Report

Ardmore Apatite Phosphate Removal

Prepared for:
Walter van Leeuwen
Agronomist
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Prepared by:
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Government of South Australia

Dear Walter,

Please see below the report for assessment of Ardmore hydroxyapatite for the removal of phosphate in a wastewater/recycled water application.

If you have any questions, please contact us using the details below.

Yours Sincerely,

Rolando Fabris
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1 Background:

Published literature (Troesch *et al*., 2016) suggests natural rock phosphate can be a sustainable solution to remove phosphorous from water sources. Agriflex have a granular rock phosphate apatite product (Figure 1) available for investigation. The goal was to characterise the performance for removal of soluble reactive phosphorous from grey/wastewater sources. Using a fixed bed contactor might provide a cost-effective design solution for smaller wastewater treatment systems or as an upstream filter system to inhibit phosphorous polluting environmental discharges. Based on published investigations, reduction of 15 mg/L phosphorous to 2 mg/L will require between 7 – 30 hours depending on the apatite content of the available product.

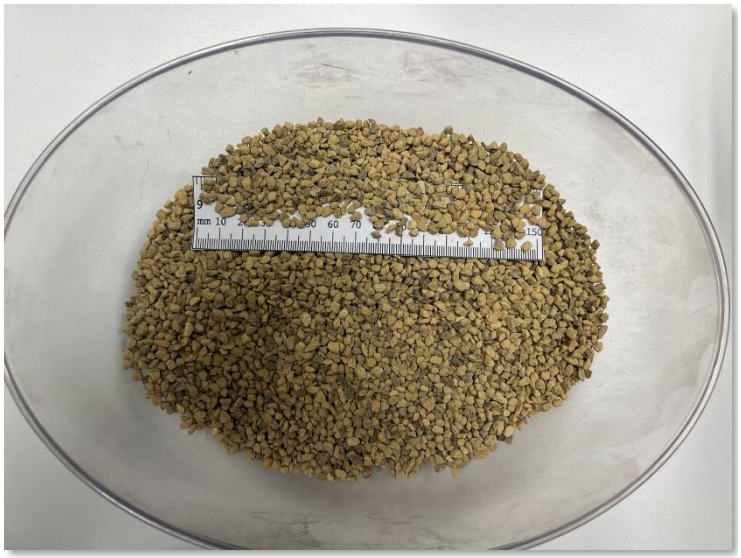

Figure 1: Agriflex Ardmore apatite (≥4mm)

1.1 Supporting Literature

Troesch, S., Esser, D. and Molle, P. (2016) Natural rock phosphate: A sustainable solution for phosphorous removal from wastewater. *Procedia Engineering* **138**, 119-126.

2 Methodology:

Investigation was conducted in 2 stages. The first stage was analysis of water extractable material from Ardmore apatite to ensure discharge quality is compliant. This was a gated decision and work only proceeded to stage 2 when compliant. Stage 2 was assessment of apatite phosphate capacity and adsorption kinetics in a secondary treated (lagoon inlet) wastewater matrix.

2.1 Trace Extractables

A representative (sieved to ≥ 4mm only) 100 g sample of apatite was left in contact with 500 mL of ultrapure water for 48 hours with periodic mixing. The water was then decanted and filtered through 0.45 µm PES and analysed for full scan metals and solutes (e.g. fluoride and chloride), as well as organic parameters; UV absorbance, true colour and dissolved organic carbon.

Testing paused to assess results against Australian Drinking Water Guidelines (ADWG) and Guidelines for Water Recycling for compliance.

2.2 Adsorption Characterisation & Capacity

Due to the anticipated slow adsorption kinetics (based on literature), a flow system arrangement needed to achieve extended empty bed contact times (EBCT), This was achieved in a cylindrical column arrangement, shown in figure 2. Using an elevated outlet as shown allowed gravity flow control while maintaining a submerged bed and only require low pressure / low flow inlet replenishment, which is very representative of a full-scale operational model.

2.2.1 Pilot column testing

1) Apatite media was packed within a pilot filter of dimensions 90mm diameter x 1500mm height at a bed depth of 500mm (Volume ~ 3.2L, Weight ~ 10kg).
2) Test waters were spiked with a soluble metal phosphate (potassium phosphate monobasic). The test water is:
   a. Secondary-treated wastewater (lagoon inlet) with 15 mg/L added phosphate (21.5 mg/L as KH_2PO_4).
3) Twice daily (9 am & 4 pm, 5 days per week):
   a. Extra spiked test water added to feed tank to replace depleted levels. 11 L at 460 mL/hr targeting 7 hr EBCT (Troesch *et al.*, 2016)
   b. Influent pH, temperature, turbidity and conductivity was measured.
   c. Filtrate pH, temperature, turbidity and conductivity was measured.
   d. Influent and filtrate sampled for total (P_TOT_6) and reactive phosphorous (FILT_P).
   e. Data recorded in primary spreadsheet.
4) Column testing was deemed complete when performance fell below **10%** of the initial week average phosphate removal, or 2 months (8 weeks) have elapsed, whichever occurred first.

Figure 2: Pilot column arrangement

Important: Minimum acceptable performance was **67%** reduction of input phosphorous (15 mg/L → 5 mg/L @ 7 hrs EBCT). If initial (week 1) results did not achieve this, the experiment would have been terminated and completed.

3 Results

3.1 Stage 1 – Trace Extractables

A representative (sieved to ≥ 4mm only) 100 g sample of apatite was left in contact with 500 mL of ultrapure water for 48 hours with periodic mixing. The water was decanted and filtered through 0.45 µm PES and analysed for full scan metals and solutes (e.g. fluoride and chloride), as well as organic parameters; UV absorbance, true colour and dissolved organic carbon.

Table 1: Organic water quality parameters

Colour (HU)	UV_{254} absorbance (/cm)	DOC (mg/L)
<1	0.002	0.5

Ardmore apatite has minimal extractable organics. No issues with progression.

Table 2: Metals – Not Detected

Element	Result (mg/L)
Antimony	<0.0003
Beryllium	<0.0002
Bismuth	<0.0001
Cadmium	<0.0001
Cobalt	<0.0001
Iron	<0.0005
Lanthanum	<0.0001
Lead	<0.0001
Mercury	<0.00003
Silver	<0.00002
Thallium	<0.0001
Thorium	<0.0001
Tin	<0.0004
Uranium	<0.0001

Metals in table 2 were analysed but returned results below detection limit, removing them from further consideration.

Table 3: Metals – Detected but below guidelines

Element	Phase	LOR#	Result	ADWG#	Australian Recycled Water Guidelines	
		(mg/L)	(mg/L)	Health	LTV#	STV#
Aluminium	Soluble	0.001	**0.006**	0.2	5	20
	Total	0.001	**0.007**			
Arsenic	Soluble	0.0003	**0.00145**	0.007	0.1	2
	Total	0.0003	**0.00146**			
Barium	Soluble	0.0005	**0.0178**	0.7	n/a	n/a
	Total	0.0005	**0.0170**			
Boron	Soluble	0.02	**0.112**	0.3	0.5	1.5
Calcium	Total	0.1	**31.2**	no value	n/a	n/a
Chromium	Soluble	0.0001	**0.0008**	0.05	0.1	1
	Total	0.0001	**0.0008**			
Copper	Soluble	0.0001	**0.0007**	2	0.2	5
	Total	0.0001	**0.0008**			
Lithium	Total	0.0003	**0.0019**	no value	2.5	2.5
Magnesium	Total	0.05	**4.40**	no value	n/a	n/a
Manganese	Soluble	0.0001	**0.0009**	0.5	0.2	1
	Total	0.0001	**0.0010**			
Molybdenum	Soluble	0.0001	**0.0041**	0.05	0.01	0.05
	Total	0.0001	**0.0041**			
Nickel	Soluble	0.0001	**0.0014**	0.02	0.2	2
	Total	0.0001	**0.0014**			
Phosphorus	Total	0.005	**0.016**	no value	n/a	n/a
Potassium	Total	0.05	**1.80**	no value	n/a	n/a
Selenium	Soluble	0.0001	**0.0001**	0.01	0.02	0.05
	Total	0.0001	**0.0002**			
Silica	Total	0.1	**10.0**	80	n/a	n/a
Sodium	Soluble	0.04	**34.4**	no value	n/a	n/a
Strontium	Soluble	0.0001	**na**	no value	n/a	n/a
	Total	0.0001	**0.0895**			
Titanium	Soluble	0.0003	**<0.0003**	no value	n/a	n/a
	Total	0.0003	**0.0006**			
Vanadium	Soluble	0.0001	**0.0169**	no value	0.1	0.5
	Total	0.0001	**0.0170**			
Zinc	Total	0.0003	**0.0026**	3	2	5

LOR = Limit if reporting; ADWG = Australian Drinking Water Guidelines; LTV = Long-term trigger value; STV = Short-term trigger value.

EPA guidelines state that meeting Australian Drinking Water Guidelines (ADWG) demonstrates the highest level of challenge and is best practice. We have compared to the Australian Recycled Water Guidelines and ADWG, consistent with possible in future developments towards environmental stewardship and circular economy United Nations Sustainability Goals.

Extractables from the Ardmore apatite product are well below the most stringent guideline limits and there were no issues preventing progress to the second stage.

3.2 Stage 2 - Adsorption Characterisation & Capacity

In processing the column performance data, plug flow characteristics were assumed for simplicity, meaning a volume of water entering the column moved progressively with minimal blending to exit the column contactor after the engineered 7-hour contact time. In practice this involved comparing the 9am (morning) influent to the 4pm (afternoon) product water quality. Similarly, the afternoon influent was compared to the following morning product water quality in all the following charts (Figures 3 – 7). To aid in clear data visualisation, daily results (Appendix A) were averaged into weekly figures for graphing.

The greatest focus was paid to the target analyte, phosphorous in figures 3 & 4., However, other water quality parameters were also consistently measured to assess if there were any undesirable consequences associated with operation of the contactor.

Total phosphorous removal was very effective (>98%) from the first sample to the final week 8 sample where influent concentrations increased (Figure 3). With such steady removal, it is difficult to reliably comment on trend and possible contactor capacity, but the indication is that effective performance would have continued well beyond the investigated period, as suggested in published literature.

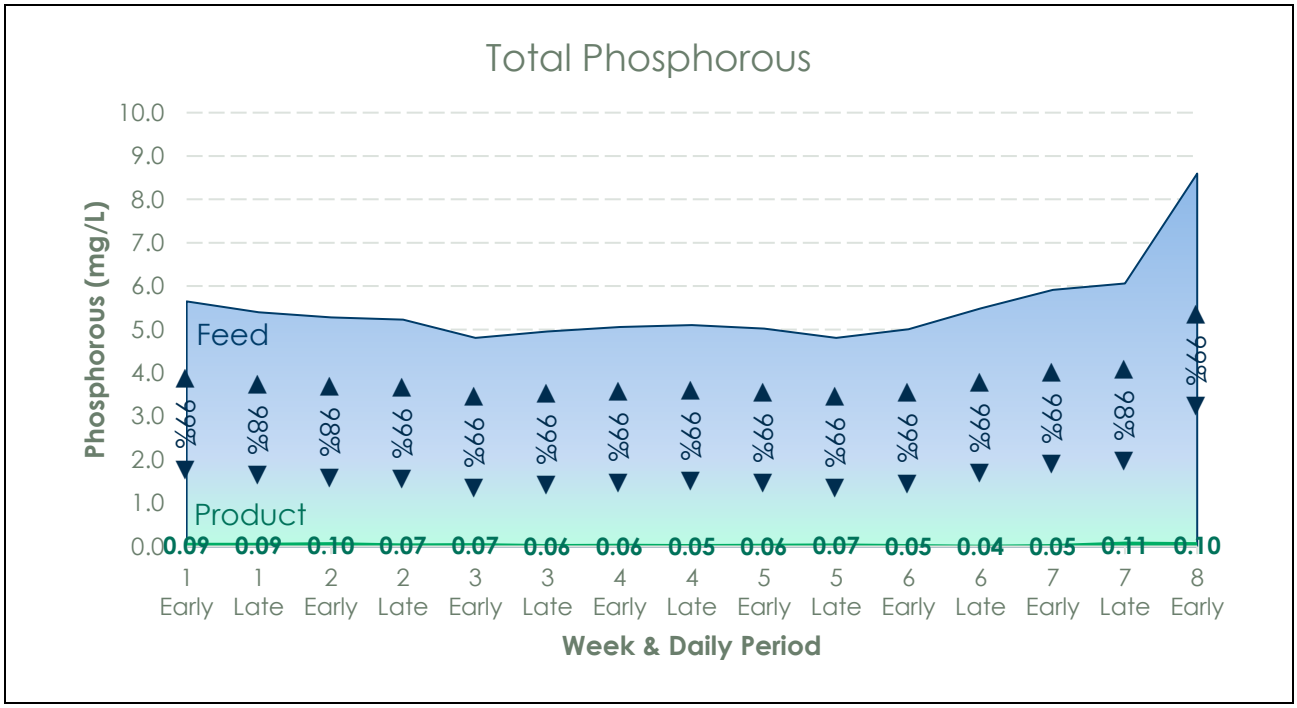

Figure 3: Column contactor total phosphorous removal

Reactive phosphorous removal is perhaps more relevant for a remedial treatment process, as it represents the fraction of phosphorous that is more bioavailable. Removal by the contactor was equally effective (>98%) and consistent (Figure 4).

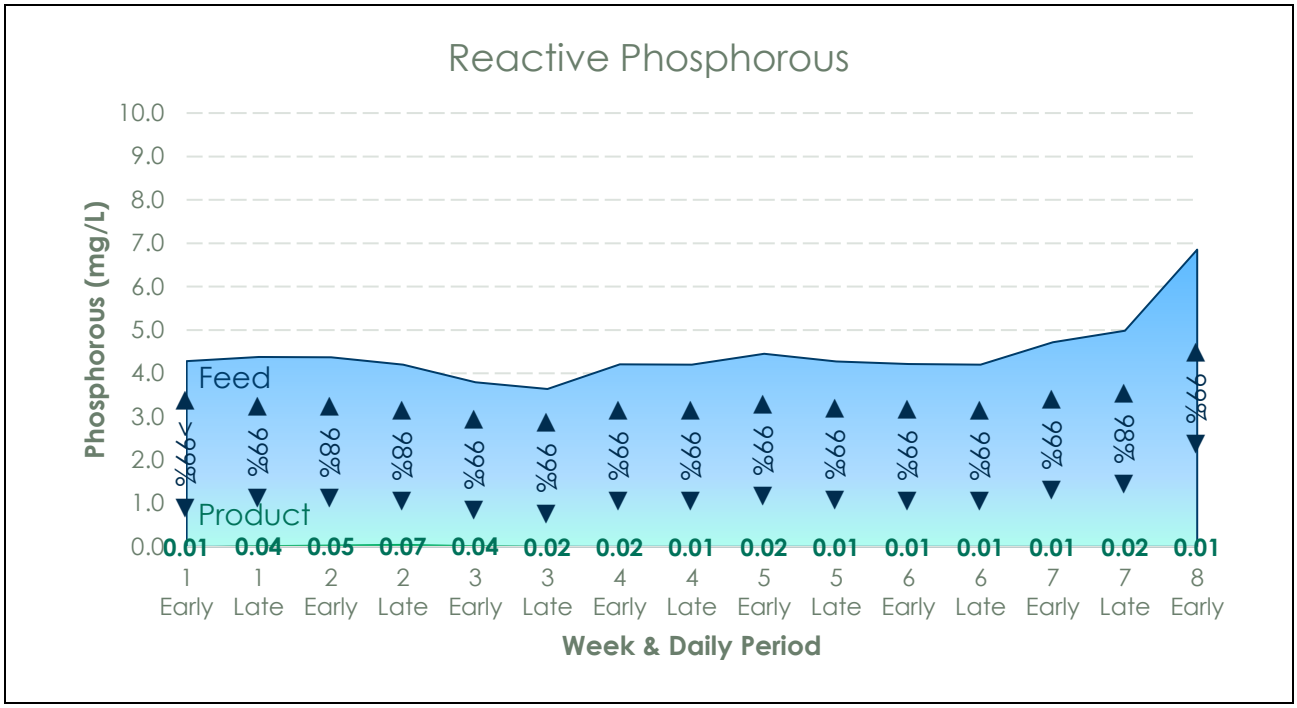

Figure 4: Column contactor reactive phosphorous removal

The change in pH across the contactor was an average increase of 0.1 units (Figure 5). This is generally within the error of the analytical testing. As such, this would not require any remedial adjustments in a typical industrial or environmental application.

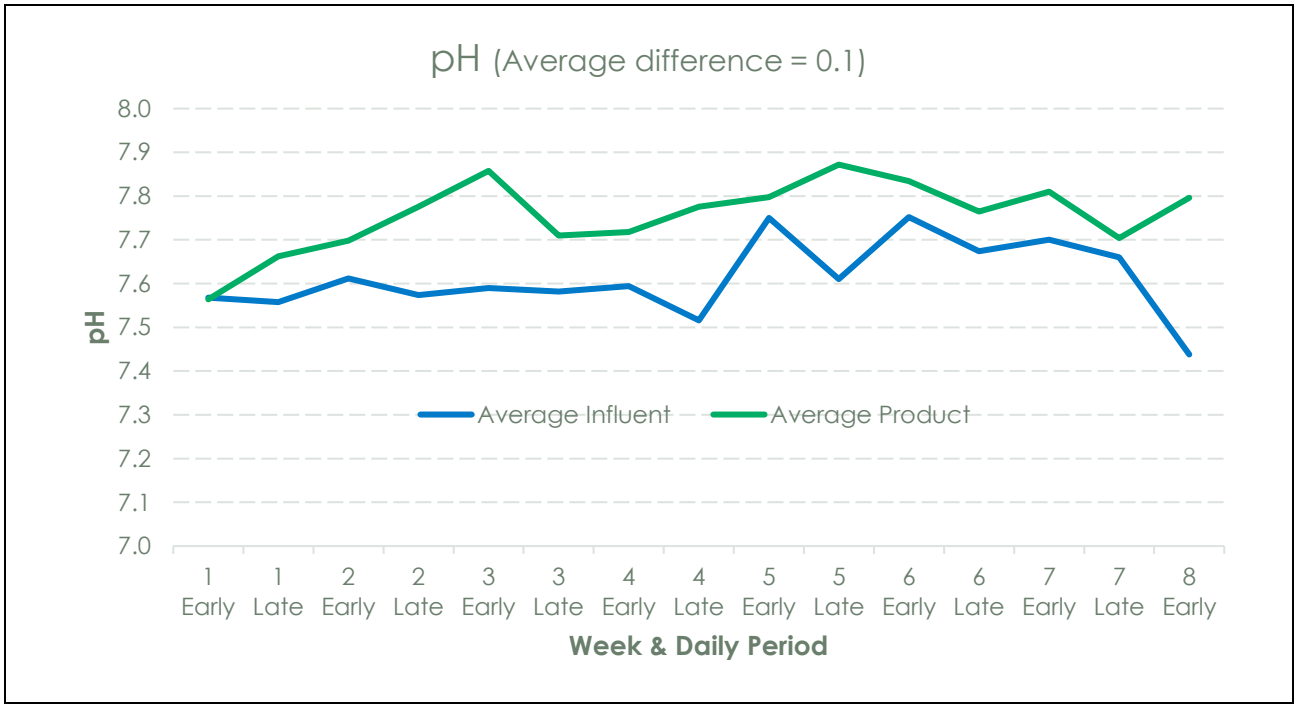

Figure 5: Column contactor pH variation influent to product

Apart from an initial turbidity spike (Appendix A, Week 1, Monday 9am) as fine material generated during sieving and column filling was purged, turbidity was low and despite

not being designed for particle removal, it acted to equilibrate the variable influent turbidity (Figure 6). This showed a trend of further improvement as the contactor matured and the apatite media fully settled around the end of week 2.

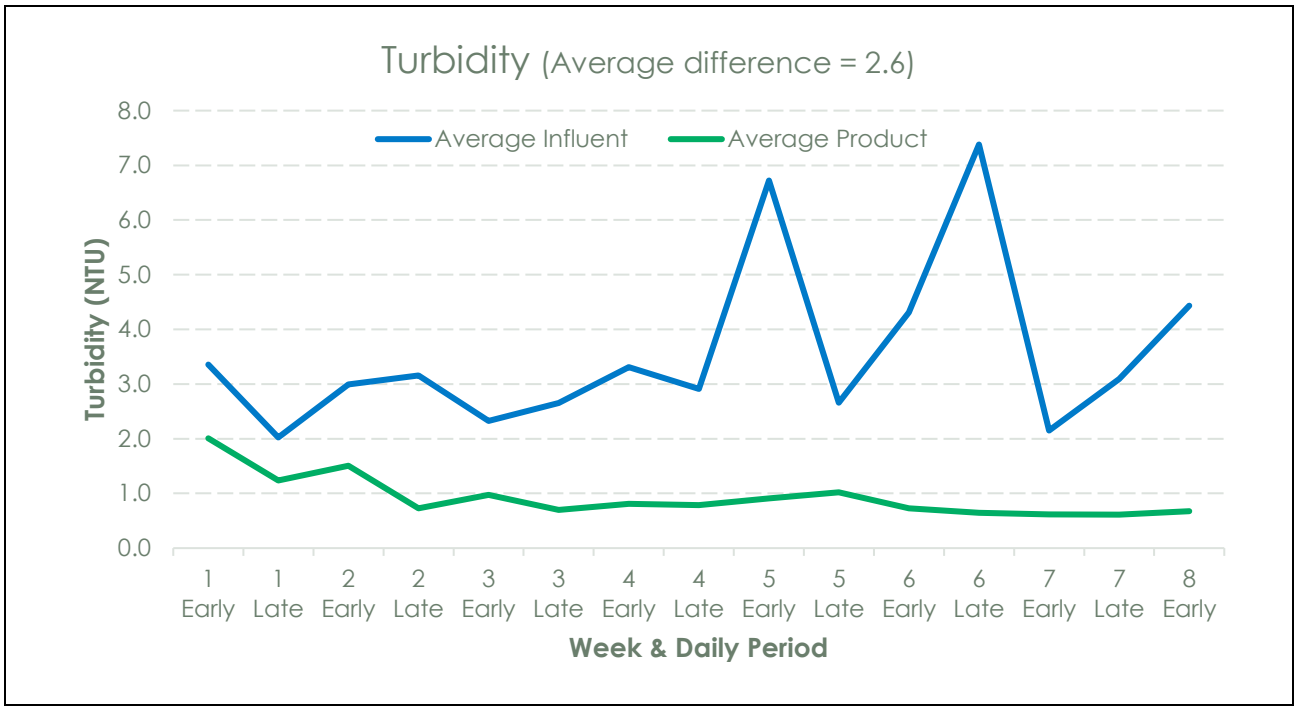

Figure 6: Column contactor turbidity variation influent to product

Conductivity was generally slightly reduced (average 36 µS/cm) across the 8-week investigation, consistent with removal of a charged compound (phosphorous) from the treated and spiked wastewater. This difference would not be considered significant enough to require any post-contactor adjustment.

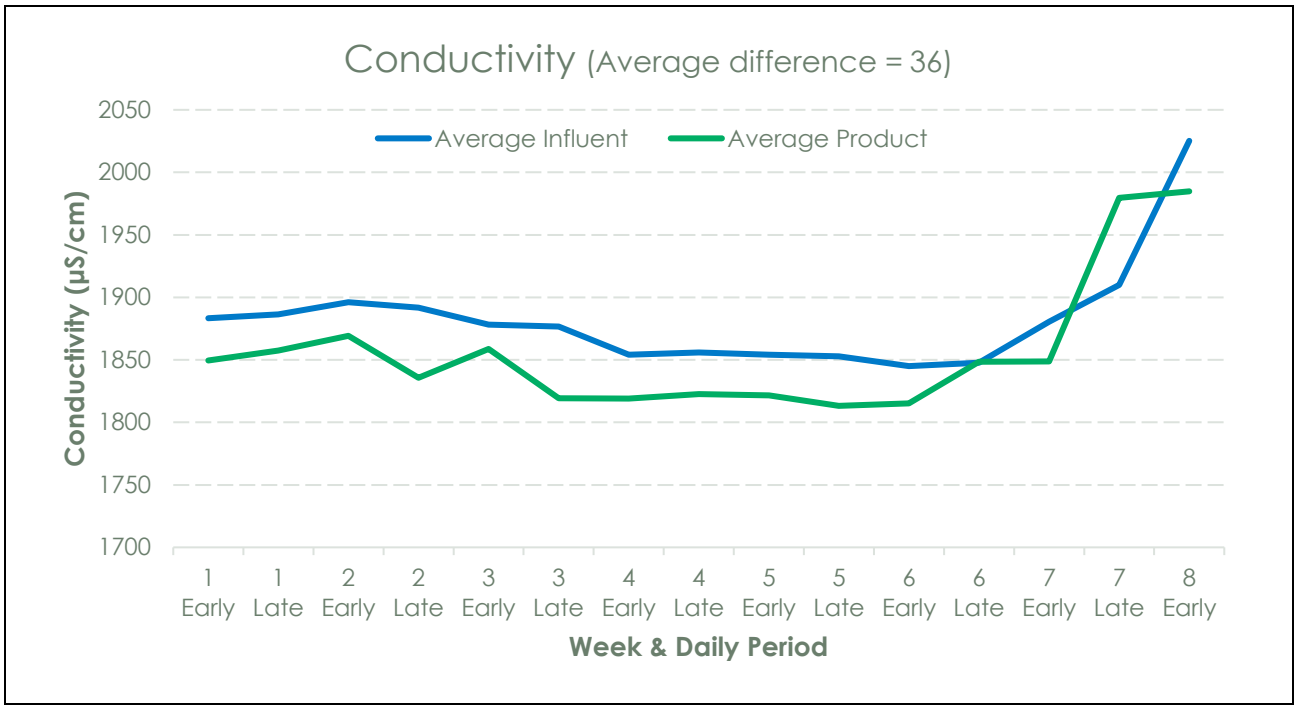

Figure 7: Column contactor conductivity variation influent to product

4 Summary and Recommendations

Ardmore apatite has minimal extractable organics and low or undetectable concentrations of soluble metals. The product water from contact with the apatite will meet stringent Australian recycled water and/or drinking water guidelines.

After an engineered 7-hour contact, Ardmore apatite removes greater than 98% of both reactive and total phosphorous at typical inlet concentrations (15mg/L as PO_4) consistently over 8-weeks with no measurable loss of performance.

Water quality (pH and conductivity) after passing the contactor is minimally impacted and inlet turbidity is attenuated, with similar performance characteristics to a coarse-grain granular media filter.

The challenge in larger scaled applications will be the requirement for long (greater than 7-hour) contact times, translating to large contactor volumes to maintain product flows and hence large plant footprint.

Generally, Ardmore apatite is a very effective low-technology solution for phosphorous removal, with minimal undesirable water quality impacts.

5 Conditions of use of this Report

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Appendix A Stage 2 Column monitoring Data

Week 1			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	01-May	1	7.4	22.4	1.61	1868	5.20	4.57	7.4	22.6	3.39	1874	5.01	4.49
Tues	02-May	2	7.6	22.4	2.59	1866	5.28	4.52	7.6	22.4	1.31	1875	5.20	4.38
Wed	03-May	3	7.7	22.3	3.34	1890	5.19	3.57	7.6	22.5	1.87	1895	5.28	4.16
Thur	04-May	4	7.7	22.3	6.36	1899	5.82	4.44	7.6	22.5	1.4	1895	5.33	4.51
Fri	05-May	5	7.5	22.2	2.89	1894	6.75	4.32	7.6	22	2.15	1893	6.16	4.35
		Mean	**7.6**	**22.3**	**3.4**	**1883**	**5.65**	**4.28**	**7.6**	**22.4**	**2.0**	**1886**	**5.40**	**4.38**
		SD	**0.1**	**0.1**	**1.8**	**15**	**0.67**	**0.41**	**0.1**	**0.2**	**0.8**	**11**	**0.44**	**0.14**
		%RSD					**11.8%**	**9.6%**					**8.2%**	**3.2%**

Week 1			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	01-May	1	7.6	22.8	217	1892	7.14	0.006	7.5	22.7	5.72	1777	0.110	0.005
Tues	02-May	2	7.4	22.5	0.81	1865	0.046	0.007	7.5	22.5	0.6	1868	0.082	0.005
Wed	03-May	3	7.5	22.4	0.49	1878	0.061	0.004	7.6	22.6	0.58	1884	0.056	0.004
Thur	04-May	4	7.5	22.3	0.8	1866	0.077	0.009	7.7	22.4	1.24	1867	0.086	0.006
Fri	05-May	5	7.6	22.2	1.14	1853	0.104	0.019	7.7	22.6	1.9	1851	0.096	0.008
		Mean	**7.5**	**22.4**	**44.05**	**1871**	**0.072**	**0.010**	**7.6**	**22.6**	**2.0**	**1849**	**0.086**	**0.006**
		SD	**0.1**	**0.2**	**96.68**	**15**	**0.025**	**0.007**	**0.1**	**0.1**	**2.1**	**42**	**0.020**	**0.002**
		%RSD					**34.5%**	**66.7%**					**23.2%**	**27.1%**

Week 2			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	08-May	8	7.6	21.8	2.62	1897	5.07	4.53	7.7	22.5	4.85	1895	5.31	4.51
Tues	09-May	9	7.6	21.9	1.98	1898	5.38	4.77	7.6	21.5	2.04	1892	5.13	4.67
Wed	10-May	10	7.6	22.1	3.63	1895	5.65	4.46	7.6	22.2	3.35	1888	5.72	4.38
Thur	11-May	11	7.7	22.1	3.85	1900	5.21	4.07	7.5	20.7	2.75	1893	5.17	3.41
Fri	12-May	12	7.6	22	2.89	1890	5.09	4.01	7.6	22.6	2.81	1891	4.82	4.03
		Mean	**7.6**	**22.0**	**3.0**	**1896**	**5.28**	**4.37**	**7.6**	**21.9**	**3.2**	**1892**	**5.23**	**4.20**
		SD	**0.0**	**0.1**	**0.8**	**4**	**0.24**	**0.32**	**0.1**	**0.8**	**1.1**	**3**	**0.33**	**0.50**
		%RSD					**4.6%**	**7.4%**					**6.3%**	**11.9%**

Week 2			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	08-May	8	7.6	22.2	0.98	1877	0.080	0.029	7.5	22.5	2.07	1943	0.128	0.025
Tues	09-May	9	7.8	22.1	2.51	1855	0.103	0.016	7.7	22.2	2.09	1857	0.110	0.009
Wed	10-May	10	7.6	22.3	1.10	1844	0.107	0.059	7.7	22.5	1.45	1843	0.107	0.027
Thur	11-May	11	7.7	22.1	0.80	1860	0.074	0.010	7.8	22.5	1.08	1856	0.071	0.122
Fri	12-May	12	7.7	22.2	0.81	1851	0.069	0.075	7.8	22.7	0.84	1847	0.070	0.061
		Mean	**7.7**	**22.2**	**1.2**	**1857**	**0.087**	**0.038**	**7.7**	**22.5**	**1.5**	**1869**	**0.097**	**0.049**
		SD	**0.1**	**0.1**	**0.7**	**12**	**0.017**	**0.028**	**0.1**	**0.2**	**0.6**	**42**	**0.026**	**0.045**
		%RSD					**20.0%**	**74.3%**					**26.4%**	**92.4%**

Week 3			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	15-May	15	7.5	21.9	1.77	1896	5.70	3.48	7.5	22.4	2.69	1892	5.54	3.47
Tues	16-May	16	7.7	22.4	2.41	1891	5.52	4.00	7.6	22.3	2.04	1889	5.21	3.79
Wed	17-May	17	7.6	21.5	2.81	1889	4.32	3.75	7.6	22.4	1.63	1887	4.75	3.63
Thur	18-May	18	7.5	20.6	1.89	1849	3.88	3.75	7.5	22	2.95	1847	4.51	3.63
Fri	19-May	19	7.7	22.3	2.75	1866	4.62	4.00	7.7	22.7	3.97	1868	4.75	3.68
		Mean	**7.6**	**21.7**	**2.3**	**1878**	**4.81**	**3.80**	**7.6**	**22.4**	**2.7**	**1877**	**4.95**	**3.64**
		SD	**0.1**	**0.7**	**0.5**	**20**	**0.78**	**0.22**	**0.1**	**0.3**	**0.9**	**19**	**0.42**	**0.12**
		%RSD					**16.2%**	**5.7%**					**8.4%**	**3.2%**

Week 3			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	15-May	15	7.7	22.3	1.00	1821	0.080	0.003	7.8	22.5	1.84	1932	0.100	0.004
Tues	16-May	16	7.7	22.4	1.10	1861	0.092	0.022	8.0	22.5	1.35	1862	0.080	0.005
Wed	17-May	17	7.8	22.3	0.63	1847	0.069	0.022	8.0	23.5	0.57	1852	0.057	<0.003
Thur	18-May	18	8.0	22	0.49	1812	0.057	0.162	7.8	22.4	0.69	1815	0.065	0.130
Fri	19-May	19	7.8	22	0.43	1837	0.058	<0.003	7.8	22.4	0.42	1832	0.067	0.011
		Mean	**7.8**	**22.2**	**0.7**	**1836**	**0.069**	**0.069**	**7.9**	**22.7**	**1.0**	**1859**	**0.074**	**0.038**
		SD	**0.1**	**0.2**	**0.3**	**20**	**0.016**	**0.081**	**0.1**	**0.5**	**0.6**	**45**	**0.017**	**0.062**
		%RSD					**23.6%**	**117.7%**					**22.8%**	**164.7%**

Week 4			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	22-May	22	7.5	22.2	1.26	1882	5.33	3.88	7.5	22.6	2.59	1882	5.11	3.94
Tues	23-May	23	7.6	22.8	1.66	1884	4.59	3.62	7.4	22.9	1.34	1886	5.11	3.64
Wed	24-May	24	7.7	22.9	11.40	1846	5.74	4.51	7.5	22.8	4.40	1855	5.85	4.60
Thur	25-May	25	7.6	22.8	1.56	1830	5.27	4.81	7.5	22.9	5.56	1829	5.19	4.75
Fri	26-May	26	7.6	22.6	0.68	1829	4.35	4.20	7.7	22.8	0.68	1828	4.27	4.08
		Mean	**7.6**	**22.7**	**3.3**	**1854**	**5.06**	**4.20**	**7.5**	**22.8**	**2.9**	**1856**	**5.11**	**4.20**
		SD	**0.1**	**0.3**	**4.5**	**27**	**0.57**	**0.48**	**0.1**	**0.1**	**2.0**	**28**	**0.56**	**0.46**
		%RSD					**11.3%**	**11.3%**					**11.0%**	**11.0%**

Week 4			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	22-May	22	7.7	22.3	1.09	1833	0.068	<0.003	7.7	22.7	1.88	1851	0.084	0.011
Tues	23-May	23	7.7	22.7	0.92	1862	0.077	<0.003	7.6	22.7	0.77	1855	0.073	<0.003
Wed	24-May	24	7.8	22.8	0.42	1813	0.054	0.009	7.7	22.8	0.36	1809	0.057	0.007
Thur	25-May	25	7.7	22.8	0.49	1797	0.050	0.021	7.8	22.6	0.47	1790	0.048	0.022
Fri	26-May	26	7.7	22.6	0.57	1792	0.042	0.034	7.7	22.6	0.58	1790	0.042	0.032
		Mean	**7.7**	**22.6**	**0.7**	**1819**	**0.056**	**0.021**	**7.7**	**22.7**	**0.8**	**1819**	**0.061**	**0.018**
		SD	**0.1**	**0.2**	**0.3**	**29**	**0.015**	**0.013**	**0.1**	**0.1**	**0.6**	**32**	**0.017**	**0.011**
		%RSD					**26.9%**	**58.6%**					**28.7%**	**62.7%**

Week 5			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	29-May	29	7.7	22.7	3.45	1861	5.41	4.36	7.7	22.9	3.08	1861	5.36	4.41
Tues	30-May	30	7.7	22.9	11.80	1857	4.89	4.72	7.5	22.9	0.75	1854	5.10	4.68
Wed	31-May	31	7.8	22.6	13.90	1855	4.99	4.36	7.6	22.6	2.36	1848	4.68	4.41
Thur	01-Jun	32	7.8	22.6	1.74	1849	4.52	4.58	7.7	22.6	3.42	1851	4.29	4.11
Fri	02-Jun	33	7.8	22.6	2.72	1849	5.31	4.23	7.6	22.5	3.68	1850	4.61	3.74
		Mean	**7.8**	**22.7**	**6.7**	**1854**	**5.02**	**4.45**	**7.6**	**22.7**	**2.7**	**1853**	**4.81**	**4.27**
		SD	**0.0**	**0.1**	**5.7**	**5**	**0.35**	**0.20**	**0.1**	**0.2**	**1.2**	**5**	**0.42**	**0.36**
		%RSD					**7.1%**	**4.4%**					**8.8%**	**8.4%**

Week 5			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	29-May	29	7.8	22.7	1.31	1828	0.056	0.037	7.8	22.7	1.19	1844	0.067	0.029
Tues	30-May	30	7.6	22.9	0.80	1819	0.056	0.003	7.6	22.9	0.81	1814	0.065	0.008
Wed	31-May	31	7.8	22.6	0.64	1821	0.053	0.024	7.8	22.6	0.93	1816	0.066	0.027
Thur	01-Jun	32	7.8	22.6	0.58	1825	0.051	0.012	7.9	22.5	0.45	1821	0.052	0.012
Fri	02-Jun	33	7.9	22.6	0.61	1820	0.053	0.009	7.9	22.8	1.16	1813	0.061	0.012
		Mean	**7.8**	**22.7**	**0.8**	**1823**	**0.053**	**0.012**	**7.8**	**22.7**	**0.9**	**1822**	**0.062**	**0.018**
		SD	**0.1**	**0.1**	**0.3**	**4**	**0.002**	**0.009**	**0.1**	**0.2**	**0.3**	**13**	**0.006**	**0.010**
		%RSD					**3.9%**	**73.6%**					**9.9%**	**54.9%**

Week 6			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	05-Jun	36	7.7	22.6	0.78	1847	4.72	4.24	7.7	23.2	0.56	1850	4.18	3.83
Tues	06-Jun	37	7.7	22.5	1.44	1841	4.83	4.21	7.5	22.7	1.61	1847	4.67	4.23
Wed	07-Jun	38	7.9	22	5.40	1844	4.87	4.21	7.6	22	2.52	1846	4.91	4.30
Thur	08-Jun	39	7.9	21.6	5.11	1845	5.39	3.95	7.6	21.7	5.21	1847	5.52	4.17
Fri	09-Jun	40	7.7	22.6	8.83	1848	5.24	4.47	7.9	22.7	27.00	1848	8.16	4.46
		Mean	**7.8**	**22.3**	**4.3**	**1845**	**5.01**	**4.22**	**7.7**	**22.5**	**7.4**	**1848**	**5.49**	**4.20**
		SD	**0.1**	**0.4**	**3.3**	**3**	**0.29**	**0.18**	**0.2**	**0.6**	**11.1**	**2**	**1.57**	**0.23**
		%RSD					**5.8%**	**4.4%**					**28.6%**	**5.5%**

Week 6			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	05-Jun	36	7.8	22.4	0.73	1812	0.244	0.098	7.8	23.2	0.90	1821	0.057	0.012
Tues	06-Jun	37	7.8	22.7	2.62	1808	0.137	0.013	7.7	22.7	0.93	1811	0.065	0.010
Wed	07-Jun	38	8.0	22	0.58	1813	0.046	<0.003	7.9	22	0.50	1811	0.044	<0.003
Thur	08-Jun	39	7.9	21.7	0.64	1814	0.048	0.004	8.0	21.6	0.57	1813	0.049	0.004
Fri	09-Jun	40	7.9	22.6	0.53	1819	0.050	0.008	7.9	22.6	0.73	1820	0.055	<0.003
		Mean	**7.9**	**22.3**	**1.0**	**1813**	**0.070**	**0.008**	**7.8**	**22.4**	**0.7**	**1815**	**0.054**	**0.009**
		SD	**0.1**	**0.4**	**0.9**	**4**	**0.045**	**0.005**	**0.1**	**0.6**	**0.2**	**5**	**0.008**	**0.004**
		%RSD					**63.4%**	**54.1%**					**14.8%**	**48.0%**

Week 7			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	12-Jun	43	Public Holiday											
Tues	13-Jun	44	7.6	22.6	1.25	1851	5.28	4.36	7.6	22.7	1.03	1847	5.29	4.37
Wed	14-Jun	45	7.8	21.9	1.69	1841	4.86	4.68	7.7	21.9	1.77	1868	5.09	4.95
Thur	15-Jun	46	7.7	22.1	4.64	1867	5.56	4.67	7.6	21.9	6.37	1962	6.40	5.48
Fri	16-Jun	47	7.7	22.2	1.03	1963	7.97	5.16	7.8	22.5	3.19	1963	7.46	5.14
		Mean	**7.7**	**22.2**	**2.2**	**1881**	**5.92**	**4.72**	**7.7**	**22.3**	**3.1**	**1910**	**6.06**	**4.99**
		SD	**0.1**	**0.3**	**1.7**	**56**	**1.40**	**0.33**	**0.1**	**0.4**	**2.4**	**61**	**1.10**	**0.46**
		%RSD					**23.6%**	**7.0%**					**18.1%**	**9.3%**

Week 7			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	12-Jun	43	Public Holiday											
Tues	13-Jun	44	7.8	22.7	0.62	1818	0.056	0.005	7.7	22.6	0.77	1814	0.055	<0.003
Wed	14-Jun	45	7.8	21.9	0.97	1826	0.006	0.011	7.8	21.9	0.65	1821	0.053	0.013
Thur	15-Jun	46	7.8	22	0.50	1834	0.052	0.004	7.9	22	0.50	1839	0.058	0.004
Fri	16-Jun	47	7.7	22	0.50	1916	0.049	0.007	7.8	22.5	0.55	1921	0.050	0.006
		Mean	**7.8**	**22.2**	**0.6**	**1849**	**0.041**	**0.007**	**7.8**	**22.3**	**0.6**	**1849**	**0.054**	**0.008**
		SD	**0.1**	**0.4**	**0.2**	**45**	**0.023**	**0.003**	**0.1**	**0.4**	**0.1**	**49**	**0.003**	**0.005**
		%RSD					**56.8%**	**45.9%**					**6.2%**	**61.6%**

Week 8			INFLUENT											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	19-Jun	50	7.4	22.5	4.00	2025	9.20	6.86	7.5	22.6	2.67	2030	8.60	6.85
Tues	20-Jun	51	7.4	22.6	4.06	2023	8.63	7.04	7.3	22.6	3.65	2025	8.57	6.99
Wed	21-Jun	52	7.4	22.2	5.87	2027	9.32	<0.003	7.5	21.3	1.88	2024	8.79	6.06
Thur	22-Jun	53	7.6	21.3	1.54	2025	7.72	6.55	7.6	22.6	0.77	2029	7.86	6.18
Fri	23-Jun	54	7.5	22.6	6.69	2026	8.11	6.96	7.4	22.7	9.44	2025	8.00	6.30
		Mean	**7.4**	**22.2**	**4.4**	**2025**	**8.60**	**6.85**	**7.5**	**22.4**	**3.7**	**2027**	**8.36**	**6.48**
		SD	**0.1**	**0.6**	**2.0**	**1**	**0.69**	**0.21**	**0.1**	**0.6**	**3.4**	**3**	**0.41**	**0.42**
		%RSD					**8.0%**	**3.1%**					**4.9%**	**6.4%**

Week 8			FILTRATE											
			9am						4pm					
Day	**Date**	Day (Integer)	pH	Temp	Turbidity	Cond.	Total P	Reactive P	pH	Temp	Turbidity	Cond.	Total P	Reactive P
Mon	19-Jun	50	7.7	22.3	1.07	1918	0.051	0.008	7.8	22.6	1.22	1929	0.049	0.009
Tues	20-Jun	51	7.8	22.6	0.49	2003	0.097	0.053	7.8	22.1	0.46	2007	0.083	0.018
Wed	21-Jun	52	7.7	21.9	0.43	1994	0.090	<0.003	7.8	21.4	0.39	1990	0.098	<0.003
Thur	22-Jun	53	7.7	21.3	0.64	1992	0.126	0.007	7.9	22.6	0.45	1988	0.134	0.008
Fri	23-Jun	54	7.6	22.7	0.43	1991	0.137	0.004	7.7	22.5	0.86	2010	0.147	0.006
		Mean	**7.7**	**22.2**	**0.6**	**1980**	**0.113**	**0.021**	**7.8**	**22.2**	**0.7**	**1985**	**0.102**	**0.010**
		SD	**0.0**	**0.6**	**0.3**	**35**	**0.023**	**0.027**	**0.1**	**0.5**	**0.4**	**33**	**0.039**	**0.005**
		%RSD					**20.1%**	**128.7%**					**38.6%**	**51.9%**

Appendix B – Images

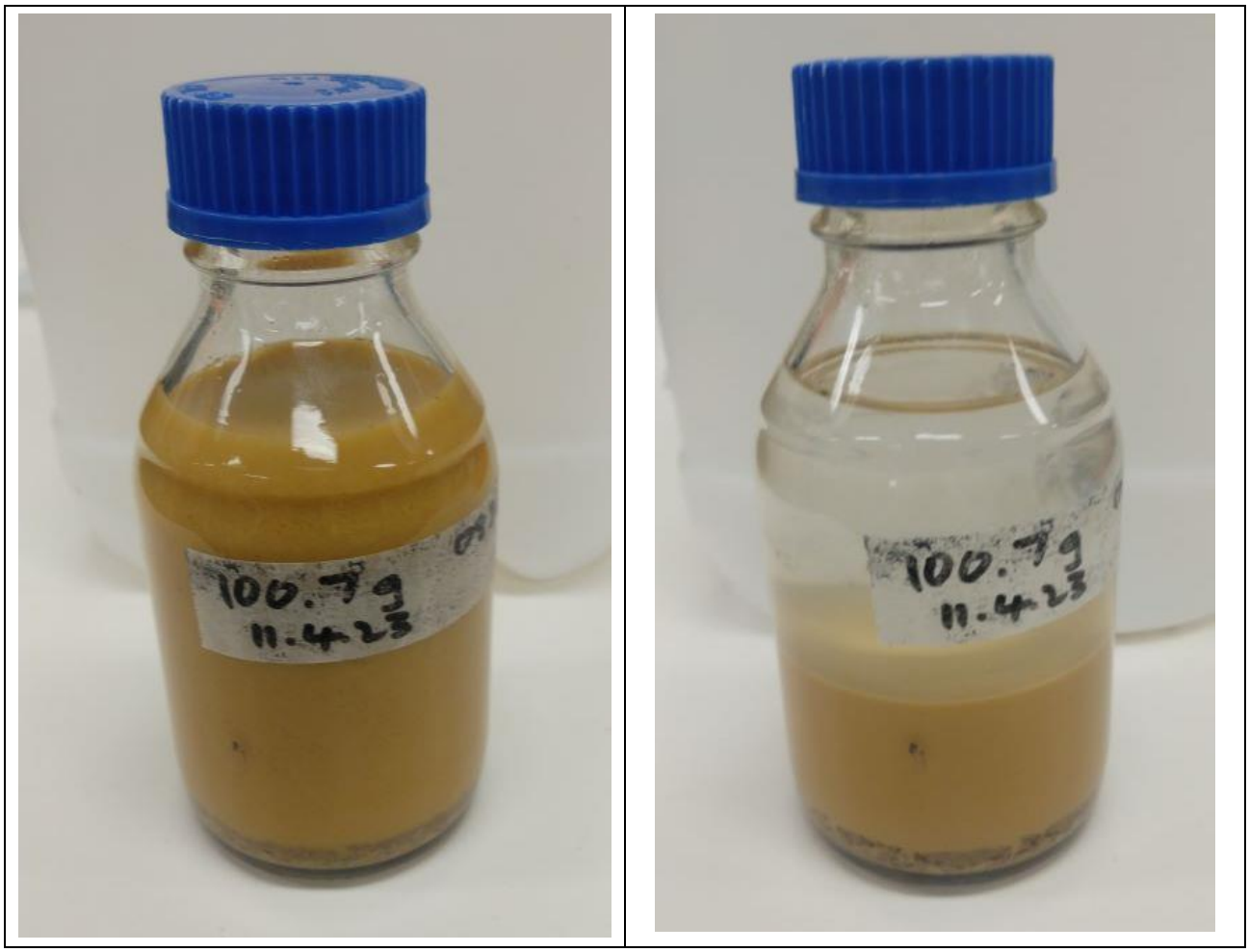

Figure 8: Stage 1 apatite extractables test (a) After 48-hours mixing. Note particle abrasion resulting in fine suspended material. (b) Sample after 30-minutes with settling of fine material.

Figure 9: Stage 2 column contactor with fixed bed Ardmore apatite