Protecting Lake Ontario - Treating Wastewater from the Remediated Low-Level Radioactive Waste Management Facility – 13227

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ABSTRACT

The Port Granby Project is part of the larger Port Hope Area Initiative, a community-based program for the development and implementation of a safe, local, long-term management solution for historic low level radioactive waste (LLRW) and marginally contaminated soils (MCS). The Port Granby Project involves the relocation and remediation of up to 0.45 million cubic metres of such waste from the current Port Granby Waste Management Facility located in the Municipality of Clarington, Ontario, adjacent to the shoreline of Lake Ontario. The waste material will be transferred to a new suitably engineered Long-Term Waste Management Facility (LTWMF) to be located inland approximately 700 m from the existing site.

The development of the LTWMF will include construction and commissioning of a new Wastewater Treatment Plant (WWTP) designed to treat wastewater consisting of contaminated surface run off and leachate generated during the site remediation process at the Port Granby Waste Management Facility as well as long-term leachate generated at the new LTWMF.

Numerous factors will influence the variable wastewater flow rates and influent loads to the new WWTP during remediation. The treatment processes will be comprised of equalization to minimize impacts from hydraulic peaks, fine screening, membrane bioreactor technology, and reverse osmosis. The residuals treatment will comprise of lime precipitation, thickening, dewatering, evaporation and drying.

The distribution of the concentration of uranium and radium - 226 over the various process streams in the WWTP was estimated. This information was used to assess potential worker exposure to radioactivity in the various process areas. A mass balance approach was used to assess the distribution of uranium and radium - 226, by applying individual contaminant removal rates for each process element of the WTP, based on pilot scale results and experience-based assumptions. The mass balance calculations were repeated for various flow and load scenarios.

INTRODUCTION

The existing Port Granby Waste Management Facility, located near the north shore of Lake Ontario in the Municipality of Clarington, has been in operation since 1955. Collection and treatment of wastewater generated from the waste storage areas has been ongoing since 1977 [1]. The LLRW generated from the former federal Crown Corporation Eldorado Ltd. and its private sector predecessors was from refining of radium and uranium ores between the 1930s and the

1980s [2]. It is in the form of marginally contaminated soil containing radium - 266, uranium, arsenic and other residues generated from the refining process. In 1988, Eldorado merged with Saskatchewan Mining and Development Corp., forming Cameco Corporation (Cameco). Under the terms of agreement between Cameco and the Crown, Cameco agreed to continue to maintain and manage the Port Granby Waste Management Facility, under its operating License from the Canadian Nuclear Safety Commission (CNSC), until a more permanent long term management could be developed.
In 2001, a legal agreement between the Government of Canada, the Municipality of Clarington, the Town, and Hope Township launched the Port Hope Area Initiative (PHAI) and committed the long term waste management plan for the Port Granby LLRW.
Following a public hearing, the CNSC announced on November 30, 2011 its decision to issue a Waste Nuclear Substance Licence to Atomic Energy of Canada Limited (AECL) for the Port Granby Long-Term Low-Level Radioactive Waste Management Project for a period of 10 years.

The Port Hope Area Initiative Management Office for the Port Granby Project is made up of the Atomic Energy of Canada Ltd. as the lead agency/licence holder; Public Works and Government Services Canada (PWGSC) managing the tenders for the major contracts; and Natural Resources Canada (NRCan) as the Project sponsor providing funding and policy direction.

OVERVIEW

Existing Port Granby Waste Management Facility

The existing Port Granby Waste Management Facility has been in operation since 1977 and is located south of Lakeshore Road on the shores of Lake Ontario. It consists of a waste storage area and water treatment ponds as shown in Fig.1. The waste storage area contains a Central and a NE Plateau. Leachate and contaminated surface runoff is collected in the West and East gorge reservoirs, where hydrochloric acid is added for pH control, and then transferred via pumping to the sedimentation lagoon for suspended solids removal, located at the water treatment ponds. After sedimentation, ferric chloride is added and the effluent is adequately mixed at the on-site treatment building from where the water is then transferred to a subsequent lagoon cell for reaction (co-precipitation of radium and arsenic with ferric hydroxide) and settling of precipitated solids [3]. The clarified water is discharged into Lake Ontario. A diversion system (perforated pipe drain) along the north boundary of the storage areas diverts uncontaminated groundwater around the storage area.

The existing Waste Management Facility is meeting the effluent limit requirements prior to discharge to Lake Ontario. Cameco's license was terminated , when the Government of Canada took ownership of the site from Cameco in March 2012, at which time AECL's license came into effect, enabling AECL to continue operation of the existing Waste Management Facility WWTP (anticipated for 3 years) until the new Long-Term Waste Management Facility WWTP is fully commissioned.

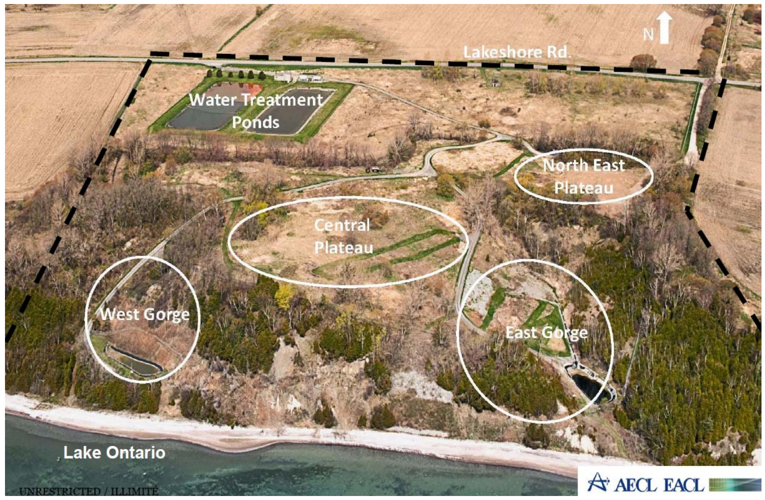


Fig. 1: Existing Port Granby WMF , [4]

Environmental Assessment (EA)

The Responsible Authorities (RAs) for the project, consisting of representatives of NRCan and the CNSC, determined that an Environmental Assessment (EA) was required for the construction and operation of the new Long-Term Waste Management Facility. In 2009, the final EA was submitted by AECL to the RAs for comment. After public consultation, the RAs concluded that, based on the information provided in the EA, there are no anticipated adverse environmental effects caused by the Port Granby Project.

However the RAs made recommendations that have been incorporated into the design for the new Long-Term Waste Management Facility. They requested that the treatment capacity for the new facility be expanded from the existing Waste Management Facility and that the treatment would be more rigorous than the existing treatment, in that it addresses all contaminants of potential concern identified during the EA and would result in high removal efficiencies of the contaminants.

Project Implementation

The implementation of the project will be initiated in three phases [5].

Phase 1- Regulatory Approvals, initiated at the signing of the 2001 Agreement between the Municipalities and the Government of Canada, with two sub phases. Phase 1 involved the EA process, regulatory approvals, bench scale testing preliminary design of the proposed treatment facility and the design of a pilot-scale test program. Phase 1A included the detailed design based on the findings of the pilot scale testing and preparation of tender ready documents.

Phase 2 – Clean-up and Construction started in 2012 and involves the construction of the new Long-Term Waste Management Facility and the remediation of the existing Port Granby Waste Management Facility. It is anticipated to take a total of seven years with five of those years being remediation and waste transfer.

Phase 3 – Long term Monitoring & Maintenance will be initiated upon completion of Phase 2. This Phase will involve continuous monitoring of the new Long-Term Waste Management Facility.

The locations of the existing and future waste management facility are shown in Fig.2.

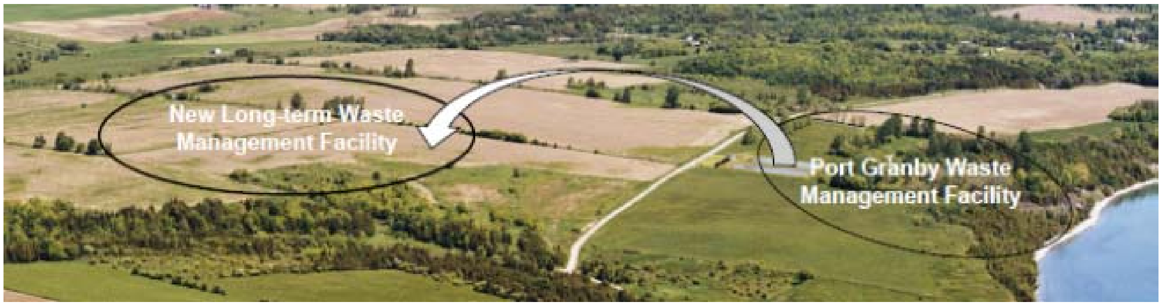


Fig. 2: Location of the New and Existing Port Granby Waste Management Facility [4]

PILOT STUDY

An extensive evaluation and design approach was used to address the flow and loading factors. AECL initiated a six month pilot study to assess the removal and treatment characteristic of various types of technologies using existing wastewater characteristics. The water treatment technologies are selected based on the results of the pilot study and are proven in their capabilities in treating the constituents. The treatment technologies included biological treatment, membrane bioreactors and reverse osmosis in series.

The pilot study confirmed that the proposed technology of microbial degradation of the ammonia and nitrate to nitrogen gas was very effective. Ammonia levels in the influent ranged from 65 mg/L to 145 mg/L with 95% removal [2]. Reverse osmosis was effective for removing the residual nitrate as well as varying levels of metals and radionuclides [2].

FULL SCALE DESIGN

During the design development various design flow options for the WWTP were assessed in combination with different storage volume for equalization. The assessment process resulted in a maximum treated water capacity of the WWTP of 40 m^3/hour with an associated equalization pond volume of 9,000 m^3 .This treatment concept thereby provides balancing for fluctuating treatment flows [6].

The design approach for the new WWTP is to divide the plant into two identical parallel water treatment trains that will allow operations to adapt to the influent flow of the plant contingent on excavation and construction progress or season, and provide flow balance in the system. Depending on the flow, one train can be stopped or altogether shut down for a longer period to obtain a more efficient operation [6].
The WWTP will receive and treat wastewater from both the East and West Reservoir pump station. The East and West Reservoir Pump Stations collect wastewater from the East and West Gorge, respectively, (refer to Fig. 1) as well as surface water impacted from remedial work. It will

also treat leachate collected from the engineered mound and impacted storm water [6].

The residual management process consists of various treatment stages for mineral residuals and bio-solids including holding tanks, chemical reaction tanks, clarifiers and dewatering units as well as evaporation and drying [6].

There are multiple factors that influence the actual flows and loads to the new WWTP. The combined (East Gorge Reservoir and West Gorge Reservoir) wastewater quality will vary depending on where excavation activities occurs, which construction year, and which type of waste is exposed. In addition, seasonal changes will also have an impact on the water constituents such as rain events, snowmelt and temperature variations.

Contaminates of Potential Concern

The anticipated Contaminates of Potential Concern (COPC) were identified through the Environmental Assessment process. Table I identifies the COPC in two separate lists. There are many similar constituents between the two Waste Management Facility's with the main difference being the new WWTP which will contain leachate and construction water. Arsenic, radium - 226, uranium, and nitrate are considered Primary COPC.

Table I: Contaminants of Potential Concern, [1]

Treatment System	Contaminants	
Existing Waste Management Facility	Ammonia	Nickel
	Arsenic	Nitrate
	Calcium	Nitrite
	Cobalt	Phosphorus
	Copper	Potassium
	Fluoride	Radium - 226
	Iron	Selenium
	Lead	Uranium
	Magnesium	Vanadium
	Molybdenum	
Projected for new Long-Term Waste Management Facility	Ammonia	Lead
	Arsenic	Magnesium
	Cadmium	Nitrate
	Calcium	Phosphorus
	Cobalt	Potassium
	Copper	Radium - 226
	Fluoride	Uranium

The WWTP treatment processes selected through the pilot system testing demonstrated greater than 90% removal efficiency for most COPC. The PGWMF effluent for the trials consisted in 50% flow from the East Gorge Reservoir and 50% flow from the West Gorge Reservoir.

Table II summarizes the combined MBR and RO removal efficiencies for the primary COPC's. It should be noted that there was 17% removal for arsenic, 77% removal for Radium - 226 and 5% removal for uranium in the biological pre-treatment prior to any RO treatment.

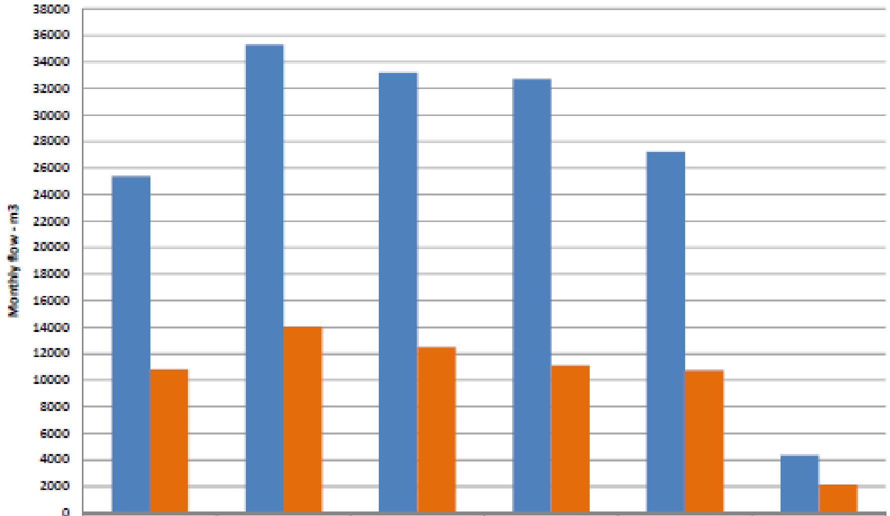
Table II: Pilot Test Removal Rates for Primary COPC (post MBR and RO), [2]

Primary COPC	Average Flow	Average Effluent	% Reduction Based on Average
Arsenic	1.1 mg/L	0.015 mg/L	98.6
^{226} Radium	0.82 Bq/L	0.01 Bq/L	99
Uranium	6.1 mg/L	0.06 mg/L	99
Nitrate	272 mg/L	3.9 mg/L	98.5

Anticipated Flow Rates for the future WWTP

For each area of the project (i.e., excavation mound, east/ west reservoir etc.) the average and maximum monthly flow of the respective catchment areas were estimated based on maximum and average monthly precipitation volumes. In summary, the highest flows are expected during the construction phase of the new Long-Term Waste Management Facility and during the excavation activities on the PGWMF (Year 2 to 4). As expected, the combined flows decrease after year 5, which is the end of the construction phase.

The following illustration (Fig. 3) shows the predicted combined average and maximum monthly flows over the construction period and Year 6.



	m3/month Year 1	m3/month Year 2	m3/month Year 3	m3/month Year 4	m3/month Year 5	m3/month Year 6
Max. Month	25393	35289	33169	32699	27205	4340
Average month	10821	14025	12526	11123	10740	2116

Fig. 3: Predicted Average and Maximum Combined Monthly Flows to new Long-Term Waste Management Facility WWTP, [6]

Process Flow Future WWTP

The key process components of the future WWTP are detailed further in the process flow diagram (Fig. 4) and are briefly described in the following sections.

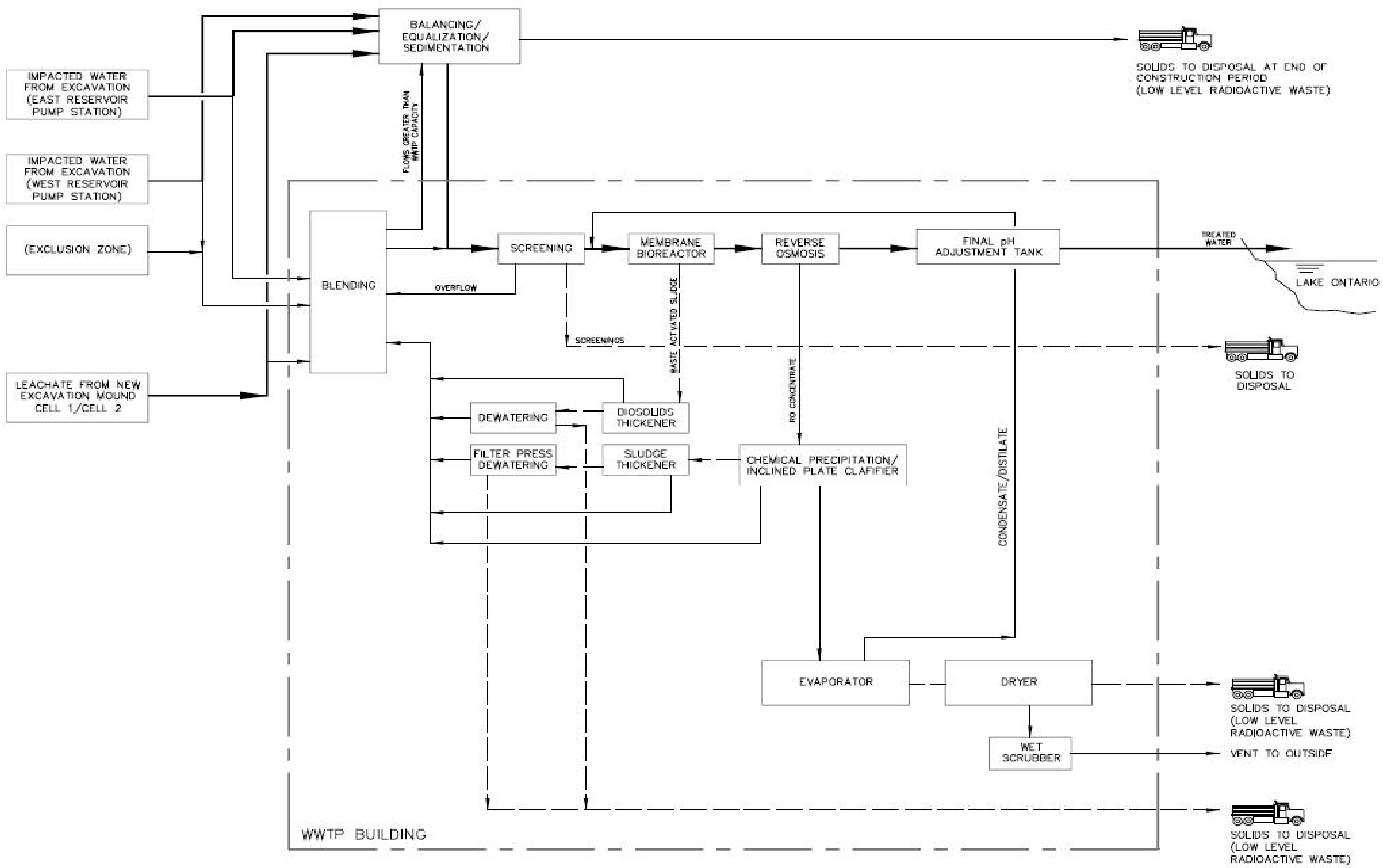


Fig. 4. Process Flow Diagram,[6]

Biological Pre-treatment

Influent flow to the WWTP will be blended and screened through two 2 mm perforated fine screens prior to biological pre-treatment for nitrogen removal. The biological pre-treatment will be located outside of the WWTP.

In the biological pre-treatment, ammonia is oxidized to nitrate by means of microorganisms (nitrification process) contained in a suspension of biomass and wastewater. The aerated zone will be supplied with process air to provide the required oxygen for the nitrification process and the aerobic removal of biodegradable matter.

In the anoxic zones, nitrates are biologically reduced to gaseous nitrogen (denitrification process) by adding methanol as an external carbon source ahead of the Anoxic Zone. The methanol dosing is proportional to the nitrate load to be denitrified.

In the event that the wastewater does not contain ammonia or nitrate (e.g. at a later phase of the project), the biological treatment trains can be bypassed directly to the membrane tanks or the reverse osmosis trains.

Phosphorous is an essential element supporting the growth of biomass. The phosphorous is also identified as a COPC and the phosphorous outlet concentration will therefore be associated with an administrative and action level. The dosing of phosphorous for biological growth has therefore to be limited to the minimum necessary.

Membrane Bioreactor System (MBR)

Mixed liquor from the bioreactors will flow from the aerated zone to the membrane bioreactor system. The membrane filtration system will separate activated sludge from the biologically pre-treated wastewater, replacing a conventional clarifier. Filtration is carried out from the outside of the membrane inwards by means of an external suction pump. The membrane separation is capable of generating a virtually solids free effluent and of providing an effective barrier for bacteria. Multiple modules or cassettes are combined in the filtration system.

The waste activated sludge is discharged to the residuals management train for biosolids.

Reverse Osmosis (RO)

Filtrate from the MBR systems overflows the MBR Filtrate/Backwash Tank and flows by gravity to the RO System pH Adjustment Tank. Antiscalant, biocide and hydrochloric acid are added and mixed via a mixer.

Reverse osmosis is a method of separation which removes larger molecules and ions from the wastewater by pumping the wastewater at high pressure through a selective membrane. The brine, with the concentrated reject, is retained on one side of the membrane. Permeate (filtered water) passes through the membrane, into the Permeate Tank.

The permeate is pH adjusted, sampled and discharged as treated effluent to Lake Ontario.

Residual Management

The residual management process for the Port Granby Project has three components:

Stream 1: Dewatering of biosolids from the activated sludge process.
Stream 2: Dewatering of precipitated mineral solids from the brine precipitation process.
Stream 3: Evaporation/Drying of supernatant from the settling stage of the brine precipitation process.

Brine precipitation

Chemical precipitation is used to decrease the concentrations of uranium, radium - 226, scaling components and metals present in the brine. Treatability tests indicated that increasing the pH to about 10 to 11.5 coupled with solids separation provides significant reduction in concentration of scaling compounds, target metals and radionuclides

Evaporation/drying

Chlorides are not removed from the system by biological pre-treatment or the chemical precipitation, and would otherwise concentrate due to the internal brine recycle. A portion of the treated brine (supernatant of the clarification of the lime precipitation) process is therefore fed to an Evaporator to remove these highly soluble salts from the water treatment system. The remaining residual slurry contains the contaminants.

The evaporator will treat approximately 81 m^3/d, with a volume reduction of about 90%. The dryer units will dry the slurry from the evaporation process.

There is also the possibility of operating in a direct brine evaporation mode in which the entire brine would be evaporated thereby removing the need to precipitate the heavy metals as they will be contained in the evaporator product and ultimately be disposed on the excavation mound as a dried product.

Biosolids

The quantity of Biosolids to be dewatered will vary depending on the growth of biomass in the biological pre-treatment stage as this is largely proportional to the amount of nitrate denitrified and methanol dosed.

Dewatering

As quantities and qualities are very different for the types of residuals, two different dewatering systems will be provided: a centrifuge for the biosolids (stream1) and a filter press for the mineral solids (stream 2). The evaporation/drying process (stream 3) will treat the pH adjusted brine supernatant. The sludge cake from the thickening process will be discharged in a roll off container and disposed of on the new Long-Term Waste Management Facility excavation mound. The dried product from the dryers will be weighed and contained in a bag tote, also for transportation to the excavation mound.

RADIUM AND URANIUM DISTRIBUTION IN THE WASTE WATER TREATMENT AND RESIDUAL STREAM

The designer used a mass balance approach to assess the fate of the elements uranium and radium-226 and their distribution in the process streams of the WWTP by applying individual removal rates for each process element (e.g. biological pre-treatment, reverse osmosis, brine precipitation process) of the WWTP.

The removal rates were based upon observations during the pilot trials, previous bench scale tests or own experience based assumptions, where no data were available. The estimated distribution of the radionuclide's loads in the WWTP process streams was based upon the following data set:

Uranium – Mass balance assumptions – Removal rates, [7]

- Average flow to WWTP: 395 m^3/d
- Maximum flow to WWTP: 960 m^3/d
- Weighted average concentration U : 7.04 mg/L (WWTP inlet)
- Weighted maximum concentration Uranium: 16.3 mg/L (WWTP inlet)
- Uranium removal in biological pre-treatment: 5% (based on Pilot Trials)
- Uranium removal in the RO stage: 98 % (Pilot Trial)
- Brine precipitation with lime: 98 % (Pilot Trials - 2 % remain in Supernatant of the clarifier)
- Chemical sludge: 95 % capture of Uranium in filter press cake
- Evaporation/drying stream: 100% of Uranium remain in dried product
- Biosolids dewatering: 90% of Uranium stays within dewatered biomass;
- Residuals Volume reduction in the dewatering stages: 90%

Regarding Uranium, the highest concentrations will occur in the thickening and dewatering stages for the brine residual treatment (precipitation- thickening dewatering).These concentrations would be present in the tanks, process units, process pipework and in the final product (i.e. sludge cake).

The approximate concentrations of Uranium would be as follows (Table III):

Table III: Uranium concentration in residual process streams (rounded numbers), [7]

Location/Equipment	Scenario 1 Avg Flow, Avg Concentration	Scenario 2 Max Flow; Max Weighted Concentration
Sludge Thickener and associated pipework	900 mg/L U	1,800 mg/L U
Filter Press and associated pipework	900 - 8200 mg/L U	1,800 – 17,000 mg/L U
Cake storage below dewatering unit (dewatered sludge cake)	8200 mg/l U	17,000 mg/l U

Radium - 226 – Mass balance assumptions – Removal rates, [7]

- Average flow to WWTP: 395 m3/d
- Weighted average activity radium - 226: 21.61 Bq/l (WWTP inlet)
- Maximum flow to WWTP: 960 m3/d
- Weighted maximum activity radium - 226: 55.39 Bq/l (WWTP inlet)
- Maximum of the range for new Long-Term Waste Management Facility: 75 Bq/l (WWTP inlet)
- Radium – 226 removal in biological pre-treatment: 75 % (high); 25% (low)
- Radium – 226 rejection in the RO stage: 95% (Pilot Trial)
- Brine precipitation with lime: 75 % (Bench Scale test)
- Chemical sludge: 95 % capture of radium – 226 in
- filter press cake
- Evaporation/drying stream: 100% of radium – 226 remain in dried product
- Biosolids dewatering: 90% of radium – 226 stays within dewatered biomass
- Residuals Volume reduction in the dewatering stages: 90%

Note: The pilot trials showed removal rates between 50 and 80% in the biological pre-treatment. The content of radium in the dewatered biosolids is directly related to the extent of removal in the biological pre-treatment. We do not know at this time if radium is retained to the same extent in the future WWTP. We have therefore assumed two scenarios with medium (25%) and high (75%) removal rates for radium - 226 in the biological pre-treatment.

Based upon the scenarios described above the highest levels of radium – 226 will occur in the dewatering stages (centrifuge and filter press). The estimate concentrations (rounded) of radium - 226 are as follows:

Table IV: Radium - 226 concentration in residual process streams, [7]

Location/ Equipment	Scenario 1 Avg Flow & Concentration; 75% U- removal in Bio-pre treatment	Scenario 2 Avg Flow & Concentration; 25% U- removal in Bio-pre treatment	Scenario 3 Max Flow & Weighted Conc.; 75% U- removal in Bio-pre treatment	Scenario 4 Max Flow & Weighted Conc.; 25% U- removal in Bio-pre treatment	Scenario 5 Max Flow & Concentration; 25% U- removal in Bio-pre treatment
Mineral Sludge Thickener and associated pipework	540 Bq/l	1600 Bq/l	1300 Bq/l	4000 Bq/l	5400 Bq/l
Filter Press	540 – 5200 Bq/l	1600 – 15300 Bq/l	1300 – 11900 Bq/l	4000 – 37800 Bq/l	5400 – 51100 Bq/l
Dewatered mineral sludge cake	5200 Bq/l	15300 Bq/l	11900 Bq/l	37800 Bq/l	51100 Bq/l
Biosolids Sludge Thickener and associated pipework	300 Bq/l	100 Bq/l	600 Bq/l	220 Bq/l	300 Bq/l
Centrifuge	300 – 2800 Bq/l	100 – 1000 Bq/l	600 – 5700 Bq/l	220 – 2100 Bq/l	300 – 2800 Bq/l
Dewatered biosolids	2800 Bq/l	1000 Bq/l	5700 Bq/l	2100 Bq/l	2800 Bq/l
Slurry dryers associated pipework and dried product	560 Bq/l	1700 Bq/l	1300 Bq/l	4100 Bq/l	5600 Bq/l

The dose simulations with above Radium - 226 scenarios generated low dose rates and did not warrant permanent shielding around the equipment. During the commissioning phase of the project the process will be optimized to minimize handling time (human) and material accumulation.

To control the inhalation hazard from uranium and radium – 226, process measures are designed to minimize/control generation of airborne particulate matter, primarily using wet handling methods and ventilation.

CONCLUSION

The PGWMF WWTP will provide flexibility in its treatment systems to adapt to the fluctuating flows and concentrations and will produce a high quality effluent. With the inclusion of a dryer and evaporator, the solid waste will be reduced and the liquid waste will be eliminated. It is a robust design, providing redundancy and significant improvements in uranium, arsenic, and radium-226 removals for the duration of construction and in the long term. Fig 5 and Fig. 6 show renderings of the future completed remediated landsite and a view of the future WWTP respectively.

The overall design of the future PGWMF WWTP and the anticipated improved removal rates of primary COPC of its treatment process is expected to significantly reduce contaminates loading to the receiving environment, thereby protecting Lake Ontario.

Fig. 5: Completed Remediated Landsite, [4]

Fig. 6: Port Granby Waste Management Facility (WWTP), [4]

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