IMPLEMENTING BEST AVAILABLE TECHNOLOGY FOR WATER TREATMENT AT THE PORT HOPE AND PORT GRANBY LOW-LEVEL RADIOACTIVE WASTE CLEANUP PROJECTS

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ABSTRACT

Through the use of a systematic and flexible developmental strategy, AECL has been able to specify water treatment requirements for the PHAI's two low-level radioactive waste cleanup projects that are examples of using Best Available Technology (BAT). These will result in substantially reduced loadings of radium-226, arsenic, uranium and other contaminants associated with the waste to Lake Ontario, when compared to the option of simply continuing to use existing water treatment facilities at the project sites. Pilot scale studies carried out by AECL in 2010 have confirmed that individually distinct BAT water treatment process for the two projects can achieve the high contaminant removal efficiencies required to make the water quality improvements. Results of the pilot scale studies have also successfully provided the necessary detailed design requirements and specifications to enable completion of the water treatment facility construction and commissioning stages as part of the PHAI.

1. INTRODUCTION

1.1 Port Hope Area Initiative

The Port Hope Area Initiative (PHAI) is focused on developing two new long-term waste management facilities in the form of above-ground engineered mounds for historic low-level radioactive wastes (LLRW). These wastes are mostly by-products of uranium and radium ore processing activities of the former crown corporation Eldorado Nuclear Limited (Eldorado) and its private sector predecessors in Port Hope dating from 1932 through 1988. The PHAI was constituted by Natural Resources Canada (NRCan) in 2001. It is being led by the Port Hope Area Initiative Management Office (PHAI MO), which consists of a partnership of Atomic Energy of Canada Limited (AECL), NRCan and Public Works and Government Services Canada. AECL has the lead role for developing the new waste management facilities and for implementing associated water treatment requirements.

1.2 PHAI Environmental Assessment Study Conclusions

AECL completed environmental assessment study reports for the proposed Port Hope Project in 2006 and for the Port Granby Project in 2008. In both cases it was concluded that there would be no significant adverse effects on the environment associated with the discharge of effluent from the water treatment facilities that would be part of the works and activities for the respective projects [1][2][3][4].These conclusions were based on the assumption that the requisite water treatment provisions would be accomplished with technologies comparable to those currently employed at the existing Welcome Waste Management Facility (WWMF) in Port Hope and at the existing Port Granby Waste Management Facility (PGWMF) in the Municipality of Clarington.

Nevertheless, it was deemed prudent to reconsider the overall effects [of the projects] from the context of the ALARA[1] principle and from the perspective of minimizing pollution. An examination of options for enhancing water treatment effectiveness was therefore carried out as part of specifying design details for the two projects. This resulted, in 2008, in the formulation of a strategy for determining the water treatment requirements applicable to the PHAI's project objectives.

This paper describes AECL's on-going efforts toward the development of enhanced water treatment options for the two PHAI projects that are a) based on using Best Available Technology (BAT)[2] and b) address a broad suite of contaminants of potential concern (COPC) with a view to minimizing effluent loadings to the Lake Ontario ecosystem. Based on regulatory agency review comments on the two PHAI Environmental Assessment Study Reports and Canadian Nuclear Safety Commission (CNSC) staff review of preliminary design description documentation for the respective projects, it became evident that CNSC staff expected AECL to first and foremost follow a technology-focused approach toward development of water treatment requirements. In other words, CNSC staff expect licensees to consider treatment requirements and environmental protection objectives in the context of using a BAT that is economically achievable. The CNSC expects licensees to take all reasonable precautions to control the release of nuclear substances or hazardous substances into the environment.

1.3 Current Conditions

Previous papers have described the scope of the PHAI's Port Hope and Port Granby Projects [5] and the historic issues associated with the collection and treatment of contaminated water at the WWMF and the PGWMF [6]. Since the late 1970s, water collection and treatment facilities have been operating at both the WWMF and the PGWMF that use a ferric chloride ($FeCl_3$) precipitation process for COPC removal. Table 1 below shows that good removal efficiency at these facilities is currently evident only for arsenic at the WWMF. AECL's primary objectives in evaluating new water treatment requirements therefore were 1) to improve the removal efficiency for all the above key COPCs and 2) ensure that other significant COPCs are also effectively addressed.

2. WATER TREATMENT DEVELOPMENT STRATEGY

In addition to the general objectives of improving treatment facility effluent quality, the implementation of the Port Hope and Port Granby Projects was forecast to involve greater volumes of water and possibly higher inflow COPC concentrations. As a result, AECL implemented a strategy to establish the overall requirements for water treatment that included an

[1] Proponents are generally encouraged to apply the ALARA principle (As Low As Reasonable Achievable, social and economic factors considered) where human health or environmental safety concerns exist to ensure that impacts are not managed to just meet regulatory objectives, but to do better if it is reasonably achievable.

[2] Various forms of this term are in use, e.g., BDAT (Best Demonstrated Available Technology) or BATEA (Best Available Technology Economically Achievable). These are assumed to have essentially the same meaning. Consequently, only BAT is used in this paper.

assessment of future treatment requirements and applicable treatment technologies followed by a follow-up program of testing and verification as described in the following.

Table 1. Summary of Current Water Treatment System Efficiencies (Average % Removal) 1997 to 2008

COPC	Port Hope (WWMF)	Port Granby (PGWMF)
Arsenic	97.4	22.9
Uranium	50.2	--[3]
Radium-226	40.6	62.4

2.1 Assessment of Treatment Requirements and Applicable Technologies

2.1.1 Future flows and water quality – Port Hope

Based on project-specific hydrological analyses, it was estimated that the maximum annual total flow that might be encountered at the existing WWMF during the Port Hope Project would be about twice the historic average annual flow, i.e., increasing from about 124,000 m^3, as measured during the period 1992 through 2004, to about 250,000 m^3 for the middle years of Phase 2 [7].

The determination of potential future inflow COPC concentrations for the existing WWMF was inferred from groundwater monitoring results obtained during the Port Hope Environmental Assessment. In addition, the results of laboratory leach tests done in 1994 on various Port Hope wastes were reviewed and considered for projecting potential future water quality, especially for leachate from the proposed new Long-term Waste Management Facility (LTWMF). The resulting projected maximum influent concentrations for primary Port Hope COPCs, which would have to be addressed by a new water treatment facility, are shown in Table 2 [7].

Table 2. Projected Maximum Concentrations for Primary COPCs in Treatment Inflows

Arsenic mg/L	Uranium mg/L	Radium-226 Bq/L
26.4	11.3	10.6

2.1.2 Future flows and water quality – Port Granby

Based on site-specific hydrological assessments, it was estimated that the maximum monthly flow rate that might be encountered at the existing PGWMF during the waste excavation period (about 5 years) would be about 1.5 times the recent historic maximum monthly flow rate, i.e.,

[3] Because uranium is not specifically targeted by the Port Granby water treatment process, it is not monitored in the Treatment Plant Inflow or in the Treatment System Discharge. Uranium concentrations are monitored, however, in the final (total) effluent from the Port Granby site prior to discharge to Lake Ontario, which includes the flow from the Treatment System Discharge and other non-contaminated groundwater and surface water flows from the site. During the same 12-year monitoring period, uranium concentrations in the final effluent averaged 1.9 mg/L.

increasing from about 9,000 m^3, as recorded on occasion during the period 1992 through 2004, to about 13,000 m^3 at times during Phase 2. Similarly, it was determined that the maximum flow rate generated at the proposed new Port Granby LTWMF[4] on a monthly basis during Phase 2 could, on occasion, reach 12,000 m^3 [4], i.e., a total maximum monthly rate of up to 25,000 m^3.

During the detailed design development for a new water treatment facility, the expected average and maximum monthly flow rates (m^3) to the new treatment system were re-estimated to account for more specific water flow and usage expectations. The revised total flows from all sources are projected to be as follows [8]:

- Average 10,700 to 14,000 m^3/mo
- Maximum 25,400 to 35,300 m^3/mo

The determination of potential future inflow COPC concentrations for the existing Port Granby WMF can be inferred from groundwater monitoring results obtained during the Port Granby Environmental Assessment. In addition, the results of laboratory leach tests done in 1994 on Port Granby wastes were reviewed and considered for projecting potential future water quality, especially at the new LTWMF. The resulting projected maximum influent concentrations for primary Port Granby COPCs, which would have to be addressed by a new water treatment facility, are shown in Table 3 [4].

Table 3. Projected Maximum Concentrations for Primary COPCs in Treatment Inflows

	Arsenic mg/L	Uranium mg/L	Radium-226 Bq/L
PGWMF	10	9	22
LTWMF	10	20	75

2.2 Technology Assessment

AECL's approach to the technology assessment was described in [6]. For both projects, it was determined that in order to achieve the general objective of improved water quality in facility discharges, the existing water treatment processes would require augmentation of the coagulation-precipitation-flocculation systems already in operation.

For the Port Hope Project the preferred feasible technology consisted of general pre-treatment (e.g., filtration or pH adjustment) followed by a two-stage treatment process utilizing coagulation / precipitation (with ferric chloride) and Reverse Osmosis (RO) [7]. Two alternatives were proposed:

1. Alternative IA – is based on the ferric chloride coagulation / precipitation being the lead step, which would be followed by RO for final polishing.
2. Alternative IB – is based on RO being the lead step followed by the ferric chloride coagulation / precipitation process for treating the reject (concentrate) stream from the RO stage.

[4] The site of the proposed new Port Granby LTWMF is approximately 800 m north of the existing PGWMF. The new water treatment plant will be located adjacent to the new LTWMF.

For the Port Granby Project the preferred feasible technology consisted of general pre-treatment (e.g., filtration or pH adjustment) followed by coagulation / precipitation using ferric chloride followed by Ion Exchange (IX) [7].

2.3 Bench Scale Studies

Bench scale testing programs were carried out during the fall of 2009 to confirm the feasibility of the respective preferred technologies.

2.3.1 Port Hope Bench Scale Studies

A series of jar tests for coagulation / precipitation experiments were designed and conducted to determine factors such as optimal ferric chloride dose rates, flocculent requirements, mixing time, settling time and the like. Jar tests were carried out at the investigating consultant's laboratories. A custom-built RO test unit was installed at the WWMF to conduct the comprehensive testing program. This unit was supplied by a vendor specializing in RO equipment for waste water treatment applications (ROCHEM). It features a unique open channel membrane configuration, which is claimed to be superior to the more conventional RO membrane designs.

The Port Hope bench scale studies confirmed that [9]:

1. The ROCHEM RO process is capable of achieving very high rejection rates (typically > 99%) for all contaminants in all the composite samples tested. When combined with the ferric chloride coagulation / precipitation process, an overall BDAT system will be capable of achieving the general water quality improvement objectives.
2. The testing also showed that a flexible configuration, switchable between Alternatives 1 and 2 may be the best overall approach. Alternative 2 may be more suitable at lower contaminant levels in the inflow, i.e., base flow conditions, whereas Alternative 1 may be better during periods when higher concentrations are expected, i.e., when certain waste types are being excavated or placed into the new LTWMF.

The preliminary overall treatment process that was proposed on the basis of the bench scale studies included the use of evaporation technology for the final volume reduction stage of the process. In addition, the implementation of the ferric chloride coagulation / precipitation process was proposed to make use of mechanical clarifiers for the solid/liquid separation step instead of external precipitate settling ponds.

2.3.2 Port Granby Bench Scale Studies

During the preliminary bench top screening tests for the Port Granby project, it was determined that due to the high levels and composition of total dissolved solids (calcium, magnesium, sodium, potassium, sulphate, ammonia, nitrate and nitrite) in the composite samples, the efficiency of an IX process would not likely be satisfactory to achieve good water quality results. Consequently, the decision was made to focus the comprehensive bench scale program on the second preferred approach – RO.

The bench scale studies were conducted in off-site laboratories with water collected from the East and West Reservoir inflows and from selected borehole monitoring wells on the PGWMF site that yielded groundwater samples from various waste burial locations. With the expectation that the ferric chloride coagulation / precipitation stage would constitute an appropriate pre-treatment stage, the comprehensive RO testing on Port Granby composite water samples was carried out with an available conventional technology lab-scale unit.

The Port Granby bench scale studies confirmed that [10]:

1. The RO process appears capable of achieving very high rejection rates (typically ~ 99% or better) for all COPCs in all the composite samples tested, including the arsenic hexafluoride and uranium, which are not removed with the existing process. When combined with the ferric chloride coagulation / precipitation process, an overall (BDAT) system will be capable of achieving enhanced water treatment objectives.
2. Pre-treatment for ammonia and/or nitrate/ nitrite removal may be required in order for the RO process to function at peak effectiveness.
3. Evaporation may be feasible for final brine (concentrate) treatment.

Follow-up test work done in 2010 March concluded that a biological treatment process had good potential for pre-treating the Port Granby effluent to reduce the relatively high concentrations of ammonia and nitrate in the inflow [11]. As a result, a pilot scale program was proposed to include a biological treatment stage followed by an RO stage. With this configuration, it was hypothesized that a ferric chloride coagulation / precipitation process would likely not be necessary.

2.4 Pilot Scale Studies

Pilot scale studies were designed for both projects to validate the bench scale testing program results as well as to identify those process issues that would likely become apparent only during real-world operations, thereby improving the robustness of the final design. Pilot scale testing was also required to identify and specify applicable design requirements to enable the preparation of detailed design documents, drawings and cost estimates for the full water treatment process, including building design, residuals handling requirements, etc.

2.4.1 Port Hope Pilot Scale Studies

The Port Hope pilot study included ferric chloride coagulation / precipitation process equipment followed by a slant-plate clarifier and two separately packaged RO treatment units. The pilot scale test process equipment was set up at the WWMF entirely inside a single marine shipping container located adjacent to the existing on-site water treatment building. In addition, two large water tanks (9,500 litres each) were located next to the marine container for storage of concentrate from the primary ROCHEM RO stage for further testing.

Due to the large flow requirements, the only feasible source of contaminated water was the East Collection Pond[5]. However, all concentrate from the primary ROCHEM RO testing stage was collected so that it could subsequently be used to "spike" incoming feed water as a way of evaluating the process with higher incoming contaminant concentrations. Concentrate was added to the inflow so that the observed Total Dissolved Solids (TDS) levels were raised to twice that observed for the initial test runs.

All "waste" streams from the pilot testing studies, including concentrate and permeate from the RO process as well as clarified water and solid precipitates from the ferric chloride coagulation / precipitation were returned to the East Collection Pond at the WWMF.

The Port Hope pilot scale studies, carried out at the WWMF from 2010 September through December [12], determined that Alternative 1, i.e., chemical precipitation and clarification followed by RO treatment was the preferred treatment configuration for the Port Hope Project at the WWMF. However, a number of variations of this alternative were tested as follows:

1. Bypassing the ferric chloride precipitation / clarification stage, i.e., direct feed to the ROCHEM RO system (see Figure 1);
2. Use of conventional RO membrane configuration instead of ROCHEM RO membranes for primary treatment; and
3. Use of conventional RO membrane system set up for "polishing" the permeate from the ROCHEM RO membrane unit.

Based on the observations from the pilot studies, it was concluded that final effluent quality did not significantly benefit from a secondary RO treatment stage. As a result, a permeate polishing stage for the water treatment process was not recommended for final design.

Figure 1. ROCHEM RO System at WWMF Pilot Study

[5] The East Collection Pond is the current main storage pond for contaminated water at the WWMF that feeds the existing water treatment process.

The pilot testing results also confirmed that the performance of the ROCHEM RO design was sufficiently superior to that of conventional RO membrane technology to warrant specification of the former for the full scale treatment system design. Although both membrane technologies provided excellent performance in regard to COPC rejection, the Port Hope Project pilot studies showed that ROCHEM RO membranes were able to perform for more than twice as long before membrane cleaning cycles had to be initiated. In addition, testing with the conventional RO membrane technology demonstrated that it was more susceptible to irreversible fouling.

Testing of the ROCHEM RO membrane unit with either direct East Collection Pond inflow or spiked East Collection Pond inflow (i.e., without the ferric chloride precipitation / clarification pre-treatment stage) demonstrated that it was consistently capable of providing excellent performance in regard to COPC rejection. In other words, pre-treatment did not offer appreciable additional final water quality improvement. However, in order to provide the greatest degree of system flexibility to accommodate the expected variability in waste water flows and characteristics during the construction and development phase of the Port Hope Project, the proposed full-scale treatment process will include the ferric chloride precipitation / clarification pre-treatment stage and the ROCHEM RO Primary treatment operations. Because the pilot study was not able to process water with the maximum projected COPC concentrations (Table 3), it is recommended that the clarification pre-treatment processes be incorporated in the full scale system so that it can be utilized as required during periods when inflow waters are characterized by higher levels of COPCs, especially arsenic, and/or elevated levels of suspended solids, e.g., during periods of high runoff due to peak precipitation events.

Select performance data relevant to the preferred overall treatment configuration with East Collection Pond feed are shown in Table 5 below. Corresponding data for tests with East Collection Pond feed spiked with previous RO run concentrate are shown in Table 6.

Table 5. Primary COPC Removal Observed Using ROCHEM RO Process Only on Normal Feed at 80% Volumetric Recovery[6].

COPC	Average Inflow	Average Effluent	% Reduction Based on averages
Arsenic	0.41	0.0018	99.6
Radium-226	0.06	0.005	91.7
Uranium	0.305	0.00124	99.6

As shown, the ROCHEM RO process was confirmed to be highly effective for metals and radionuclide removal. In the case of radium-226 however, it was concluded that the actual removal efficiency may be better than the 91.7% level shown in Tables 5 and 6 because 1) inflow radium-226 levels are relatively low to begin with and 2) radium-226 concentrations in the effluent were typically at or below the analytical method detection limit, thus making

[6] The pilot scale testing program included treatment runs at 75%, 80% and 85% recovery rates. Since 80% is typically adopted as the design requirement, these results are shown in this summary.

calculations less meaningful. The pilot scale studies also showed that even without pre-treatment by chemical precipitation, the ROCHEM RO membrane system was shown not to be adversely effected by potential fouling agents in the feed water.

Table 6. Primary COPC Removal Observed Using ROCHEM RO Process Only on Spiked Feed at 80% Volumetric Recovery.

COPC	Average Inflow	Average RO Effluent	% Reduction Based on averages
Arsenic	0.773	0.007	99.1
Radium-226	0.06	0.005	91.7
Uranium	0.72	0.0075	99.0

On-site laboratory scale test work on the residuals from the RO process were also conducted during the pilot trials. These confirmed that evaporation is feasible and will therefore be the key component of the residuals treatment stage.

2.4.2 Port Granby Pilot Scale Studies

The Port Granby pilot scale study program was developed in the spring of 2010 to conduct large scale treatment testing on-site at the PGWMF. It had the two-fold objective to 1) confirm the performance of the treatment processes as indicated by the bench scale studies and 2) to determine the design requirements for the design of a full scale system. The pilot study included a biological treatment process, utilizing a membrane bio-reactor (MBR) system, and an RO treatment process in series. Testing of treatment residuals (RO concentrate) for further volume reduction was carried out at off-site laboratories with samples collected during the pilot trials.

In order to conduct meaningful tests of the biological treatment process, a sizable set up was required (see Figure 2). The process included five large tanks ranging in size from about 2 to 11 cubic metres. In addition, three 75 cubic metre tanks were used for treatment inflow storage and interim effluent storage. As a result, the pilot testing process, which occupied an area of approximately 800 m^2, was set up within the PGWMF waste burial area under large, open-sided tents.

The biological reactor system operated at a typical flow rate of 10 to 15 litres per minute and once the process achieved stable performance, was put into 24 hour per day continuous operation. Discharge from the biological process was collected in an interim storage tank as the feed for the RO process, which operated at approximately 30 litres per minute. As a result, the RO process was only operated during the day when operators were on site.

Concentrate and permeate from the RO process were collected in separate storage tanks for analytical determination of COPC concentrations, and in the case of the concentrate, for subsequent off-site testing of residual treatment processes, e.g., evaporation. RO concentrate and permeate were periodically returned to the PGWMF's Sedimentation Lagoon[7]. Testing consisted of using water from three on-site sources to enable evaluation of the effectiveness of the biological processes with varying levels of ammonia and nitrate in the inflow.

Figure 2. MBR System at PGWMF Pilot Study

Nitrogen removal can be achieved biologically through a number of activated sludge processes. The biological treatment process tested at Port Granby consisted of two stages. The first stage is an anoxic reaction maintained as a low oxygen environment where microbe-assisted denitrification of nitrate to nitrogen gas occurs. The second stage is an aerated, oxygen rich environment where microbe-assisted nitrification of ammonia and nitrite to nitrate occurs. In order for both reactions to be completed, a recycle flow from the aeration reactor (with Return Activated Sludge (RAS)) to the anoxic reactor is maintained so that a satisfactory Hydraulic Retention Time (HRT) is achieved. A smaller volume flow from the aeration reaction stage is passed on to the membrane tank of the MBR.

[7] The Sedimentation Lagoon is the storage pond for collected contaminated water prior to treatment. Contaminated water at the existing PGWMF is collected at two locations – the East Reservoir and the West Reservoir – and pumped uphill to the Sedimentation Lagoon.

The membrane tank is also an aerated stage where liquid-solid separation takes place. A membrane pore size of 0.04 μm is used to effect the filtration of the Mixed Liquor Suspended Solids (MLSS) from the treated water. With this type of membrane, the volume and footprint of the overall process can be significantly less than with conventional activated sludge clarification processes. Water is filtered through the membrane by means of a suction pump and a small MLSS stream is wasted – the Waste Activated Sludge, or WAS – to keep the MLSS concentration optimal. During the pilot scale tests, the WAS stream from the MBR was directed to an existing dewatering trench immediately west of the pilot set up that is normally used during the clean out of the on-site water collection reservoirs for sediment dewatering.

2.4.3 Results

The pilot scale studies, carried out at the Port Granby WMF from 2010 August through October, confirmed that the proposed biological treatment process, which involves microbial degradation of the ammonia and nitrate to nitrogen gas, was highly effective for ammonia and nitrate reduction [11].

Ammonia levels in the pilot inflow ranged from about 65 mg/L to 145 mg/L as nitrogen (N). Based on 13 designated sampling occasions, ammonia removal by the biological treatment stage throughout the pilot testing period was consistently at 99% or greater.

Nitrate levels in the inflow varied from 184 mg/L to 327 mg/L as N. Nitrate removal rates through the biological reactor stage were typically above 90%. Exceptions were found to be correlated to operational difficulties, e.g., a Dissolved Oxygen sensor malfunction experienced about two thirds of the way into the testing program. The subsequent RO stage was found to be effective for removing residual nitrate (see below). In addition, the biological treatment process was shown to achieve varying degrees of metal and radionuclide COPC removal as shown in Table 7.

Table 7. Primary COPC Removal Observed with MBR Process.

COPC	Average Inflow	Average MBR Effluent	% Reduction Based on averages
Arsenic	1.1 mg/L	0.9	18
Radium-226	0.82 Bq/L	0.19	77
Uranium	6.1 mg/L	5.8	5

As expected, the RO process was confirmed to be highly effective for metals and radionuclide removal [11]. Table 8 shows the combined MBR and RO removal efficiencies for the primary COPCs. Laboratory scale test work on the residuals from the RO process have confirmed that evaporation is feasible and will therefore be the key component of the residuals treatment stage.

Table 8. Overall Removal Rates for Primary COPCs (after MBR and RO).

COPC	Average Inflow	Average RO Effluent	% Reduction Based on averages
Arsenic	1.1 mg/L	0.015	98.6
Radium-226	0.82 Bq/L	0.01	99
Uranium	6.1 mg/L	0.06	99
Nitrate	272 mg/L as N	3.9	98.5

3. NEXT STEPS

Due to the comprehensive scope of the pilot scale studies, AECL is confident that with the positive results from both the Port Hope and Port Granby water treatment pilot scale studies, pursuing the detailed design of new and substantially enhanced water treatment facilities for the respective projects can proceed. To date, detailed design requirements and specification for the respective processes, as well as preliminary Process & Instrumentation Drawings and building construction drawings and specifications, have already been prepared. The final water treatment facility construction design submissions are expected to be completed in mid to late 2011.

For the Port Hope Project, the new water treatment facility will be designed on the basis of the two primary treatment processes – chemical precipitation and RO. The system will be configured such that treatment feed can either be directly routed to a ROCHEM RO-based treatment train or to a ferric chloride precipitation / clarification pre-treatment stage followed by ROCHEM RO processing. In either case, evaporation will be used to treat residuals (permeate) from the RO train.

For the Port Granby Project, AECL is pursuing the detailed design of the water treatment facilities on the basis of the two stage biological treatment followed by RO treatment approach. As expected, the pilot scale testing results also confirmed that continued use of the ferric chloride coagulation / precipitation process would not be required as part of a new water treatment facility. Evaporation is proposed to treat residuals (permeate) from the RO train.

AECL is also in the process of developing, in conjunction with its engineering design teams, the required commissioning plans and procedures required to bring these facilities on-line at the appropriate timeframe within the overall Port Hope and Port Granby project time lines.

4. SUMMARY AND CONCLUSIONS

AECL's strategic approach for the development of water treatment processes for the two projects was shown to be very effective. The systematic process of conducting technology assessments, identifying and quantifying treatment requirements, conducting bench scale tests and finally conducting pilot scale tests, proved to be advantageous at a number of stages. For example, the initially preferred technologies (for both projects) from the technology assessment were revised as a result of finding from the respective bench scale studies. As well, preliminary design proposals, prepared after the bench scale studies, were revised in a number of areas specifically as a result of details that emerged during the pilot scale studies. Lastly, due to site-specific differences between the WWMF and the PGWMF, individualized water treatment processes have been developed and proposed. In order to achieve maximum environment benefit, the existing similar treatment processes at the WWMF and the PGWMF will therefore be upgraded into distinct BAT-based systems.

Substantial improvements in removal efficiency for the primary COPCs (As, Ra-226 and U) are therefore expected to result in reduced loadings of these constituents to Lake Ontario during the conduct of both the Port Hope Project and the Port Granby Project.

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