GRAFTA™

Mining and Industrial Water Remediation Technology

Contaminant Matrix
2023

Performance of GRAFTA™

GRAFTA™ in its original form, with no alteration and engineering is a combination of graphene and graphene oxide nanosheets that have shown to be highly capable of adsorbing heavy metals and organic compounds from aqueous solutions.

Bench scale tests mostly conducted in the form of adsorption column tests along with batch adsorption tests (also known as isotherm tests) have been conducted for a variety of contaminants including heavy metals, organic compounds, and inorganics such as nitrate, phosphate, and sulfate, mostly for real-life contaminated waters from mining related tailing waters, oil and gas produced water, landfill leachate, and few other industrial wastewaters along with some water samples spiked with certain target contaminants.

The key advantage of using GRAFTA™ is that it simultaneously adsorbs both heavy metals and tough to remove organic compounds such as chlorinated solvents, petroleum hydrocarbon, polycyclic aromatic hydrocarbons (PAHs), Volatile Organic Compounds (VOCs) such BTEX (benzene, toluene, xylene, ethylbenzene) and more importantly PFAS which is currently under further investigation.

Recent performance test for the removal of a variety of metals including but not limited to copper and selenium from mining tailing waters, indicated that GRAFTA™ can remove these metals to nondetectable concentrations.

Typical retention times required to adsorb contaminants by over 90% removal efficiency is about 15 minutes to 45 minutes.

Heavy Metals Removal Using GRAFTA™

Extensive testing of both G1 and G2 using real-life and spiked waters, indicated that majority of heavy metals including but not limited to mercury, selenium, lead, arsenic, manganese, chromium, cobalt, cadmium and uranium are removed by G1 and G2 where applicable.

In some mine waters, selenium, being the main contaminant of concern, is present in form of selenate which along with relatively high concentration of nitrate makes the treatment challenging. To tackle the challenges, G2 which is amended with a reducing agent was used to effectively reduce selenate to selenite and elementals selenium which was then adsorbed by the graphenic structure of GRAFTA™.

A summary of the removal efficiencies using G1 and G2 for a variety of waters contaminated with heavy metals is presented as follows:

Case	Type of GRAFTA™	Heavy Metal	Unit of Concentration	Initial Concentration	Effluent Concentration	Removal Efficiency (%)	Description of Water	Notes on Chemical Conposition
GNT22-US-003	G1	Mercury	ppb	0.17	0.01	94	Contaminated Salt Lake Water	Extremely high in chloride concentration
		Barium		332	66.5	80		
		Cadmium		2.01	0.1	95		
		Chromium		7.6	1.24	84		
		Cobalt		2.83	0.76	73		
		Copper		16.2	7.9	51		
		Lead		298	11.1	96		
		Nickel		13.8	8.7	37		
		Uranium		3.63	0.74	80		
		Selenium		171	3.2	98		
GNT22-CA-007	G1	Arsenic	ppm	8.2	<0.2	98		
		Nickel		3.8	0.1	97		
GNT20-CA-001	G1	Manganese	ppm	1.91	0.66	65	Landfill Leachate - After aearation.	Mild concentration of organics and ammonia.
		Iron		3.2	0.048	99		
		Zinc		0.08	0.008	90		
GNT22-CA-002	G2	Selenium	ppb	142	<1	99	Mine tailing water containing selenium in form of selenate and copper.	Relatively high concentration of sulfate and carbonate (940 and 999 mg/L).
		Copper		66	<1	98		
GNT22-CA-006	G2	Copper	ppb	33	<1	97	The main contaminant of concern in the water accumulated in the mine pit is copper, and minor constituents of nickel and selenium.	Moderate concentration of sulfate and hardness (over 300 mg/L).
		Nickel		23	<5	78		
GNT23-CA-002	G2 and G1	Selenium	ppb	26	<1	96	The main contaminant of concern was nitrate, however, selenium, and particularly uranium were among the key metals targeted for removal.	Moderate TDS of about 710 mg/L, relatively high phosphate (144 mg/L) and sulfate (460 mg/L). Nitrate concentration of about 14 mg/L.
		Uranium		11	<1	91		
		Nickel		42	5	88		
GNT23-CA-008	G2	Arsenic	ppb	31.9	0.23	99	Contaminated mine tailing waters.	
		Nickel		9.7	<0.5	95		
GNT23-CA-010	G2, G2, G1	Selenium	ppb	56	5	91	Simulated water quality based on a specific chemical composition, targeting selenium in form of selenate as well as nitrate removal.	Moderate nitrate and relatively high concentration of sulfate.

Organic Contaminants Removal Using GRAFTA™

G1 is most suited for a direct adsorption of organic contaminants including but not limited to petroleum hydrocarbons (F1 to F4), BTEX (benzene, xylene, ethylbenzene and toluene), chlorinated compounds (tetrachloroethylene, trichloroethylene, vinyl chloride and chloroform), phenolics (pentachlorophenol etc.), Polycyclic aromatic hydrocarbons (PAHs) at very high rates.

Case	Type of GRAFTA™	Organic Compound	Unit of Concentration	Initial Concentration	Effluent Concentration	Removal Efficiency (%)	Description of Water	Notes on Chemical Composition
Soil Washing Water Tests	G1	PCB	ppb	27	1.9	93	Soil Washing Effluent (Water)	
		PCB		13200	4550	66	Soil Washing Effluent (Surfactant and Water)	
Batch Adsorption Tests		Benzene	ppb	562	3.8	99	Spiked Water	
		Toluene		909	1.2	100		
	G1	Ethylbenzene		528	0.7	100		
Batch Adsorption Tests	G1	Tetrachloroethylene (TCE)	ppb	494	3.8	99	Spiked Water	
GNT22-CA-001	G1	Benzene	ppb	1100	230	79	About 5 kg of GRAFTA™ was injected into a well at a depth of about 14m at the groundwater table which was impacted by petroleum hydrocarbon. This was only one injection event and the water quality was analyzed a week after the injection.	
		Toluene		6000	57	99		
		Ethyl Benzene		1700	1500	12		
		Xylene		5700	1300	77		
		F1-BTEX		7600	3100	59		
		F2		1600	1200	25		
GNT22-CA-003	G1	2,3,4,6 & 2,3,4,5-tetrachlorophenol (PAH)	ppb	24.1	<1	96	The site releases process water that after an oil-water separator contains polycyclic aromatic hydrocarbons (PAHS) as well as phenolics including but not limited to pentachlorophenol, at concentrations exceeding the local discharge bylaws.	Process Water
		2,3,5,6-tetrachlorophenol (PAH)		7.6	<1	87		
		Fluorene		0.5	<0.1	80		
		Pentachlorophenol		125	<1	99		
GNT-CA-001	G1	F1 (C6-C10)	ppb	7831	25	>99	A leaking underground fuel storage tank impacting the local aquifer and lake provides the opportunity to passively manage the environmental risks of hydrocarbon migration towards the lake through an in situ installation of a Permeable Reactive Barrier (PRB).	
		F2 (C10-C16)		967001	100	>99		
		F3 (C16-C34)		661001	630	>99		
		F4 (C34-C50)		2971	250	91.5		
		F1 - BTEX		7831	25	>99		
		Hydrocarbons, Total (C6-C50)		1640001	630	>99		

Inorganic Constituent Removal Using GRAFTA™

GRAFTA™ being a carbon-based adsorbent, was not necessarily designed for removal of inorganics such as nitrate, phosphate, sulfate and carbonate. However, experiments conducted on various waters with relatively high concentration of total dissolved solids (TDS) indicated that phosphate and ammonia are directly adsorbed by GRAFTA™ (G1).

However, considering the rising demand of the industry, in particular the mining sector, to remove relatively high concentrations of nitrate in tailing waters, GRAFTA™ was modified with a reducing agent to chemically reduce nitrate to ammonium, followed by adsorption of ammonium within the same reactor (vessel) on the graphenic structure (G2).

Case	Type of GRAFTA™	Inorganic Constituent	Unit of Concentration	Initial Concentration	Effluent Concentration	Removal Efficiency (%)	Description of Water	Notes on Chemical Composition
GNT22-CA-009	G2 and G1	Nitrate	mg/L	11.9	0.7	94	Mine Tailing Water accumulated over several years with high concentration of nitrate. The applicable regulatory limit of 10mg/L for nitrate has led to accumulation of water near existing onsite storage capacity with no feasible alternative treatment system in sight.	Mine Tailing Water high in sulfate and hardness concentrations (over 1200 and 1600 mg/L respectively)
GNT23-CA-002	G2 and G1	Nitrate	mg/L	14.05	0.1	99	The main contaminant of concern was nitrate, however, selenium, and particularly uranium were among the key metals targeted for removal	Moderate TDS of about 710 mg/L, relatively high phosphate (144 mg/L) and sulfate (460 mg/L). Nitrate concentration of about 14 mg/L.
		Phosphate		144	10	93		
		TDS		710	380	46		