# Prospects of the application of curable decontamination solutions in problems of impact improving of nuclear power plants

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## Abstract

The technology of power generation from nuclear power is accompanied by the formation of radioactive waste, which has significant potential environmental hazards. This paper proposes new methods of decontamination of NPP equipment with fluids that immediately after use can be converted into an environmentally safe condition – curing methods of decontamination solutions. A characteristic feature of curable solutions decontamination methods is that the composition of the decontamination solution, and also processes in the solution during deactivation, affect the subsequent transfer of this solution to a solid state, as well as on the properties of the matrix, which will be "sealed" removed radionuclides. The main factor determining the course of the process of decontamination methods can be divided into contact, acid-abrasive, ultrasound and combined. Concerning the main component of the decontamination solution (slurry) methods can be subdivided into solutions with hydraulic binders, clay slurry (with conventional clay and a clay with a high alumina content) suspension of diatomite and combined. The means of transfer of the solutions used in the solid state methods are divided into "self-curing" heat treatable and cemented. Application of methods of the curing solution allows us to reduce the number of operations to deactivate air conditioning that provides economic benefits and allows us to create a whole class of portable equipment and to reduce the amount ongoing to dump 4–6 times in comparison with cemented.
*Keywords: nuclear energy, safety, environment protection, radioactive waste.*

WIT Transactions on Ecology and The Environment, Vol 190, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/EQ140872

# 1 Introduction

The process of power generation in nuclear power plants (NPP) results in the formation of radioactive waste (RW) with significant potential environmental danger. In this paper, new methods of AS equipment decontamination by using fluids that immediately after their use can be converted into environmentally safe state – the methods of curable decontamination solutions- are proposed. The proposed methods not only simplify the conversion of radioactive waste from a liquid state (LRW) into a solid state (SRW), but also provide the means to obtain for RW conditioning a matrix that is highly resistant to external influences, reduces the potential risk of long-term storage of RW and allows us to reduce their volume.

Standards for radioactive waste management along with the requirements of public health and environment protection, the need to minimize the volume of RW and other factors make it necessary to consider the interdependence of the various stages of RW treatment. However, in practice, this requirement is not always enforced or it is simply ignored in the interest of receiving some benefits from the current practice of RW treatment, forgetting that on the subsequent stages this benefit could be blocked significantly greater expenses.

Nowadays the decontamination of radioactive deposits on equipment is mainly performed by chemical methods using a variety of deactivating fluids [1]. As a result, a large amount of liquid radioactive waste is produced which is subsequently subjected to various time-consuming operations for reprocessing into a solid state suitable for long term storage. Handling the problem of decontamination of AS equipment from this perspective, it was decided that the decontamination solution must not only perform its direct functions (deactivate radioactive deposits effectively and economically) but also in the sequel serve as the basis of a matrix for reliable RW fixation. In addition, the task was not only to reduce (simplify) the entire chain of operations (steps) of conversion LRW into a solid matrix, but also to make each stage contribute most to implementation of Standards of RW management. The decontamination methods developed to meet the given requirements have been entitled "decontamination by curable solutions."

# 2 The methods of decontamination with curable solutions

The specific characteristic of the decontamination by curable solutions method is that the composition of the decontamination solution, as well as the processes, which occur in it (in the solution) during deactivation, have an influence on not only the process of subsequent conversion of this solution into a solid state, but also on the properties of the matrix, in which removed radionuclides will be "sealed".

By the main component of the decontamination solution (suspension) the methods, in varying degrees verified to date, can be divided into the methods of hydraulic binder solutions, clay slurries (with the usual clay and clay with a high content of aluminum oxide); diatomite suspensions, as well as combined solutions [2–4].

By the main factor determining the course of the decontamination process, developed to date methods can be divided into four groups: contact, acid-abrasive, ultrasonic and combined (concurrent use of ultrasonic, chemical, abrasive and sorption effects) [5].

By the technique of converting radioactive liquid waste produced after decontamination into a solid state the methods can be divided into “self-hardening”, with low-temperature treatment (up to 300°–400°), with high temperature treatment (900°–1200°), as well as cementation, including the use of phosphate ligaments.

The most visible example of these techniques is ultrasonic decontamination in solutions of hydraulic binders, particularly in cement with additives designed both to increase the effectiveness of decontamination and to improve the properties of cement stone (fig. 1).

When ultrasound passing through the liquid, the shock waves arising from the collapse of cavitation bubbles can pull radionuclides out of a decontaminated surface and translate them into a solution. Furthermore, in the liquid acoustic flows appear under the influence of which cement and additive particles have an abrasive effect on the surface, improving the efficiency of removal of radionuclides. It is known that sonication of cement slurries positively influence on the cement stone durability [6]. After decontamination the solution is discharged to a tank where it solidifies.

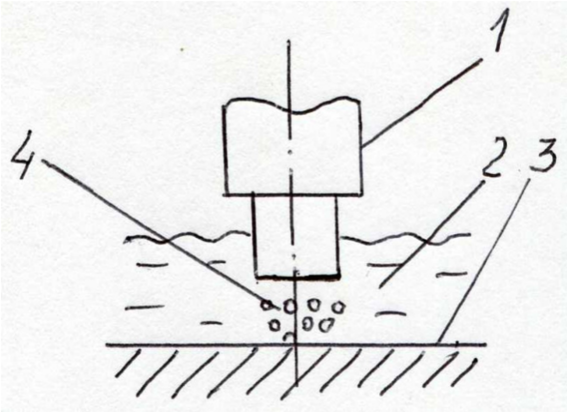


Figure 1: Ultrasonic decontamination: 1 – ultrasonic transmitter; 2 – decontamination solution; 3 – treated surface; 4 – cavitation zone.

## 3 The experiments results

Experiments performed on the samples cut from the coolant circuit of the first stage of Beloyarskaya NPP have shown that decontamination is performed up to the natural background exposure for 20 seconds of ultrasonic treatment per unit of decontaminated surface. This method despite all its shortcomings, in particular – the impossibility of storing of the decontamination solution in liquid form, can be successfully applied in the liquidation of any emergency or accidents, reducing the possibility of releasing radioactivity into the environment.

For this purpose a manual ultrasonic transmitter was developed (figs 2 and 3).

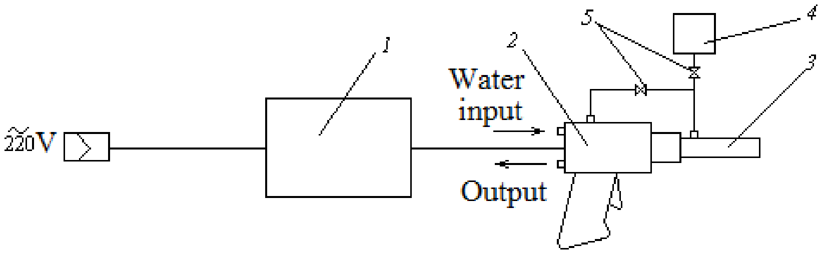


Figure 2: Ultrasonic transmitter scheme.

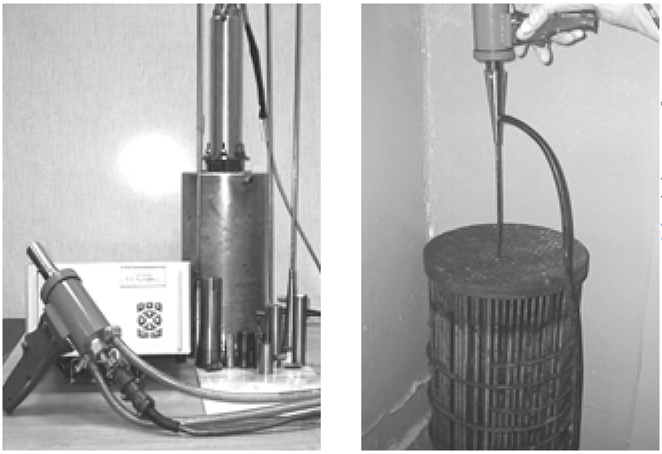

Figure 3: Decontamination of heat-exchanger tubes.

The apparatus is designed to decontaminate the surfaces of individual equipment elements that are not readily deactivated by conventional methods: blind and threaded holes, chinks, corners, grooves etc. Using the device it is possible to remove local contamination which for various reasons remains on equipment surfaces after decontamination by conventional methods.

The device consists of a generator of electrical oscillations of ultrasonic frequency 1, a magnetostrictive transducer 2, a replaceable waveguide emitter 3, a tank with decontamination solution 4 valves for supplying of decontamination solution 5, connecting hose pipes and cables. It can be used with all the above mentioned curable decontamination solutions.

Curable solutions based on clay suspensions are not capable of “self-solidification” without the application of special measures such as solutions based on hydraulic binders. For this reason they are stored for a long time in working condition, and this eliminates the possibility of them being converted into a solid state, for example, within the decontaminated work piece. In addition, clay is a perfect natural sorbent, which allows for a more reliable fixing of the radionuclide in its matrix compared with a cement matrix.

Suspensions based on diatomite are similar in technical properties to clay suspensions. However, diatomite, as a sorbent, is much superior to clay. Furthermore, the diatomite density is lower than the density of clay which provides further benefit for using diatomite suspensions.

Spent clay and diatomite suspensions after evaporation or settling in a solid state can then be converted by traditional cementation. However, cementation is always associated with an increase in volumes of RW being sent to storage.

The presence of a sufficiently large amount of alumina in clays means clay slurries can be solidified by converting them to low temperature phosphate ceramics. Such a method would reduce the amount of SRW being sent to storage.

But the most radical and the safest method for the long-term storage of RW, in our opinion, is to convert both the clay and diatomite into ceramics by high-temperature heat treatment. It is known that the ceramics obtained from natural minerals, which include clay and diatomite, is thermodynamically more stable than glass [7]. Furthermore, experimental results show that ceramics obtained from the clay slurry exposed to ultrasonic radiation in the process of decontamination, after heat treatment at 1000°C had a compressive strength of 63.0 MPa, and water absorption of 12.15%. The same results were achieved for clay slurry without ultrasonic treatment only after calcination at 1350°C. Hence it follows that by using clay slurry as a decontamination solution in ultrasonic decontamination, we get not only a highly durable and environmentally friendly matrix, but also consume less power in doing so. Moreover, compared with cementing the volume of ceramic waste being sent to storage will be reduced by a factor of 2.5–3.

Similar results, but on a larger scale, were obtained for diatomite suspensions. For example, the volume of waste in the form of diatomite ceramics will be in 5–6 times less than that of cementing (fig. 4) and almost half that of the clay ceramics.

And more worth mentioning one important advantage of decontamination curable solutions compared with conventional methods. In current practice the “decontamination” and “RW recycling” processes are distinctly separate, with little interdependency.

In the procedure of decontamination the main aim is to find the simplest and most effective way of removing radioactive contamination and the selection of

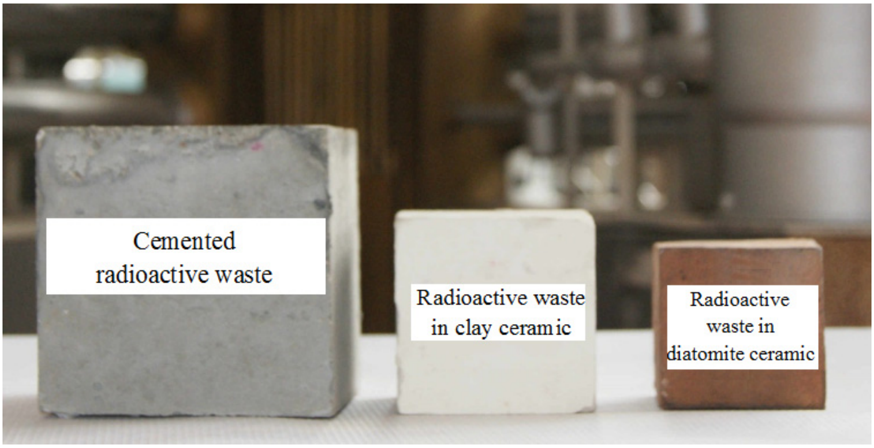


Figure 4: Ratio of the volumes of RW in matrices: cemented RW; RW in clay ceramic; RW in diatomite ceramic (from left to right).

the conditioning technology is determined mainly by the level of specific activity and isotopic composition of the waste. In the decontamination of curable fluids both of these operations are combined in a single continuous process chain from the selection of decontaminating fluid to the transportation of the conditioned waste to storage. In this connection there is a possibility of achieving the integrated automation of this technological process and creating compact and mobile units for performing all operations from the preparation of the decontamination solution through to the packing of the conditioned RW.

## 4 Conclusion

Compared to traditional methods of decontamination and waste recycling an application of methods of curable solutions will allow us to:

- obtain a matrix for RW conditioning, highly resistant to external influences, that reduces the potential hazard during their long-term storage;
- reduce the number of operations and simplify the technological process from decontamination to RW conditioning, which in turn will provide not only economic benefits, but also allows to found the class of portable and mobile equipment for decontamination and RW recycling;
- achieve a higher specific concentration of radionuclides in the matrix, which will reduce the volumes of RW requiring disposal by a factor of 4–6;
- increase the efficiency factor and performance rate of decontamination by a factor of at least 3–5.

The most significant application for the curable solutions method will be in the decontamination of dismantled equipment during NPP decommissioning work as well as the elimination of consequences due to accident.

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