

ELABORATION OF NOT LARGE MOBILE MODULAR INSTALLATION "AQUA - EXPRESS" (300 L/H) FOR LRW CLEANING

Yurii Karlin, Sergey Dmitriev, Vadim Iljin, Mihail Ojovan
State Unitary Enterprise MosNPO "Radon",
7-th Rostovsky Lane 2/14, Moscow, Russia, Fax: (095) 248 1941,
E-mail: karlinyr@tsinet.ru
Rudolf Burcl
International Atomic Energy Agency,
P.O. Box 100, Wagramerstrasse 5, Vienna, A-1400, Austria,
E-mail: R.Burcl@iaea.org

ABSTRACT

Mobile modular installation "Aqua-Express" is a liquid low level and intermediate level radioactive waste (LL&ILRW) treatment facility, intended for not large research centers and other organizations, which activity causes the formation of a few quantity (up to 500 m³/year) of low and intermediate level radioactive waste water. Mobile modular installation "Aqua-Express" has the following features: 1) filtration, sorption and ultrafiltration units are used for LL&ILRW purification; 2) installation "Aqua-Express" consists of a cascade of three autonomous aqueous liquid waste-purifying installations; 3) installation "Aqua-Express" is a mobile installation; the installation can be transported by car, train, ship, or plane, as well as placed in a standard transport (sea or railway) container; 4) installation "Aqua-Express" does not includes any technological equipment for conditioning the secondary radioactive waste. Productivity of the installation "Aqua-Express" by purified water depends on composition of the initial liquid waste and makes up to 300 l/h. In present report is described the design of installation "Aqua-Express", theory of LRW purification in the installation "Aqua-Express" and some results of its use at cleaning real radioactive waters at State unitary enterprise – MosNPO "Radon".

INTRODUCTION

Mobile modular installation "Aqua-Express" is a liquid low level and intermediate level radioactive waste (LL&ILRW) treatment facility, intended for not large research centers and other organizations, which activity causes the formation of a few quantity (up to 500 m³/year) of low and intermediate level radioactive waste water.

Basic characteristics of liquid waste:

- $\Sigma\gamma \leq 1 \cdot 10^5$ Bq/l (main contaminants: ¹³⁴, ¹³⁷Cs up to $5 \cdot 10^3$ Bq/l), ^{110m}Ag, ¹⁴⁰Ba, corrosion products);
- $\Sigma\beta$ (mostly ⁹⁰Sr) $\leq 1 \cdot 10^3$ Bq/l;
- $\Sigma\alpha \leq 3 \cdot 10^2$ Bq/l; pH 1–10;
- moderate salinity of waste up to 10 g/l.



Fig.1. Mobile modular installation "Aqua-Express" for clean-up of LRW.

Mobile modular installation "Aqua-Express" has the following features:

- Filtration, sorption and ultrafiltration units are used for LL&ILRW purification.
- Installation "Aqua-Express" consists of a cascade of three autonomous aqueous liquid waste-purifying installations.
- Installation "Aqua-Express" is a mobile installation; the installation can be transported by car, train, ship, or plane, as well as placed in a standard transport (sea or railway) container.
- Installation "Aqua-Express" includes a sampling system, but it has no equipment for LL&ILRW sampling from an initial tank, as well as any equipment for chemical and radiochemical analysis of taken liquid samples.
- Installation "Aqua-Express" does not include any technological equipment for conditioning the secondary radioactive waste.

Spent filtration materials and ion-exchangers (and also membranes) are suitable for simple conditioning and disposal. Resulting water is acceptable for recycle (reuse) or for discharge to the environment. Installation "Aqua-Express" does not desalinate water, but only selectively extracts toxic impurities from water. Productivity of the installation "Aqua-Express" by purified water depends on composition of the initial liquid waste and makes up to 300 l/h. Working nominal pressure in membrane apparatus and poured filters does not exceeds 0,45 MPa. To maintain the installation 2-3 specialists will be enough.

TECHNICAL DESCRIPTION

Table I. Basic technical specification of installation "Aqua-Express"

| | |
|---|--------------------------------------|
| Installation type | mobile, modular |
| Productivity by purified water | up to 300 l/h |
| Volume of the secondary radioactive waste | from 1% up to 10% |
| Secondary radioactive waste | filter-container, sorbents, tailings |
| Maximum pressure in the installation | not more than 0,45 MPa |
| Permissible temperature range of initial liquid waste | from + 5 °C up to + 40 °C |
| Electric current type | 220 V; 50 Hz |
| Nominal electric power | not more than 3 kW |
| Minimum square for the installation placement | 8-10 m ² |
| Total weight of the installation filled with water | not more than 1500 kg |

Overview of the installation "Aqua-Express" and its structural diagram are represented in Fig.2 and Fig.3.

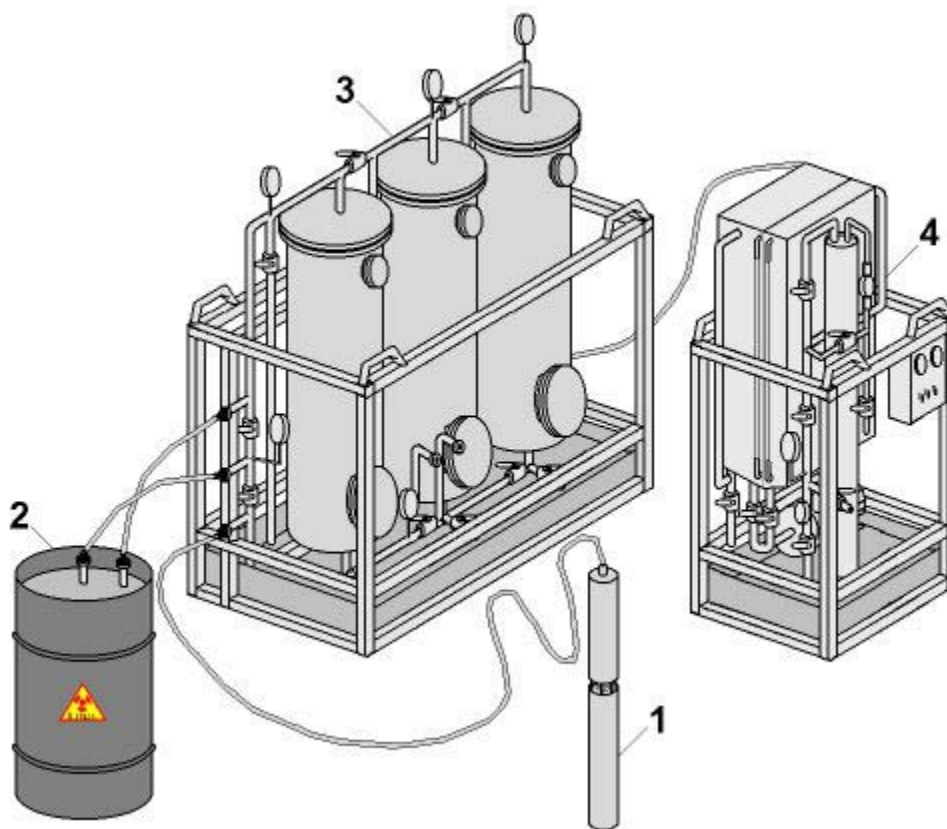


Fig.2. Overview of installation "Aqua-Express" as an assembly: 1 – Drowned Pump, 2 - Filter-Container, 3 - Filtration Module, 4 - Ultrafiltration Module.

The installation consists of three main units: Filter-Container, Filtration Module, Ultrafiltration Module, as well as a Drowned Pump, which is included in the Filtration Module, but during the purification process is immersed into a vessel with initial liquid radioactive waste.

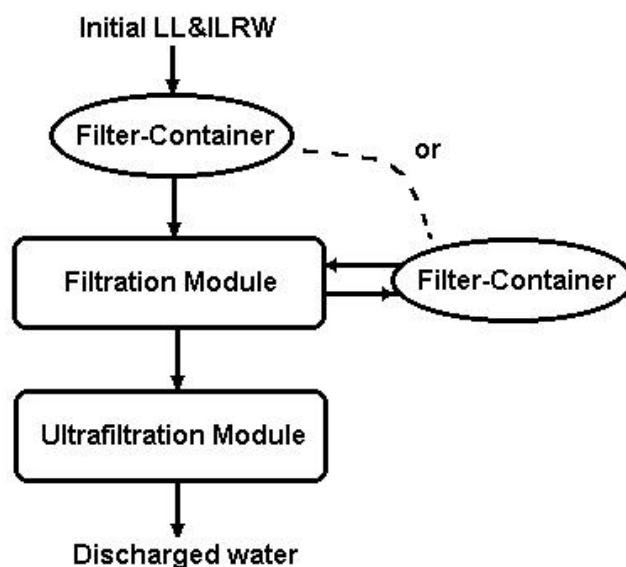


Fig.3. Structural diagram of mobile modular installation "Aqua-Express".

Filter-Container (Fig.4) is intended for sorption of gamma-active isotopes. The stainless steel filtration cartridge is fixed in a standard 200-liters drum and poured with cement grout, which plays role of a biological shielding. Filter-Container filled with a selective to cesium and cobalt synthetic inorganic sorbent (nickel ferrocyanide, precipitated on silica gel, the size of granules is 0.5 - 0.8 mm).

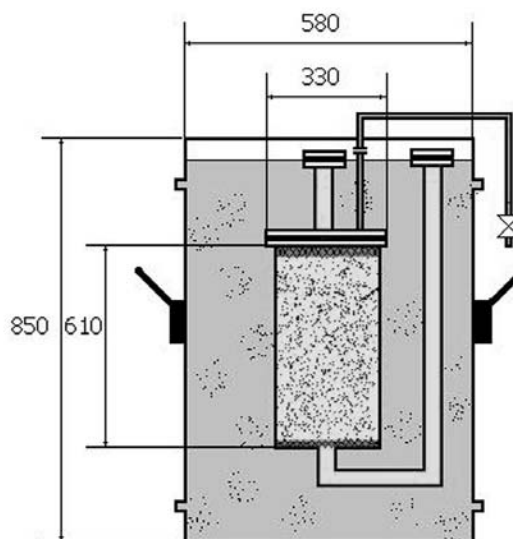


Fig.4. Filter-container with synthetic inorganic sorbent.

Filtration Module is intended for LL&ILRW purification from suspensions, oil products, dissolved organic substances and radionuclides by filtration of LL&ILRW through poured filters, filled with divers granular or stringy materials (for example, sand, activated charcoal, crushed natural zeolites, ion exchange resins, synthetic inorganic sorbents).

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Filtration Module consists of three poured filters, a pump, five manometers, pipelines, a bed frame, equipped for the Module loading-unloading, stainless steel tray, being intended for leakage collection and able to accommodate the whole volume of LL&ILRW from Module equipment.

Ultrafiltration Module is intended for deep purification of LL&ILRW from suspensions, colloidal particles, and large polymeric molecules. Ultrafiltration in the given technological scheme is a final stage of LL&ILRW purification and provides impediment to all the suspended particles (including particles of sorbents attrition being of submicron sizes and micelles of colloidal particles). To improve LL&ILRW purification from radionuclides, it is supposed to add divers high-molecular complexing agents and sludge-forming agents in processed water at ultrafiltration stage. Regeneration of the spiral ultrafiltration element is possible with washing regenerating solutions.

Ultrafiltration Module consists of an ultrafiltration apparatus, a rotary pump, tanks, a manometer, a flowmeter, a thermometer, an electric heating unit, pipelines, a bed frame, equipped for the Module loading-unloading, a stainless steel tray, being intended for leakage collection and able to accommodate the whole volume of LL&ILRW from Module equipment.

PRINCIPLE OF OPERATION OF INSTALLATION "AQUA-EXPRESS"

Schematic technological diagram of the installation «Aqua-Express» can be divided into the following elements, which correspond to certain stages of water purification (Fig.2): filter-container with the sorbent of ferrocyanide type, poured filters, ultrafiltration apparatus. In common case the installation can include also other water purifying modules, however, the pointed complementary of the installation is usually enough for purification of low level radioactive and low salinity liquid waste (salinity below 3 g/l). Let us see principles of radioactive water purification in the installation «Aqua-Express».

Initial liquid radioactive waste from a storage-tank are pumped by drowned pump (Fig.2) and sequentially passed through the filter-container with a sorbent of ferrocyanide type and poured filters.

Sorbent of ferrocyanide type is a synthetic sorbent (for example, nickel ferrocyanide or copper ferrocyanide deposited on silica gel), which selectively extracts cesium ions, including radionuclides ^{134}Cs and ^{137}Cs from LRW. In many radioactive waters cesium isotopes are primary gamma-emitters, so their extraction from the solution at the first stage of purification promotes improving the radiation situation in the whole water-purifying installation. Factors of radioactive water purification from cesium isotopes at this stage can make up to 10^4 times.

Composition of applied sorbents in poured filters is depends on composition of liquid radioactive waste and in each case is individually determined on the basis of preliminary chemical and radiochemical analysis. This is the main stage of liquid radioactive water purification from radionuclides, therefore sorbents selection should be carried out by experts in the field of radioactive water purification. Factors of radioactive water purification from radionuclides at this stage usually make from 10 up to several thousand times.

Further, water, mainly purified from radionuclides, arrives into a tank of Ultrafiltration Module. It is circulated in the system "tank E1 – ultrafiltration apparatus" by rotary pump under surplus pressure 0,2 – 0,3 MPa. A part of water (so called as a permeate) under surplus pressure is

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pumped through an ultrafiltration membrane. At that, water is completely purified from all suspensions, colloids, polymeric molecules, because the size of membrane pores does not exceed 50 – 100 nm. Use of ultrafiltration allows securing complete purification of water from radionuclides, which are sorbed on submicron size suspension particles, as well as from products of sorbents abrasion. The late is especially important in the case of natural sorbents and activated charcoals use (for example, clinoptilolite, chabazite, bentonite, etc.). Factors of radioactive water purification at the last stage can make from 1 up to 10 times, depending on the ratio of submicron size suspensions in an initial liquid radioactive waste and intensity of their carry over through the poured filters.

In case of purification of liquid radioactive waste containing a considerable quantity of oil products or suspensions, it is recommended to use the first poured filter of Filtration Module, loaded layer by layer with a stringy synthetic and hydrophobic material, sand or crushed claydite, activated charcoal or crushed anthracite, as the first stage of the purification process. At that the Filter-Container is connected up to the Filtration Module between the first and the second poured filters (Fig.3).

During operation of the Filter-Container and poured filters, it is necessary periodically to withdraw gases accumulated in the upper part of filters, and to loosen the filter loading with a reverse water flow.

PURIFICATION OF LRW IN THE INSTALLATION "AQUA-EXPRESS"

Proceeding from the practical experience of different organizations on cleaning liquid radioactive waste it is possible to outline three main stages of works carrying out.

1. Preliminary (exploratory) stage

- 1.1. Study of LRW being a subject to purification
 - 1.1.1. Determination of LRW volume
 - 1.1.2. Determination of LRW chemical and radionuclide composition
 - 1.1.3. Study of conditions of LRW accommodation with the purpose to determine limiting dimension and power consumption by water-purifying installation
- 1.2. Carrying out preliminary research and development works
 - 1.2.1. Determination of water purification efficiency by different methods
 - 1.2.2. Development of flow diagram of supposed water-purifying installation
 - 1.2.3. Checking efficiency of designed flow diagram at laboratory conditions in model stands
- 1.3. Developments of technique-economic report on carrying out works with indicating the required equipment, account of expendables, required effort and time schedule of works fulfillment.
- 1.4. Mounting the water-purifying installation and associated units.

2. Stage of works schedule coordination with local supervising authorities.

- 2.1. Development of engineering specifications on the water-purifying installation (maintenance instruction and description, sanitary passport, procedures of safe dumping account, depending on local conditions other documents are also possible).
- 2.2. Coordination of works fulfillment with local supervising authorities.

3. Stage of works fulfillment.

- 3.1. Start-and-adjustment works to operate the installation on a regular mode of purification (LRW recirculation back into the initial tank)

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- 3.2. Purification of a bulk of LRW under conditions of periodic purified LRW quality control in a control tank before dumping into sewerage
- 3.3. Writing certificates for dumping treated water.
- 3.4. Unloading installation, conditioning and disposal of the secondary radioactive waste.
- 3.5. Decontamination and preservation of installation (water-purifying equipment).
- 3.6. Writing the final report.

In practice not always there is a necessity for all stages or steps, as some information about LRW could be already received, and the water-purifying installations could be already built earlier as a result of other work fulfillment. Nevertheless, in scheduling LRW purification it is recommended to use the mentioned above order of operations.

It should be underlined, that writing the final report after each campaign on LRW purification is recommended, because it allows not only taking particular lessons and analyzing error operations of executors, but also giving the accumulated practical experience to the future LRW purification campaigns.

EXPERIENCE OF INSTALLATION "AQUA-EXPRESS" USE AT CLEANING REAL LRW AT STATE UNITARY ENTERPRISE - MOSNPO "RADON"

The most part of real LRW at State unitary enterprise - MosNPO "Radon" is typical radioactive drainage waters of any near-surface disposal of radioactive waste. In conditions of near-surface disposal of radioactive waste by them cementing in trenches or concrete tanks drain radioactive waters can form. Reasons of their formation can be atmospheric falls (rain, snow) at breakdown of engineer barriers integrity (waterproofing, monolith matrix, etc.); condensate accumulated in cavities of tanks for solid radioactive waste disposal, ground waters, which can accumulate in such repositories during long time, because practically all the grounds and even rocks have some permeability.

Such radioactive waters usually have low contents of suspensions, emulsified oil products and colloidal particles. Chemical composition of such waters is similar to ground waters (overwhelming majority of near-surface ground waters are a sodium-calcium hydrocarbonate type). However, as a result of contact with the cement matrix, such radioactive waters have the higher alkalinity (pH up to 11-13) and salinity (up to 3 - 4 g/l).

Volumetric radioactivity of waters is usually not very high – not more than $3.7 \cdot 10^2$ - $3.7 \cdot 10^4$ Bq/l ($1 \cdot 10^{-8}$ – $1 \cdot 10^{-6}$ Ci/l). The basic radionuclides are $^{134,137}\text{Cs}$, ^{90}Sr , ^{60}Co , and in less quantities other radionuclides. Contents of α -nuclides can achieve up to 20-100 Bq/l. In common case character of contamination can strongly depend on specific conditions of the near-surface disposal.

On the first stage such liquid radioactive waste should be acidified, because any ferrocyanide sorbent, which selectively extracts cesium isotopes, begins quickly to dissolve at $\text{pH} > 11$ of treated water. Acidation (or neutralization up to $\text{pH}=6-8$) can be conducted in a temporal tank – repository of sewage radioactive waters or in some interim tank, which is not included in the installation "Aqua-Express".

Filter–Container is connected to the Filtration Module in the first jointing position (before first filter). Its life time in the given case can be estimated as 2000-5000 column volumes (or 60-150 m^3 of LRW). Poured filters (first and second) with cation-exchange and anion-exchange resins allow considerably decreasing the concentration of radionuclides in anionic forms and

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multicharged cations. The third poured filter is filled with a sorbent or a mixture of sorbents, which are determined by radionuclide composition of the filtrate after the first two poured filters and provide water after purification till norms of radiation safety.

In case of need, if the sorption purification does not provide satisfactory quality of drain waters purification, for multicharged cations (especially for d-elements such as ^{60}Co , ^{56}Fe , ^{54}Mn and many other) it is possible to after purify water by ultrafiltration with the preliminary formation of macromolecular complices (for example, with polyethylenimine, polyacryl acid, etc.). For this polymeric complexing agents should be dosed in quantity 50-100 mg/l in tank of the Ultrafiltration Module. This will not considerably change the salinity of liquid radioactive waste.

To extract iodine isotopes by ultrafiltration, starch should be added in the treated solution. To increase the purification factor of water from α -nuclides, alkaline should be dosed up to pH 10-11 in tank of the Ultrafiltration Module. Alkalization of the solution will increase hydrolysis of multicharged cations (including α -nuclides), and hence, allow them holding up by ultrafiltration membrane as hydrolyzed associates. Ultrafiltration will also hold up submicron particles of initial suspensions and scuffed sorbents, which will come in small quantities from poured filters.