Form 2: *International Research Institute for Nuclear Decommissioning (IRID)*

RIF for contaminated water issues submission

Technology Information	
Area	3. Removal of radioactive materials from the seawater in the harbor
Title	Xogen Electrochemical Removal of Caesium from seawater
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1. Overview

Xogen the Company

Xogen Technologies Inc. is an emerging Canadian clean tech OEM with Leading Edge technology that provides electrochemical wastewater treatment systems for the Mining, Pharmaceutical, Municipal, Industrial, Power Generation and Oil & Gas Industries.

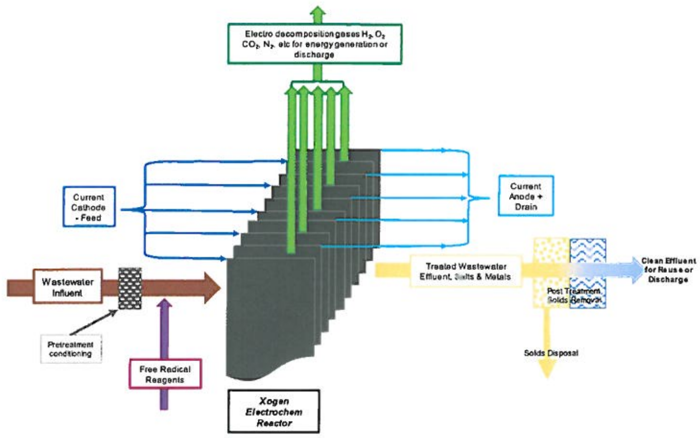
Technology Overview:

Xogen has developed a patented advanced electrochemical wastewater treatment technology process which combines the benefits of electro-oxidation, electro-flotation, electro-coagulation, electro-flocculation and disinfection into one unit process. Xogen's technology is proven effective for the treatment of wastewaters containing organics, ammonia, cyanides, nitrates, metals, oil and grease, suspended solids and deactivation of microorganisms.

How Xogen's Technology Works:

Screened wastewater is pumped through Xogen's electrolysis reactor that is comprised of a series of specially designed electrodes. The wastewater makes contact with the electrodes and passes between them as it flows through the reactor. When the wastewater makes contact with an electrode direct oxidation of the contaminants occurs on the surface of the electrode as well as the generation of highly oxidative species including ozone, hydrogen peroxide and hydroxyl radicals. As these highly oxidative species form they immediately react with organic matter, ammonia compounds and other constituents in the aqueous solution between the electrodes and get converted into a mixture of hydrogen, oxygen, carbon dioxide and nitrogen gas. Suspended solids in the wastewater will precipitate or float to the surface by the micro-bubbles of gas generated while pathogens are completely killed.

Xogen Electrochem Flow Diagram



Caesium Removal

It is a well known and proven fact that Prussian Blue ($Fe_{III4}[Fe_{II}(CN)_6]_3$) can be used to absorb caesium from an aqueous medium (Kobayashi, 1998; Ikeshoji, 1986). It is also known that Prussian Blue could be electrochemically generated (Neff, 1978). Electrogeneration of Prussian Blue typically involves oxidation of hexacyanoferrate complexes in the presence of ferrous salts (Gomathi, 1990; Yang, 1998). Xogen is in the process of commercializing their Electrochemical Water Treatment Reactor and believe it is ideally suited for the electrochemical generation of Prussian Blue. Xogen's patented system has the potential to electrochemically produce Prussian Blue by electrochemical reduction of dissolved ferric ions and subsequent bulk reaction of ferrous ions with ferricyanide. The Prussian Blue forms an insoluble solid that precipitates and can be separated from the aqueous medium.

Xogen hypothesizes that by generating Prussian Blue in Caesium contaminated seawater with their electrochemical technology a Prussian Blue Caesium insoluble complex will be formed that can be separated from the aqueous medium by commercially available separation technologies and techniques.

2. **Notes**

Xogen's technology has been shown capable of advanced electro-oxidation, electro-flotation, electro-coagulation, electro-flocculation and disinfection of a number of different water contaminants at a pilot plant and bench scale level. Table one below is an example of the reduction capability of that we have been able to demonstrate.

Table : 1

Typical Contaminant Removals

Note: The values presented below represent examples of the results that can be expected. These results have been obtained through pilot plant and bench scale testing on various samples obtained from a range of wastewater generators in different verticals and by no means represents the specific performance of the Xogen technology for every situation. For the actual effectiveness of the Xogen technology representative samples must be submitted for evaluation. These values are for example of the capability of the Xogen technology for treating wastewaters from a variety of sources only.

Wastewater Vertical	Contaminant	Raw (mg/L)	Treated (mg/L)	% Removal
Pharmaceutical				
	Acetaminophen	147.00	39.60	73.06
	Carbamazepine	0.29	0.11	61.75
	Diclofenac	0.26	0.10	63.18
	Erythromycin	0.00	0.00	62.50
	Indomethacin	0.08	0.00	97.53
	Sufadiazine	0.03	0.01	80.00
	Sulfamethoxazole	0.77	0.05	94.05
	Tetracycline	0.15	0.03	82.99
	Triclosan	1.90	0.19	89.84
	Trimethoprim	0.33	0.05	83.97
	Docopfemac	0.43	0.15	65.51
	Irgasan	1.14	0.38	66.75
	Naproxen	10.40	1.38	86.73
Abattoir				
	BOD	1310.00	86.00	93.44
	COD	1050.00	154.00	85.33
	Total Nitrogen	123.00	30.90	74.88
	Phosphorus	18.50	1.83	90.11
	Oil and Grease	125.00	2.00	98.40
	Suspended Solids	290.00	70.00	75.86

Municipal				
	COD	341.43	111.29	67.40
	E. coli (CFU/100mL)	56700.0 0	100.00	99.82
	Phosphorus	10.63	0.60	94.36
	Suspended Solids	128.71	3.78	97.06
	E. Coli (CFU/100mL)	56700.0 0	100.00	99.82
Industrial				
	Oil & Grease (animal/vegetable)	100.00	19.00	81.00
	Oil & Grease (mineral)	62.00	0.50	99.19
	Fluoride	52.50	1.50	97.14
	Phenols	75000.0 0	0.70	100.00
	COD	7310.00	73.00	99.00
	Ammonia	1905.50	0.00	100.00
	Cyanide (total)	0.039	0.002	94.87
	Chromium (Cr)-Total	0.01	0.001	90.00
	Copper (Cu)-Total	0.08	0.004	95.00
	Manganese (Mn)-Total	0.05	0.013	74.00
	Tin (Sn)-Total	0.01	0.001	90.00
	Methanol	27800	28.7	99.9

The capability of Xogen's technology of *in situ* production *of* Prussian Blue and Caesium removal is still in the proof of concept stage. Our submission consists of a plan for five phases of experimentation using Xogen's FlexiCell Reactor to not only prove the concept but also find optimum operating conditions for application to Caesium removal. These phases include:

Phase 1: Reagent Consumption Efficiency and Power Consumption Efficiency by Generating Prussian Blue in the ElectroCell

Tests will be carried out to understand and model how the rate of consumption of ferric salts, ferricyanide and electric current is related to the production of Prussian Blue.

Phase 2: Generating Caesium Absorption Isotherms from Electrochemically Generated Prussian Blue

This will allow us to establish residency time criteria as well as compare the adsorption rate of Caesium in electrochemically generated Prussian Blue vs chemically generated Prussian Blue. Further we will establish the total absorption capacity of electrochemically generated Prussian Blue.

Phase 3: Particle Size distribution analysis with Prussian Blue Sludge Recycle

Experiments will be conducted to establish particle size distribution for the electrogenerated Prussian Blue. This is important because if ion exchange is the primary mechanism for absorption then particle sizes will matter significantly due to a trade-off between surface area and volume. However the trade-off for an increase in surface area vs volume is the settling characteristics of the solid. (This will be explored in the following Phase). Moreover we can explore if recycling the sludge to form additional layers of Prussian Blue will allow for the removal of more caesium.

Phase 4: Settling Characteristics of Electrochemically Generated Prussian Blue

Since the removal of Caesium is due to the absorption by Prussian Blue and subsequent settling, settling tests will be conducted to understand the settling characteristics of the Prussian blue. This will help us to ascertain if the particles generated are easy to settle. If they are not, we will need to explore how to remove the particles from solution. It will also help us understand the effect that larger particles have on the absorption of Prussian Blue.

Phase 5: Impact of Saltwater Matrix on Prussian Blue Generation and Caesium Absorption

In order to better understand the performance of the electrogenerated Prussian Blue on Caesium removal in the field, tests will be carried out in a salt water matrix. This will allow us to better project the performance of the cell in real world situations. Specifically we will explore if the Caesium desorbs when it hits fresh seawater. If so, we will establish the time period over which this occurs.

Current Status

Xogen is currently participating in a collaborative research agreement with the Atomic Energy of Canada in this area. The research is centered on conducting tests at Xogen Technologies Inc. facility using inactive surrogate solutions to demonstrate the applicability of the Xogen wastewater treatment technology to cleaning nuclear process streams. Xogen is seeking additional partners to participate in this very exciting and promising line of research to confirm the hypothesis proposed in this submission and provide solutions to challenges such as this. Interested parties can contact Xogen through our website www.xogen.ca. The projected timeline

to complete this research is 5 months. Should this research prove successful the time to modify the existing Xogen Electrochem Technology to implement a removal process of radioactive Caesium from the seawater in the harbor would be 8 to 12 months.