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

Technology Information	
Area	3 (Select the number from "Areas of Technologies Requested")
Title	**Removal of radioactive materials from the seawater in the harbor**
Submitted by	**Kurion, Inc.**

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

(1) Removal of radioactive cesium and strontium inside the sea

a) Radioactive cesium and strontium in the sea inside the harbor need to be removed, which is to say, their concentrations need to be decreased dramatically.
b) Upon removal of above mentioned materials, the decrease in efficiency of removal due to absorption of materials other than targeted materials, such as magnesium and calcium should be limited.
c) The amount of wastes produced due to cesium and strontium absorption should be limited.
d) The removal systems should be a simple structure.

In order to address these critical concerns as they apply to the decontamination of seawater inside the harbor (e.g., strontium and cesium), Kurion has, over the past 2 ½ years, developed a series of Ion Specific Media (ISM) that specifically target these isotopes, even in extreme competition in seawater (e.g., sodium, calcium, magnesium, potassium, etc.). The amount of media required to surgically remove only the target isotopes greatly reduces the amount of material required compared to standard water treatment techniques, thus minimizing secondary waste streams. Furthermore, all of the media have been specifically designed to be vitrification friendly, as they are all inorganic and are glass formers. This even further reduces the volume of waste while providing the safest possible ultimate waste form for storage or disposal.

As importantly as the on-going media development since 2011, systems for deploying such media have developed over the last year in laboratory- and now full-scale testing and deployment. Those systems, applicable to this harbor water application, include the Submersible Media Filters (SMF), Submersible Columns (SC) and External pilot- and full-scale, lead-lag, vessel systems. This description will include the media development and testing, as well as that of the proposed deployment systems themselves.

Historical Kurion Media Systems and Decontamination Applications and Experience

The 1200 ton/day Kurion ISM System (also known as the Kurion Cesium Removal System) went into service June 17, 2011 after a record 8-week design, fabricate and commission emergency turnaround. Of the Kurion, SARRY and AREVA cesium removal systems, the Kurion System is the only system to see the high-activity, high-salinity (100% seawater) water present during the initial system startup. This was due to the fact that i) the AREVA system operated downstream of the Kurion System so it received less than 1% of the original activity and ii) the SARRY System started up more than two months later and initially behind the Kurion System, so it never received more than 60% of the initial cesium level or 50% of the salinity present in June of 2011. Because of the enormous activity removed by the Kurion System in 2011 it has been responsible for about 69% of the total activity removed from the reactor and turbine buildings to date, with the SARRY system responsible for the balance of cesium removal. By any measure these system have demonstrated great success in removing cesium activity, now only about 2% of the original value.

Current Media and Deployment Systems Proposed for the Harbor Water Application

While the cesium levels have been reduced at the front end of the plant by the Kurion ISM System (and others) to some 2% of original concentrations at Fukushima Daiichi Station due to extensive treatment and recycle, strontium levels have remained at initial levels of ~1 x 10^5 Bq/mL and fairly constant levels in the Harbor. While the strontium Bremsstrahlung x-ray dose contribution is approximately 3% of the cesium (gamma) equivalent, to further reduce dose to workers and the environment, development and testing of ion specific media (ISM) for strontium (Sr-89 & 90/Y-90) that began in June of 2011 has now been deployed at full scale. During this time, verification testing of the work done in Oak Ridge, TN was carried out at the Japan Atomic Energy Agency (JAEA), see Waste Management 2013 reference. Testing of the Sr media (KUR-TS-G), with and without Cs, was carried out at various seawater concentrations, including 100% (e.g., Harbor water) as well as additional competition amounts of calcium (Ca) and magnesium (Mg), with exceptional removal affinities and capacities (Kd's of 10^3 – 10^4).

An additional concern has arisen during operations due to the increased competition from calcium (Ca) and magnesium (Mg), likely being leached from the concrete in the containment

and basement areas of the plant, as well as in natural seawater. In order to insure that this increasing competition did not adversely affect the media's removal of Sr, tests were also run comparing Kd's for Sr against those of Ca and Mg for a variety of media. The key here is to compare the Separation Factors (SF) of Sr/Ca and Sr/Mg. The two most important current waste water conditions at Fukushima are the system influent 2.5% seawater (SW), the Tank Farm reverse osmosis (RO) 31% seawater and the Harbor water at 100% SW. In the case of Sr studies, the collaboration was with JAEA (Japan Atomic Energy Agency, JAEA, June 21, July 25 and October 12, 2012), *Performance Test of Kurion TS-G (Test No. TS-G-1, 2 and 3r).*

Of course, Kurion cesium (Cs) removal media (H, EH and KH) has been thoroughly tested in the most stringent of conditions in seawater and H and EH deployed at full scale in the existing Kurion ISM System

In addition to the development of a number of unique ion specific media (ISM), Fukushima experience also lead to the development of three new media delivery systems deployed full-scale in 2013 in Commercial NPP applications. These three media systems are:

1. **Submersible Media Filters (SMF):** These submersible units are designed for any type of fuel pool, pond or underwater isotope specific remediation. They fit into existing Tri-Nuc (Tri Nuclear Corp.) filter housings (single, dual or quad.) commonly used in the industry and use standard Tri-Nuc tools. They have an annulus (between two sheet filter) filled with an appropriate ion specific media (ISM) developed for each application (e.g., Cs, Sr, Ni, Co, C14, etc.) and are inside to out flow. Applications for these units would include the remediation of low activity levels such as for decontamination & decommissioning, D&D, or outages and operate in the recycle mode.

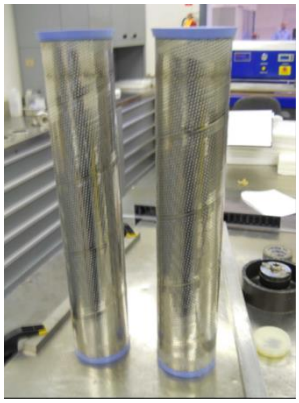
2. **Submersible Columns (SC):** These are also submersible units for similar applications but are able to remediate higher levels of activity due the fact that the entire unit is filled with ISM (vs annulus only) with top to bottom flow with discharge out the screened insert into the Tri-Nuc housing. Like the SMF, they too are designed to fit into a Tri-Nuc filter housing by utilizing this reusable screen insert (including lifting bales).

3. **External Modular, Skid-Mounted, Lead-Lag Vessel System:** These are basically mini-Fukushima ISM vessels capable of being used in a lead-lag configuration and utilizing different media in each vessel. The vessels can be either sluiceable or disposable as a whole. The vessels come with no, light or heavy shields depending on the application**.** As one would expect, these units are capable of much higher capacities and run times due to the amount of media present and added flexibility. Again,

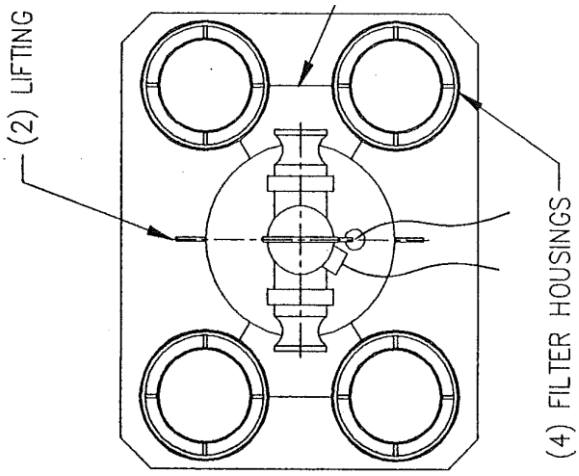
applications include fuel pool or pond applications allowing for remediation and dose reduction during outages, D&D or pool draining.

The primary reasons these media systems were developed and being deployed are to 1) Supply dose reduction/mitigation to workers and the environment during pool/pond outages, area D&D or even draining of the entire containments, 2) Offer a portable, skid-mounted mitigation system allowing the larger plant waste treatment system to be augmented, or by-passed (outages) or even shut down in the case of plant D&D, and 3) Offer a system that requires no plant modifications or license amendments.

In order to offer an end disposition path for the small amount of secondary waste produced and full life-cycle cost, all of the systems have been designed to be vitrified into glass utilizing the Kurion GeoMelt® System, to be covered in a separate document.



Submersible Media Filters (SMF) and Submersible Columns (SC) Utilizing S.S. Insert for Tri-Nuc Housing



Tri-Nuc Housings- single, double, or quadruple depending on flow rate.

Kurion Submersible Columns (SC) at Magnox Station.

Kurion Modular Cs Removal Vessels (EH), Sr Removal (TS-G) and Full, Shielded, Lead-Lag Modular System

Pond Trial Mitigation Application: An on-going application of all three ISM media systems involves deployment at a Magnox Plant in the UK in order to reduce dose and provide redundant (submersible and external) mitigation systems during D&D. This again involves the application of very specific media systems to surgically remove recalcitrant isotopes. In this case, strontium (Sr) being the primary and cesium the secondary (similar to Fukushima Harbor). The trials included Kurion EH-G and EH-P (granular and powder) for Cs^{+} and TS-G and TS-P for Sr^{2+}.

Several trials were run on-site and on actual wastewaters for Total "others" (beta including Sr-90/Y-90) and Cs-137 including:

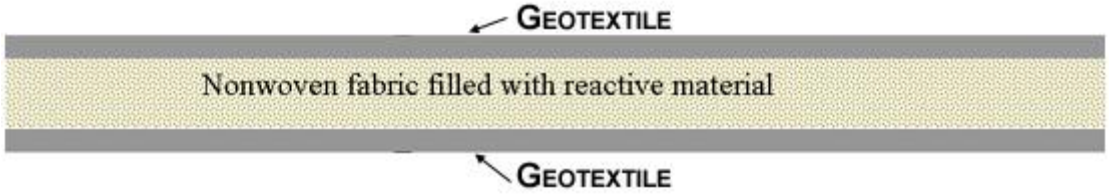
- Vault water at pH 10.4 and conductivity 3.0 mS
- Pond water at pH 7 and conductivity 3.0 mS
- Pond Water + Powdered Pond Paint/Concrete, pH 11.4, Conductivity 3.66 mS: These trials, even at the higher competition and pH, showed high removal efficiencies for total beta and Cs-137.
- Pond Water + Pond Sludge, pH 11.09, Conductivity 6.4 mS: Again high removal efficiencies were reported for total beta and Cs-137.

While the Magnox Pond Trials had a goal of a 10% overall reduction in dose (DF 1.1), the once-through system is easily providing a DF of >700 for Cs and > 1500 for Sr in a 166,000 gallon vault, allowing direct discharge of the effluent.

(2) Installation of a silt fence that absorbs radioactive materials

・ Transport of radioactive materials should be blocked by installing a silt fence made of absorption materials mentioned above in inside the harbor.

In order to make a more effective Silt Fence (sometimes referred to as a Reactive Core Mat), Kurion proposes to use our proven media for Sr and Cs removal in Geo-Membranes developed by and produced by our Japanese partner.



The objective here is to remove the radioisotopes as they permeate the Reactive Core to further

reduce the dose in the Harbor as well as prevent disbursement to the sea. The design will be such that it is easily installed in the Harbor as well as easily removed when saturated.

The Geo-Membrane, as well as media, is further designed for a stable end disposition in our Vitrification system, Geomelt®, which will be described in a different section.

Technology Ownership:

- Media development is by Kurion and production is with our exclusive production partners.
- Submersible Systems design by Kurion and production with our exclusive production partner.
- External Shielded Lead-Lag Systems by Kurion
- Harbor Silt Screen (Reactive Core Mat) Replacement Option: Design and Media by Kurion with our Geo-Membrane production partner in Japan.

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

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

Kurion Ion Specific Media (ISM) and deployment systems are very mature treatment technologies, having been successfully deployed internationally, including in Japan, the UK, and the United States. The two Kurion Submersible technologies, have been used to treat radioactively contaminated water in Magnox Plants (UK) vaults and ponds (fuel pool) at full scale. The Kurion External Lead-Lag System has also been applied at full scale in Magnox vaults and ponds. The latter, externally shielded system, is currently being successfully used to reduce dose in a 166,000 gallon vault to allow the Decontamination and Decommissioning (D&D) of that part of the plant. We are currently replacing the plant's Active Effluent Treatment Plants (AETP) with Kurion Modular Active Effluent Treatment Plants (MAETP) allowing the former to be shut down and decommissioned.

By United States Government standards, Kurion Modular Systems are considered mature

technologies. The United States uses a Technology Readiness Assessment (TRA) wherein Technology Readiness Levels (TRL) are applied to define technology maturity, on a scale of 1 to 9. A score of 7 and above indicates mature full-scale demonstrations and deployments. Because Kurion Modular Treatment Systems (KMTS) deploy in a range of configurations, depending on the site and waste to be treated, it is expected to achieve a TRL ranging from 7 to 9, when evaluated against each site's project specific requirements.

United Kingdom (Magnox and Sellafield) waste owners are actively partnering with Kurion to treat radioactive waste at several commercial (7) and government sites where their most problematic wastes are stored, and for which there are few, if any, other treatment options for such dose reduction by such mobile or modular systems.

By Japanese Government standards, Kurion ISM media and systems has been deemed mature after 2.5 years of full-scale operations at the Fukushima Daiichi Nuclear Plant. The Magnox Lead- Lag external vessel system is merely a mini-Fukushima system for the removal of strontium and cesium in waste waters (vaults, ponds and tanks).

The extension of the deployment of submersible systems (self-shielding) is merely a refinement of the application for such applications as the Harbor decontamination to not only reduce dose in the Harbor, but to reduce dose to the workers. Of course all TRA evaluations and TRL levels have to be applied to actual conditions and waste streams.

- **Challenges**

  - While submersible ISM (and pump) systems greatly reduce shielding requirements and dose to workers, this is, of course, a huge body of water and at extreme seawater conditions. Placement of such submersible vessels is routine, as it is in fuel pools, etc. However, removal and storage of any media or vessel would be required. The ISM Submersible Columns (SC) and Submersible Media Filters (SMF), as well as their containment systems, have been designed for ease in removal and replacement. Such systems could be arranged on pontoon or float systems for ease of access, or simply accessed from the Harbor dock.

  - Since there is little one can do to mitigate additional Sr and Cs from entering the Harbor from trenches and ditches at this time, this will require the application of a considerable number of systems and media to bring this dose level down and maintain it at acceptable levels.

- Considering the location and lack of protection of any system deployed at or in the Harbor, one will have to address the potential for storm conditions, etc. The advantage here is that these KMTS are submersed under the surface and be able to withstand considerable hardships regarding weather.

- Since there is more beta (Sr) than gamma (Cs) in the Harbor, shielding is not as big of an issue as at other Kurion locations within the plant. However, as concentrations build up, this will have to be carefully addressed.

- While Kurion Modular Treatment Systems do not need constant monitoring, especially in a submersible application, the ISM media will become saturated if not replaced (as will the Silt Fence). However, as more and more strontium (Sr) is loaded, the media will "roll off" first the calcium (Ca), then the potassium (K) and, finally, the magnesium (Mg). The Sr will merely saturate, but not roll off or dump as more is added at this point.

- A similar situation will be reached with the Silt Fence (Reactive Core Mat) as it becomes "saturated." A design would be deployed for ease of removal, dewatering, storage and final disposal. This, like the submersible filters, submersible columns, external vessels and media are all candidates for melting in the Kurion Geomelt® Vitrification System.

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

  - All proprietary Submersible Systems are patent pending both in the U.S. and International.

  - Waste Management Conference: International Collaboration and Continuous Improvement, Phoenix Convention Center, Phoenix, Arizona, US, February 24-28, 2013 "Isotope Specific Remediation Media and Systems" - Paper 13614

  - EPRI International Low Level Waste Conference 2013, Kurion Paper "Novel Isotopic Specific Systems For Commercial Nuclear Power Plant Applications"