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Low-Level Liquid Radioactive Waste Treatment at Murmansk, Russia: Facility Upgrade and Expansion

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ABSTRACT

Today there exist many almost overfilled storage tanks with liquid radioactive waste in the Russian Federation. This waste was generated over several years by the civil and military utilisation of nuclear power. The current waste treatment capacity is either not available or inadequate. Following the London Convention, dumping of the waste in the Arctic seas is no longer an alternative. Waste is being generated from today's operations, and large volumes are expected to be generated from the dismantling of decommissioned nuclear submarines.

The US and Norway have an ongoing co-operation project with the Russian Federation to upgrade and expand the capacity of a treatment facility for low level liquid waste at the RTP Atomflot site in Murmansk. The capacity will be increased from 1200 m^3/year to 5000 m^3/year. The facility will also be able to treat high saline waste. The construction phase will be completed the first half of 1998. This will be followed by a start-up and a one year post-construction phase, with US and Norwegian involvement for the entire project.

The new facility will consist of 9 units containing various electrochemical, filtration, and sorbent-based treatment systems. The units will be housed in two existing buildings, and must meet more stringent radiation protection requirements that were not enacted when the facility was originally designed. The US and Norwegian technical teams have evaluated the Russian design and associated documentation. The Russian partners send monthly progress reports to US and Norway.

Not only technical issues must be overcome but also cultural differences resulting from different methods of management techniques. Six to eight hour time differentials between the partners make real time decisions difficult and relying on electronic age tools becomes extremely important. Language difficulties is another challenge that must be solved. Finding a common vocabulary, and working through interpreters make the process very vulnerable. Each of these obstacles can be overcome when there is a common goal and vision shared by all parties and adequate funds are provided to accomplish the task.

The upgrading and expansion of this facility and the construction of a similar facility on the Far East coast of Russia will enable the Russians to sign the London Convention dumping prohibition. This project is one of the first waste management construction projects in the north-west of Russia with foreign contribution. Its success may open for additional co-operative projects with Russia in the future.

INTRODUCTION

Dumping of liquid radioactive waste in the Sea of Japan by the Russian Navy in the Autumn of 1993 and in the Barents sea the previous year, made the international community focus on this practise. Within the framework of the autumn 1993 meeting of the London Convention, the prohibition of all dumping was adopted. The Russian Federation reserved against it. They declared that they did not have the technical facilities to treat the waste. However, they have managed to comply with the dumping prohibition, primarily through tank and on-board storage.

The Project known as the "Murmansk Initiative" is an ongoing collaboration between Norway, the Russian Federation and the United States of America [1]. It is one of the first real co-operative construction projects in the field of Radioactive Waste Management with the Russian Federation.

The co-operation started in 1994. The co-operative design and feasibility effort was conducted from April to December 1995, when an agreed upon scheme for the financing and construction upgrade for the facility was approved. The protocol (signed in Oslo in December 1995) between the three member nations required construction evaluations at the 20, 50, 80 and 100 % completion milestones in the project. Completion of the construction phase of the project is scheduled for the first half of 1998.

The primary thrust of the tri-party collaboration is the expansion and upgrade of the low-level liquid radioactive waste facility located in Murmansk, Russia. The capacity of the plant will be increased from today's 1200 m^3/year to 5000 m^3/year. It will also be expanded so it can treat three different liquid waste streams: Low-salt solutions (#1); Decontamination and laundry waste, medium salt content solutions, (#2); and High-salt solutions (#3).

The current treatment plant is located at the facilities of the Russian company RTP Atomflot, which provides support services for the Murmansk Shipping Company's (MSco) nuclear icebreaker fleet. The new facility will be built with mainly Russian technology.

CURRENT DESIGN STATUS

The principles for treating the three waste solutions have been used elsewhere in both radioactive and non-radioactive treatment facilities within the former Soviet Union. They are based on adsorption, ion exchange, electrodialysis, and electrochemical destruction. Some technological advances developed in Russia, namely sorbent materials, are being applied. The current design, summarized in a report [2] referred to as "the Green Book", has been approved by the Russian regulatory authorities, Gosatomnadzor and the Murmansk Environmental Committee. This design establishes a well-defined set of operational limits for the facility.

General chemical characteristics of the liquid solutions to be treated are summarized in Table I. Small quantities of other liquids may be treated also, but these will only be allowed after permission is obtained from the regulatory authorities. The three waste streams have different treatment schemes, according to their chemical characteristics.

Solution #1 Treatment Scheme

Solution #1 is a low-salt-content water with a maximum radioactivity concentration of 10^{-5} Ci/L, which results from its use as primary coolant in ship-board reactors. Suspended solids will be present up to a maximum of 50 mg/L. Because of the low total solids content (100 mg/L maximum), Solution #1 can be treated with a combination of filters and sorbent columns in Unit 9. Further treatment by ion exchange in Unit 7 is available, if needed.

Unit 9 contains a series of five sorbent columns and one filter, arranged in the following order: clay (Clinoptilolite), nickel ferrocyanide (NGA), microfiltration, zeolite (CMP, equivalent to A-51), clay (Clinoptilolite) and zeolite (CMP). The Schematic for the process is shown in Figure 1. NGA is a proprietary Russian development, consisting of a silicate carrier coated with a ternary metal ferrocyanide compound abbreviated as nickel ferrocyanide. It was developed as a cesium-specific sorbent. CMP is intended to remove cesium and strontium.

After the column treatments, the liquids are held for analysis in the Unit 9 control tank. If further radioactive decontamination is needed, the liquid is sent to Unit 7 to a mixed bed ion exchanger. After that it is returned to the control tank for testing before release to the environment (the Kola Bay).

Included in the Green Book is a mass balance analysis, which demonstrates that the facility will operate as required within regulatory limits. Figure 2 presents projected decontamination achieved during treatment of Solution #1. Activity levels of cesium-137 and strontium-90 drop well below the regulatory limit of 10^{-10} Ci/L per radionuclide. The total activity of all other radionuclides (except tritium) amount to approximately 10^{-10} Ci/L. Decontamination values may differ somewhat from those projected, due to process conditions and variations in solution chemistry. However, discharges to the environment are permitted on a batch basis only. The contents of the control tank are tested before permission can be obtained. If the test results show that regulatory limits will not be met, the solution can be treated further in Unit 7 or re-treated within Unit 9.

Solutions #2 and #3 Treatment Scheme

Because of their similarities and higher salt content, Solutions #2 and #3 are treated in the same units, although the liquids will be treated separately. The higher salt contents result from diluting solutions with sea water so that on-board shielding requirements during transportation are reduced. The presence of decontamination reagents, especially complexants such as Trilon B, presents an additional challenge because the complexing agents must be destroyed to allow the removal of radionuclides from the solution by sorption methods.

The original design combined various components in discrete Units for the treatment of Solutions #2 and #3 to be carried out in separate equipment lines.[1] However, in the design modifications introduced in early 1997, the order of sorbent columns and their locations were changed to conform with space limitations and NRB-96 radiation safety standards [3]. The use of the Unit nomenclature is a carryover from this design, but the liquid flow does not necessarily progress with unit number.

Unit 1 consists of tanks and chemical additive systems which adjust pH and remove hardness. The solutions then pass to Unit 2, an electrochemical destructor system which removes the complexing agents. Following this, the solutions pass through a series of filters and sorbent columns located in Units 2, 3, and 4/5, which remove suspended solids and a large portion of the radioactivity, much of which is Cs-137 and Sr-90. The progression is as follows: sand filter (removal of particles >100 microns), sulpho-carbon column, Porolas™, NGA, and CMP. After this point the solution passes to Unit 6, an electro-dialyser and electro-concentrator system which removes salt. Downstream of Unit 6, the desalinated solution will be diverted either to Unit 9 or back to Unit 4/5 for further sorbent treatments. The choice of Unit will depend on cesium and residual salt concentrations. Higher chloride, sulphate, and phosphate concentrations will force the use of Unit 9, since the return route to Unit 4/5 results in the use of Seleks-KM sorbent further down in Unit 7. Seleks-KM is a cesium-selective sorbent, and its performance can be adversely affected by the presence of the anions mentioned. Specific process requirements delineating which route the solution will take will be developed during the start-up phase of the project.

The mass balance analysis assumed that the treatment line returning to Unit 4/5 and through Unit 7 (and Seleks-KM) would be used. Before Unit 7 is accessed, there is a second option to move the treated solution to the Unit 9 control tank for discharge to Kola Bay, if the treatment has been effective enough. Unit 7 is used if necessary to achieve discharge limits. Calculating decontamination from the mass-balance data for both solutions #2 and #3 shows that reduction of radionuclides is achieved by the system to levels even lower than that found for Solution #1.

NON-TECHNICAL "CHALLENGES"

This project for the construction of a waste treatment facility in north-west Russia, one of the first with foreign partner involvement, poses many challenges. The US and Norwegian teams have resolved to keep in close contact with and throughout the project. All design and construction is being performed by the Russian partner. The Russian side has agreed, under the protocol signed in Oslo December, 1995, to send monthly progress reports to the Norwegian Radiation Protection Authority (NRPA) and Brookhaven National Laboratory (BNL), and money is released from Norway and the US to the Russian partner based on the evaluation of these reports.

There are a number of difficulties which arise from attempting to evaluate and characterise the efforts of a construction site from over 6,000 km away (in the case of the US). The first major obstacle to overcome is the system of reporting the construction status in a manner that all parties can agree upon. The difficulties encountered can be mitigated if electronic mail and Fax services are available. This may seem to be a common sense issue; however, with time differentials of 6 to 8 hours between participants, real time decision making must rely on the electronic-age tools available.

A second hurdle to overcome is the discrepancy between the different methods of management techniques arising from cultural differences. In the US, management is accomplished through the use of various tools which are effective on US projects, but may be cumbersome and unwieldy when trying to evaluate construction progress at great distances without a continuous on-site presence.

An unexpected impediment has been the protracted time it takes for money to be transferred to the Russian accounts and at the same time assure appropriate tax exemptions. In July, 1996, a 30 day payment flow was agreed upon (first review and approval of reports and then transfer of money). This has been proved to be unrealistic and has been upgraded to a 6 week estimate for the flow.

The final complication to an already complex formula for "success" is the language difficulties one may encounter. The use of phrases such as "baseline inspection" may require long discussions and tedious explanations. A competent technical translator is a necessity if there shall be any hope of mutual understanding between the participants. The use of the same translator through the total life cycle of the project would also provide continuity and consistently reproducible interpretations.

PROJECT MILESTONES

April to December, 1995: The US and Norwegian technical teams reviewed the Russian design [1] and agreed to continue with the construction phase. The Russian side then began work on the final design and working documentation.

November, 1996: A "0 %" (baseline) inspection of the facility was performed by members of the US and Norwegian team. The purpose of this visit was to evaluate the status of the facility and determine the extent of re-work and new construction necessary to upgrade the treatment capacity of the facility to 5,000 m^3/year.

April, 1997: The "20 %" meeting/inspection was held in both St. Petersburg and Murmansk. During these meetings, the Russian partner revealed that several design changes were instituted to meet changing government regulatory requirements. The new and more stringent radiation safety standards, NRB-96 [3] and requirements for thicker walls thus affected the project. The upgraded facility will be constructed in existing buildings, the original design had therefore to be optimised. The overall effect was increased cost and delays for construction completion.

June and July, 1997: Visits were made by the US and Norwegian experts to Murmansk. The purpose of these visits/inspections was to evaluate the construction progress to date, and to discuss the "new design and cost".

October, 1997: The "design envelope" (known as the "Green book") and safety analysis for the project was approved by the Russian authorities [2].

November, 1997: The "50 %" meeting was held in Murmansk, with a week long technical pre-meeting in St Petersburg. A total of 250 working albums (design specifications) were finalized. Continuing construction and reconstruction work is being performed at the site. Long lead time equipment/components have been ordered and to a large part manufactured. They are "on hold" at different plants awaiting final payment before transportation to RTP in Murmansk.

The project will continue with both 80% and 100 % meeting/inspections and then into the start-up and post-construction operational phases. The Norwegian and US technical teams will continue their close co-operation with their Russian partner in this phase, according to a program to be developed. The project is considered to be finished after a year of satisfactory operation.

CONCLUSIONS

This project is an example of a coherent initiative developed to solve environmental problems in Russia. It is a good example of how co-operation can be developed and function between Russian authorities/companies and corresponding entities from the Western side. It is also of great importance to the "stakeholders" that Russian technology is being used. This technology is innovative and, in some instances, it is "one of a kind".

The project has necessitated co-operation between different Russian organisations and authorities. Western methods of project management, with close project follow up, including quality control and quality assurance, is being transferred to a Russian construction project, of course, neither painlessly nor without considerable effort.

There have been and continue to be many challenges to overcome. Working in Russia requires a great deal of patience and human knowledge, in addition to professional and technical skills. These challenges can be overcome when there is a common goal and vision shared by all parties, and there are adequate funds to accomplish the task at hand.

It has been an important learning process for all parties involved. Looking at it from the environmental and safety viewpoint, this project is an introduction to other more important projects within Russia. This project continues to be important because it is one of the first waste management construction project in the north-west of Russia with foreign partners. The completion of the project will enable the Russian Federation to comply with the current prohibition on dumping of low-level nuclear wastes. Additionally, when a similar plant in the Far East of Russia starts operating it will allow the Russian Federation to sign the amendment to the London Convention.

The treatment facility in Murmansk will also have the ability to handle waste from the northern navy and will play an important role in the treatment of the liquid radioactive wastes that will be generated during the dismantling of decommissioned nuclear submarines. It is a civilian plant but the military contact points makes this project of special interest for the Norwegian and US partners and for future co-operation projects with the Russian Federation.

REFERENCES

1. R.S. DYER, et al, "Low-Level Liquid Radioactive Waste Treatment at Murmansk**,** Russia: Technical Design and Review of Facility Upgrade and Expansion," Brookhaven National Laboratory, BNL-52505, July, 1996.

2. VNIPIET, Modernization of Plant Processing Liquid Radioactive Waste, Approved Part, Vol.1 (the Green book), St. Petersburg, 1997.

3. Normy Radiatsionnaya Bezorasnost, NRB-96. (Radiation Safety Standards, 1996).

Table 1: Characteristics of Radwaste Solutions

Component (units)	Solution #1 (Low-salt)	Solution #2 (Decon,salt)	Solution #3 (High salt)
pH	7 - 12	6 - 12	6 - 9
Total solids (maximum, g/L)	0.1	4	20
Suspended solids (maximum, mg/L)	50	150	300
Ammonia (maximum, mg/L)	50	50	20
Iron (dissolved, mg/L)	trace	10 max	10 max
Chloride (maximum, g/L)	trace	1	14
Phosphate (maximum, g/L)	trace	0.2	0.01
Nitrate (maximum, g/L)	trace	0.2	0.2
Petroleum Byproducts (mg/L)	trace	3 - 200	3 - 200
Sodium (maximum, g/L)		2	8
Potassium (maximum, g/L)		0.1	0.2
Hardness (maximum, mg-eq/L)		20	40
Oxalate (maximum, g/L)		0.5	0.2
Trilon B (maximum, g/L)		0.2	0.2
Sulphate (maximum, g/L)		0.4	0.8
Carbonate (maximum, g/L)		0.02	0.07
Total specific activity (Ci/L)	10^{-5} to 10^{-7}	10^{-5} to 10^{-7}	10^{-5} to 10^{-7}
Cs-137 (maximum, % of total)	10	70	70
Sr-90 (maximum, % of total)	10	30	30
Ce-144 (maximum, % of total)	70	10	10
Other radionuclides (% of total)	10	10	10
Total volume (m^3/yr)	750	2550	1700

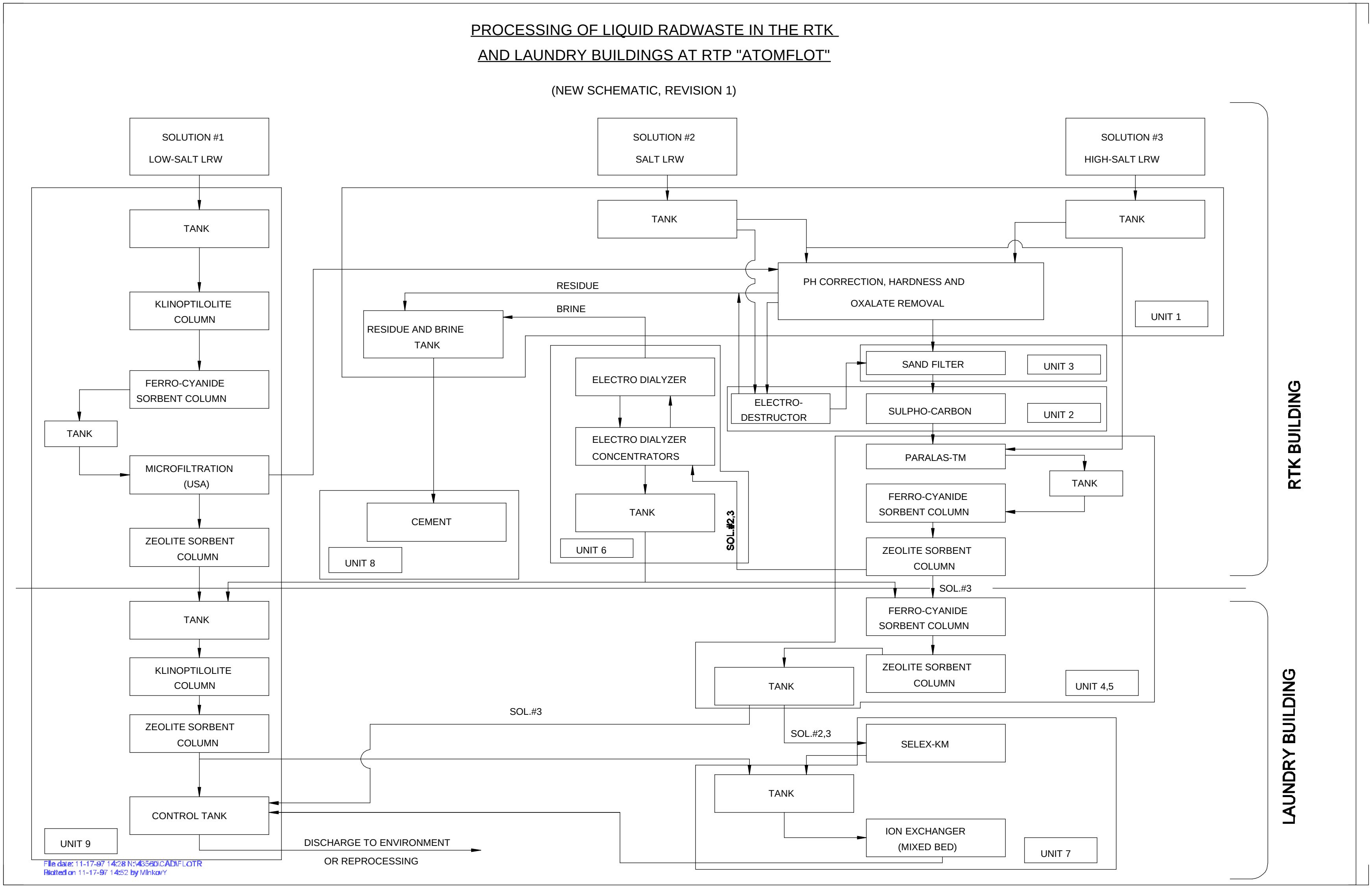
PROCESSING OF LIQUID RADWASTE IN THE RTK
AND LAUNDRY BUILDINGS AT RTP "ATOMFLOT"
(NEW SCHEMATIC, REVISION 1)
SOLUTION #1
LOW-SALT LRW
SOLUTION #2
SALT LRW
SOLUTION #3
HIGH-SALT LRW
TANK
KLINOPTILOLITE COLUMN
FERRO-CYANIDE SORBENT COLUMN
TANK
MICROFILTRATION (USA)
ZEOLITE SORBENT COLUMN
TANK
TANK
PH CORRECTION, HARDNESS AND OXALATE REMOVAL
UNIT 1
RESIDUE
BRINE
RESIDUE AND BRINE TANK
ELECTRO DIALYZER
ELECTRO DIALYZER CONCENTRATORS
TANK
UNIT 6
SOL.#2,3
CEMENT
UNIT 8
SAND FILTER
UNIT 3
ELECTRO-DESTRUCTOR
SULPHO-CARBON
UNIT 2
PARALAS-TM
TANK
FERRO-CYANIDE SORBENT COLUMN
ZEOLITE SORBENT COLUMN
SOL.#3
RTK BUILDING
TANK
KLINOPTILOLITE COLUMN
ZEOLITE SORBENT COLUMN
FERRO-CYANIDE SORBENT COLUMN
ZEOLITE SORBENT COLUMN
TANK
UNIT 4,5
SOL.#3
SOL.#2,3
SELEX-KM
TANK
CONTROL TANK
ION EXCHANGER (MIXED BED)
UNIT 7
UNIT 9
DISCHARGE TO ENVIRONMENT
OR REPROCESSING
LAUNDRY BUILDING

Figure 1

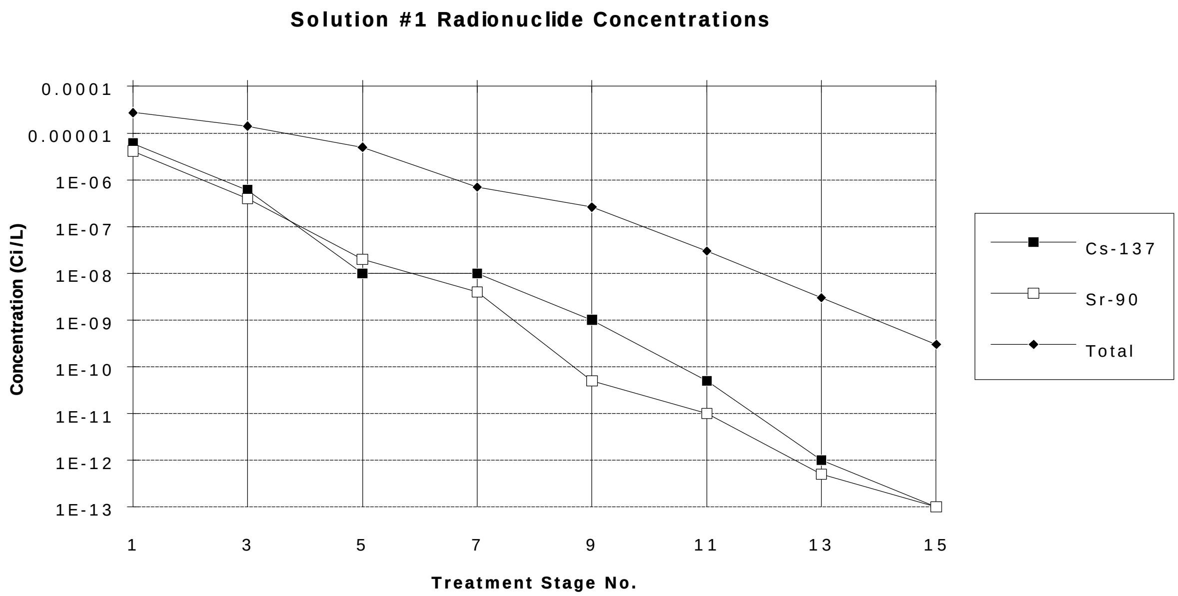

Figure 2. Decontamination of Solution # 1 at each treatment stage