OPERATING EXPERIENCE OF STATION FOR LRW TREATMENT

Gagik A. Martoian, Sahak G. Intsheian, Sukias G. Tonikyan and Gagik G. Karamian
Scientific Productive Co. "AMROTS", ARMENIA

Abstract

In Republic of Armenia, lacking own fossil fuel, the reliable exploitation of NPP is the problem of great importance. From environmental point of view, during NPPs operation a small volume of radioactive materials in the form of nuclear fuel is transformed into medium- and low-level wastes, as well as highly concentrated high-level waste with considerable large volume.

In on-stream NPPs a great amount of liquid radioactive waste (LRW) is produced. The profitability of further processing with the purpose of reduction of their volumes depends on selected system of assembly and classification by a level of activity and composition of salt in solution. In stream water tanks of NPPs the salinity usually does not exceed 5g/l and the radioactivity level of 10^4 Bk/l.

Now in practice for diminishing the LRW volumes the following care are widely applied:

1. **The evaporation method.** The main deficiency of this method is that all radionuclides remain in final products of evaporation, being solid radioactive withdrawal.

Therefore the question arises of their further storage.

2. **The ion-exchange method.** The main deficiencies of this method are following:

- this method is applied for LRW with salinity no more than 1g/l,
- applied ion-exchange resins transform into a radioactive waste,
- practically it does not ensure indispensable depth of cleaning, that is why this method is applied only at enclosed cycles of operation.

3. **The electrodialysis method.** The installations based on this method were earlier applied for reduction of LRW volumes, which ones have not found further applying, because they did not give essential diminishing of volumes compared with evaporation method and did not ensure desired depth of cleaning.

We shall note that deep evaporation method most frequently used in practice is not only expensive from an economical point of view, but it is also the reason for formation of a significant amount of solid radioactive waste (60 t/year in one block of NPP with WWER-440) with medium-level activity (10^6 Bk/l). The radioactivity of solid products emerged from deep evaporation plant (DEP) is stipulated by presence of radionuclides Cs^{134}, Cs^{137}, Co^{60}, Na^{24}, Mn^{54} in its composition.

In Table 1 the dates on activity of these isotopes in composition of DEP products, as well as their half-decay time are given, while in the Table 2 the basic performances of LRW are given:

Table 1. Activity of Some Isotopes in DEP Products

Radionuclide	Activity (Bk/l)	Half-decay time
Cs^{134}	$6.6x10^{5}$	2.07 years
Cs^{137}	$1.4x10^{6}$	30 years
Mn^{54}	$2.9x10^{4}$	312.3 days
Co^{60}	$3.8x10^{4}$	5.3 years
Na^{24}	$1.9x10^{4}$	14.9 hours

Table 2. Basic Performance of LRW

Total specific β-activity in Bk/l	$2.2x10^{4}$
Specific activity of nuclides, Bk/l	
Cs^{134}	$5x10^{3}$
Cs^{137}	$1.5x10^{4}$
Co^{60}	$1.2x10^{3}$
Mn^{54}	$6x10^{2}$
Na^{24}	$2x10^{2}$
Salinity (g/l)	3
Chemical composition	Synthetic SAC, detergents, inorganic builders

Because of a long half-life period of Cs^{137} and Co^{60} at long-term storage of DEP products their activity will be defined predominantly by these isotopes. For this reason, evidently, the extraction of cesium and cobalt isotopes from LRW has crucial importance.

As it is known during an electrodialysis in three-chamber electrodializer under influence of direct electric field, the cations are moved through the cation-exchange membrane to the cathode chamber, and the anions through the anion-exchange membrane to the anode chamber. The depth of extraction of radioisotopes is limited by a back diffusion of these ones from electrode chambers, as soon as their concentration in these chambers starts to grow. So, it is necessary to reduce the concentration of isotopes in the electrode chambers to increase the depth of extraction. It can be achieved, for example, by magnification of water volume in these chambers, but then because of magnification of water volume the general efficiency of volume reduction by electrodialysis method is decreased.

Advanced method of LWR treatment developed by specialists of AMROTS Co. is based on electrodialysis principle [1]. Due to the unique technology, the equipment (LRWE) increases the effectiveness of processing. The employment of this method allows the LRW purification without production of new waste volumes. The experience of usage of this method in Armenian NPP shows that the incoming water for electrodialysis should not contain fluidized particles which could be settled in chambers; the water should not call formation of calcium and magnesium depositions on membranes. The combating with depositions is carried out by acidation of incoming water or alternation of electrode polarity in electrodialyzer.

In the process of electrodialysis the formation of a solid phase is possible due to the electrocoagulation of colloid particles. The precipitate is deleted easily by a prompt alteration of water speed. The ultrafiltration is an efficient method for combating fluidized particles, as well as for condensate cleaning from oil tracks. However for this purpose it is necessary previously reducing the concentration of oil in water to 1-2g/l. To do this, an installation for preliminary removal of water from oil is stipulated in the technological scheme of cleaning.

The separation of boric acid substantially reduces the volume of LRW and meanwhile allowing extraction of radioactive isotopes of cesium and other radionuclides which reduces storing requirements, life time of the remaining waste, and makes further treatment of the remaining waste safer and more efficient.

Equipment Description

1. LRWTE - Liquid Radioactive Waste Treatment Equipment

The equipment is designed to solving the following tasks:

- reduction the LRW volume,
- separation the boric acid from LRW,
- providing a selective separation of radioactive isotopes, specifically radioactive isotopes of Cs and Co.

The treatment system is based on the method of electrodialysis. Particularly, the new method allows unique selective separation of radioactive isotopes based on the differences of several parameters (electrochemical potential, factor of diffusion, ion sizes, etc.). The main parts of the equipment include filters, electrodialyzers, tanks and ion-exchangers. There are three types of filters: mechanical filter, oil filter, and ultra filter. The radioactive isotopes are separated by the system, which contains six modified electrodialyzers.

2. Operational Units and Activities

The main part of the equipment is installed in the hall. It allows performing the following operations:

- final collection of LRW,
- filtration,
- multistage electrodialysis processing,
- collection of boric acid,
- collection of the remaining waste,
- collection and transfer of purified water.

The final stage of electrodialysis and the collection of concentrated Cs and Co are carried out in hot camera. In the remote control center the following processes are conducted:

- controlling the overall operation,
- measuring concentration of separated compounds,
- measuring the electrochemical parameters,
- measuring the level of radioactivity at each operational unit,
- controlling radiation dosage.

3. Operation Steps

The processing of LRW by LRWTE includes the following sequential steps:

- removal of mechanical particles through the mechanical filter,
- removal of oil particles through the oil filter,
- removal of disperse particles through the ultra filter,
- ion exchanging process through membranes,
- ion separation process through electrodialyzer,
- concentrating of separated isotopes through the elecrodialyzer-concentrator,
- processing of the resulted mass through the new special electrodialyzer-concentrator,
- separation of certain isotopes in the form of solid homogeneous chemical compounds.

4. Technical Characteristics of LRWTE

The LRWTE have the following characteristics:

- weight is 10 tones,
- installation area is 100 sq. m,
- content of salt in initial LRW must be less than 5g/l,
- capacity of the equipment is 1ton/h,
- electric power consumed is 25 kW,
- separation of Cs and Co isotopes is up to 99.9%,

- degree of radioactivity in purified water is less than 3 Bk/l, which means that purified water meets the sanitary standards (3 Bk/l).

5. Competitive Advantages

As already noted, the proposed method and system have a high technical efficiency, while reducing the treatment expenses and purification time in comparison with other methods. Table 3 summarizes the main competitive advantages of the suggested system as compared with currently applied evaporation method for processing LRW with 5g/l salt content and 3 Bk/l radioactivity in terms of cesium.

Table 3. Comparison of Various Methods

Performance	Current evaporation method	Proposed electrodialysis method
Volume reduction	160 times	2000 times
Boric acid	Not separated	Separated
Technical complexity	Moderate	High
Cost of construction	High	Low
Cost of operation	High	Low
Life time of resulted solid radioactive waste	Long (186 years)	Short (6 years)
Required number of barrels	Large	Few
Cost of water purification	High	Low
Durability of barrels	Low	High
Special personnel training	No need	Needed

Conclusions

All these results are supported during processing of 500 t of LRW in Armenian NPP.
Due to the separation of boric acid the new treatment system reduces the volume of LRW. Besides that Cs, Co isotopes are removed from the liquid waste which means short life time of the remaining solid waste. In this case, this solid waste must be stored for 6 years, and less storage facilities (tans, barrels) are required. In addition, durability of storage is increased, which avoids the potential dangers of corrosion. These technical advantages lead to significant cost reduction. Costs of construction of storage facilities is to be less, because of less storing requirements. Operation and maintenance costs are decreased due to the expected easy treatment of solid waste (with low level of radioactivity) for a short period of time. The major result is a large amount of purified water that meets the required sanitary standards and can be used repeatedly at NPP.

The following features were also revealed in a processing period:

- the station works properly in a long period of time,
- a deviation of some characteristics of purified water (pH, salinity, etc) from average value has little or no effect on cleaning depth,
- the station operating is subjected to completely automated control, and a special software package is created for this purpose,
- equipment requires special technical handling,
- boric acid is extracted on 40% when MK-40 and MA-40 ion-exchange membranes were used while in the case of non-standard ("make-it-yourself") one a depth of removal was enhanced up to 80%,
- during 500 t water treatment the ion-exchange membranes were four-time regenerated by electrode polarity alteration and 20 minute processing in closed cycle; each of this regeneration process results to production of 200 l low-level LRW.
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Consequently, membranes are in working state after overall operation period. This means that the station can work at least one month without membranes changing.

Thus, the proposed LRWTE based on the new method of electrodialysis allows the solving of liquid radioactive waste problem for NPP’s more effectively than other current methods.

The experience of reprocessing of stream water in our station shows a possibility of usage the analogous equipment for treatment of LRW with high salinity. As shown calculations, economically, the utility of such stations is advisable even if LWR with salinity of 150-200 g/l will diluted up to necessary concentration of 5 g/l by means of special mixer. This will be a simpler usage of the ideas lying on the base of proposed method of low-level LRW treatment. As we expect, the development of electrodialyzers allowing operating in high electric current regimes will provide a possibility to treat the LRW of high salinity without their preliminary dilution.

References

1. G. A. Martoian, S. G. Intsheian, S. G. Tonikian, G. G. Karamian, Plant for LRW Treatment in Armenian NPP, Proc. ICEM'99 Conference, Nagoya, September,1999.