.01
Lu	22	0.01
Y	1514	0.025

*Red numbers denote half analytical detection limits, *na* – not analysed

In the specific context of Fukushima, the hydrotalcite-based technology could be applied to a range of radionuclide contaminated waters, both fresh and saline. Where contaminated saline waters are present, the application of hydrotalcites is especially simple where Mg already present is used as a building block for hydrotalcite formation with only the addition of Na aluminate in the required stoichiometry required. In fresh waters, the technology only requires the appropriate addition of Mg and Na aluminate to form hydrotalcites.

Treatment of radionuclide contaminated waters could be undertaken in either batch or continuous flow configurations. In batch mode, appropriate reagents could be simply added to a tank as solutes, mixed, the hydrotalcite containing the radionuclides and other contaminants allowed to settle, and the waters either decanted or pumped off. In continuous flow mode, soluble reagents could be injected into a pipe containing the contaminants and allowed to react with the precipitated hydrotalcite removed via settling, filtration, or continuous flow centrifugation.

3. Notes (Please provide following information if possible.)

- **Technology readiness level (including cases of application, not limited to nuclear industry, time line for application)**

The Virtual Curtain technology has already been evaluated at laboratory scale using a range of U, Cu, Zn and Au mine water effluents where it has been demonstrated to be successful. The technology has also been used to remove a range of contaminants including Cu, Zn, Mn, and Fe from 70 megalitres of an acidic mine pit water demonstrating the capacity to easily upscale to volumes commensurate with those present at Fukushima.

CSIRO as the Australian national scientific agency with its considerable scientific resources, in collaboration with Virtual Curtain Limited have the technical expertise and experience to quickly evaluate and implement this technology in collaboration with a Japanese government agency or private partner. Both CSIRO and Virtual Curtain Limited are also working in collaboration with AusTrade, an Australian government agency in Sapporo to support the introduction of the technology. Evaluation of the Virtual Curtain technology could be completed within one month and deployment could occur soon thereafter with very low infrastructure and application costs.

- **Challenges**

Given its inherent simplicity, there are few technical challenges in terms of the evaluation of the Virtual Curtain technology or in implementation. To optimize the speed and efficiency of evaluation and implementation Virtual Curtain Limited would seek to partner with a Japanese government agency or private company as described above. Dr Grant Douglas, a Senior

Principal Research Scientist with CSIRO for over 20 years and the inventor of the Virtual Curtain technology (in addition to the patented Phoslock anion absorption technology now used in 25 countries) already has experience working in Japan having made five scientifically-based visits, the most recent in September, 2013. Dr Douglas and Virtual Curtain representatives are available to travel to Japan at short notice to demonstrate and implement the technology.

- **Others (referential information on patent if any)**

The Virtual Curtain technology is licenced to Virtual Curtain Limited, an Australian innovation and technology company. Two patents have been granted internationally and considerable knowledge on process understanding and optimization resides within Virtual Curtain Limited and CSIRO that would facilitate rapid and efficient deployment of the technology.