

The Strategy for Management of Toxic Waste Produced during Decommissioning and Environmental Remediation in Northwest Russia

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The activities on decommissioning and environmental remediation of nuclear- and radiation-hazardous naval facilities result in the generation of not only large amounts of radioactive waste but also of Toxic Waste (TW). As demonstrated in References [1-4], chemical risks caused by toxic waste at decommissioning enterprises under normal operating conditions exceed the relevant radiation risks by several orders of magnitude. This is due to the use of thermal and mechanical procedures while cutting and dismantling Nuclear Submarines (NS) and Nuclear-Powered Surface Ships (NPSS). As the result are produced: -noxious chemical substances consisting of oxides and ingredients of work materials; -large amount of dust [5]; and –fragments of constructions and different-type coatings stored for long at the site of enterprises. At the pre-dismantling stage large quantities of various process liquids are removed from ships that results in the generation of gaseous, liquid and solid waste [6].

Gases, aerosols and dust are released to the atmosphere without purification. Some liquid waste is neutralized, treated and incinerated and some waste is gathered into special tanks. Solid waste is put into containers, placed at open pads and removed to city dumps. Heavy particles of metals, their oxides and other chemical substances deposit from aerosols and dust onto sites of enterprises, next - via rain water and melt water – they migrate to the nearby water area, accumulate in soil and bottom sediments. Aquatic systems are also polluted with rinsing, industrial and domestic water containing admixtures of oil products, hydraulic liquids etc. Protracted storage of dismantled constructions and various materials (including coatings, insulating materials, etc.) at open-air pads is another source of pollution of territories (Fig. 1).

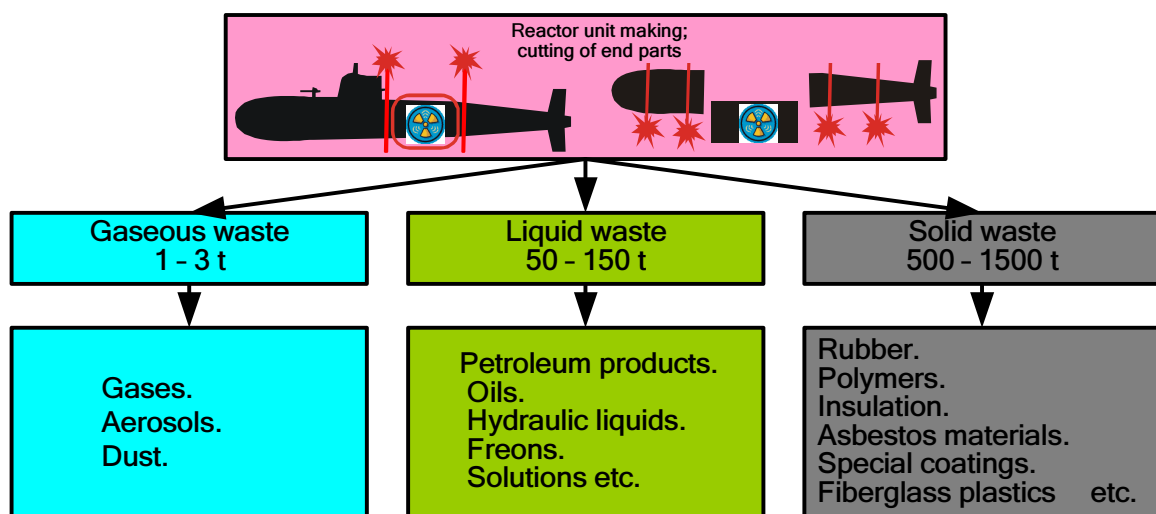


Fig. 1. Nuclear submarine dismantling stages resulting in toxic waste generation

Virtually all categories of liquid TW are hazardous waste being subject to processing and elimination. Some categories of liquid TW (individual lubricants, hydraulic liquids, chlorofluorocarbons (freons), chromium-containing water solutions etc.) pose special problems to the enterprises: such waste is neither treated nor eliminated. Rinsing water is disposed into the system of sewage-disposal installations following preliminary removal of oil products.

Many TW represent an inseparable mass of mixed materials (“layer-cakes”) consisting of: plates, fragments, crumbs, odds and ends, fibers, bands and threads with vestiges of adhesives and paint coats, filling materials, resins, compounds etc.; there are also unbroken plates, mats and sheets. Adhesives, compounds, paint coats and filling materials are contained in TW in a polymerized hardened state. Such TW as insulation on the basis of plates (mats) represents glued joints of mats with fabrics, seals of joints with mastic and waterproofing compounds painted from the outside. They are made on the basis of glass-and-basalt fibers, kaolin wool and asbestos (85-90% of the whole mass). Other TW contain rubber, mercury compounds (luminous lamps), etc.

Toxic wastes are grouped into the following five hazard classes: class 1 - extremely hazardous waste; class 2 - highly hazardous; class 3 - moderately hazardous; class 4 - low hazardous and class 5 – virtually not hazardous waste [7]. TW of classes 1-3 (4) are subject to processing and elimination; wastes of classes 4 (individual types) and 5 are removed to city dumps. The actual TW categorization is based on the regulations “*Toxic Waste Categorization Criteria by Classes of Environmental Hazard*” [8] and “*The Federal Classification Toxic Waste Catalogue*” [9] and has a multi-level character. If the data on individual TW compounds are lacking, their categorization is based on calculations or experimental procedures. To this end maximum concentration limits for hazardous substances in air and water are applied; sanitary requirements to the quality of atmospheric air and water supply in settlements are accounted for along with the requirements to sanitary protection of surface water and water bodies including those used in the fish industry [10-14].

Over the preceding NS-decommissioning period about 120000 t of TW classes 1-5 were generated at the involved enterprises in Northwest Russia. Of that quantity up to 30000 t were “disposed of”, i.e. removed to city dumps in bulk without compacting and assortment; about 20000 t were “processed”, i.e. eliminated and used at the decommissioning enterprises or transferred to other enterprises for neutralization. About 40000 t of TW are pasty waste (carbide sludge - waste caused by making of acetylene used to cut NS hulls) still stored at non-equipped pads outside/at sites of the enterprises. Liquid waste (classes 1, 3) and solid waste (classes 1,3,4) have been accumulating at the enterprises, and if nothing is done (i.e. if the current TW-management approach is used) about 110000 t of TW may be accumulated at different locations of the region by ~ 2025 (planned completion date of complex decommissioning of NS, NPSS, Nuclear Maintenance Service (NMS) ships and environmental remediation of Temporary Storage Facilities (TSF)) (Table 1).

Table 1. Dynamics of toxic waste accumulation during decommissioning and environmental remediation of nuclear- and radiation-hazardous naval facilities in Northwest Russia using the existing management procedures

TW hazard class	Amount, t							
	2006	2007	2008	2009	2010	2015	2020	2025
Murmansk region								
Liquid waste*								
Class 1	-	-	-	-	-	470	760	950
Solid waste								
Class 1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0,3
Class 3	570	590	610	610	610	800	1200	1600
Class 4	1687	1793	1900	2000	2050	2250	3050	4000
Class 5	10800	11400	12000	12400	12500	15000	17000	19000
Pasty waste								
Class 4	19600	21000	22300	23000	23500	25000	28500	31500
TOTAL	32700	35200	37500	39000	39800	46500	53600	59800
Arkhangelsk region								
Liquid waste*								
Class 1	-	-	52	88	124	600	880	1100
Solid waste								
Class 1	0,3	0,3	0,3	0,3	0,3	0,3	0,3	0,3
Class 3	770	1000	1300	1330	1350	1500	1700	2200
Class 4	1220	2200	3000	3100	3200	3500	3700	5500
Class 5	10600	12700	14200	15000	16000	18000	20000	22000
Pasty waste								
Class 4	11200	14000	15000	16500	17000	18000	20000	22000
TOTAL	23800	30000	33700	36300	37500	42200	46300	52500

Note: Liquid TW of hazard class 2 are transferred to the owner and to the manufacturing plant.

Each type of TW is handled individually depending on physical state, physical and chemical properties, health hazard and environmental hazard. TW are stored at sites of enterprises in accordance with special “authorizations” and “quantity limits” established on agreement with environmental supervisory authorities. However to date the existing industrial-waste sites do not cope with increasing TW amounts [15,16], and each enterprise has to establish new temporary pads depending on its own resources that is fraught with violations of the regulations and standards in force. Some TW is burnable that augments fire hazard. Thus the actual TW-handling procedures are reduced to: gathering, assortment, storage or partial processing, elimination, transfer to other enterprises and removal to city dumps, wherever possible (Fig. 2, Table 2).



Fig. 2. Gathering and storage of rubber materials (a), mercury lamps (b) and carbide sludge (c)

Table 2. Handling of main TW types at enterprises and facilities of Northwest Russia

TW type	Handling	End state	Needs
Liquid waste			
Ozone-destroying substances	1. Storage in tanks	1. Reuse (50%) 2. Accumulation (50%)	An elimination complex is required
Hydraulic liquids	1. Storage in tanks	1. Accumulation (20%) 2. Reuse (30%) 3. Discharge to sewage disposal plant (50%)	A processing complex is required
Chromium-containing solutions	1. Storage at NS (within biological-shielding tanks)	1. Accumulation (100%)	A processing complex is required
Oil products	1. Burning of light fraction* 2. Storage of heavy fraction**	1. Elimination of light fraction (100%) 2. Accumulation of heavy fraction (100%)	The procedure is allowable. Incinerators for waste oil products are required
Sewage water with admixtures	1. Discharge into sewage disposal plant	1. Discharge to water area (100%) 2. Gathering and removal of slime to dumps (100%)	The procedure is allowable.
Solid waste			
Mercury-containing substances (luminous lamps)	1. Transfer	Removal to special enterprises (100%)	The procedure is allowable.
Rubber materials	1. Storage 2. Removal 3. Selling	1. Reuse (30%) 2. Accumulation (10%) 3. Removal to dumps (30%) 4. Selling (30%)	A processing complex is required
Asbestos materials	1. Removal	1. Removal to dumps (100%)	A processing complex is required
Insulation of the hull with resins	1. Storage	1. Accumulation (20%) 2. Removal to dumps (80%)	An elimination complex is required
Mixed waste	1. Storage 2. Removal	1. Accumulation (50%) 2. Removal to dumps (50%)	A processing complex is required
Pasty waste			
Carbide sludge	1. Storage	1. Reuse (10%) 2. Accumulation (90%)	A processing complex is required

Notes: * - "Zvezdochka" SC and Sevmash sell their conditioned oil products; non-conditioned oil products are transferred to the Environmental Center in Cherepovets-city. "Nerpa" SRZ and Poliarninskiy SRZ incinerate their oil products at boiler installations.

** - To incinerate mazouted ground, a special incinerator (type 'UZG-1M' manufactured at the "Emergency Environmental Aid" enterprise (Bryansk) was purchased by "Zvezdochka" SC. The expediency of its use at other concerned enterprises of the region will depend on the outcomes achieved at "Zvezdochka".

The data of Table 2 and Figure 2 clearly illustrate the actual TW-management level and the resulting problems: processing-and-elimination complexes are necessary for 80% of main TW types. No consolidated TW-disposal infrastructure exists in the region yet. Each enterprise attempts to cope with the situation on its own, however, most often such efforts are vain.

Thus to date the activities on chemical risk reduction should be focused on the establishment/modernization of TW-management infrastructure to enable integration and management of generation, gathering, compacting, processing and elimination of TW flows at each enterprise and in the whole region with efficient use of available and planned resources over the whole period of decommissioning and environmental remediation up to its completion.

The toxic waste management strategy developed within the framework of the Strategic Master Plan (SMP) [16] is based on the "Vision", "Mission", "Objectives" and "Key enabling strategies" formulated in the SMP providing for the generation of a comprehensive programme for Northwest Russia

based on the use of system engineering principles. The implementation of functional strategies of the programme developed will enable:

- optimization of decommissioning-and-remediation infrastructure, minimization of the cost for construction/modernization of facilities via integration of functional industrial capacities in order to avoid unnecessary duplications;
- selection of locations for infrastructure facilities and identification of related functions to minimize risks caused by handling/shipment of hazardous waste;
- establishment of initial and subsequent requirements to facilities via determination of the type and flows of hazardous waste and solution of the issues related to their safe management;
- environmental remediation of TSF Andreeva (TSFA) being the most nuclear- and radiation-hazardous facility in the region and acceleration of remediation of TSF Gremikha (TSFG) taking into account the increasing problem of labour force flow-out at TSFG; and
- solution of safety problems (environmental monitoring, environmental safety, etc.) for the sake of human health and protection of the environment.

The TW-management strategy was developed in compliance with the Federal Law [17] determining the legal basis for handling of industrial and domestic waste in order to prevent hazardous effects on human beings and on the environment and introduce such waste into reuse as additional sources of raw materials. The provisions on management of hazardous waste requiring its differentiation by hazard classes were accounted for. An additional Concept “*On Handling, Elimination and Ultimate Disposal of Toxic Waste Generated during Decommissioning of Nuclear Submarines and Environmental Remediation of Temporary Storage Facilities for Spent Nuclear Fuel and Radioactive Waste*” was developed as well [18].

The development of the strategy based on system engineering principles necessitated a consideration of not only general approaches and requirements but also of industrial capabilities together with approaches/intents to be applied while implementing the strategy in order to achieve the end goal. The managerial-and-engineering policy enabling achievement of the end goal has the following key points: processing/elimination of hazardous waste in proper time; efficient use of secondary products; and minimization of all interim-storage stages. An analysis of the outcomes of performed investigations allowed generating a matrix of the strategy, which reflects the logic of activities (infrastructure development – TW processing) and identifies the actual (▲) and desirable (■) states as well as the gap between them, i.e. the strategic priority ($\Delta = \blacksquare - \blacktriangle$). That work enabled selection of priority activities (Table 3).

Table 3. Matrix of the TW-management strategy for Northwest Russia (key lines of activities)

Parameter			Actual (▲) and desirable (■) states, Δ strategic priority, %										
Facility	strategy		0	10	20	30	50	60	70	80	90	100	Δ
Infrastructure	Facility	Develop minimum necessary unified infrastructure at each enterprise and facility		▲								■	90
	Region	Establish: - a processing center at “Nerpa” shipyard (Murmansk region); - a processing center at “Zvezdochka” SC (Arkhangelsk region)	▲									■	100
Waste	Liquid	1. Partial use. 2. Sending for processing (2 class) 3. Processing and elimination <i>in situ</i> 4. Selling of secondary products.			▲■		▲■					■▲	0 0 80 100
	Solid	1. Partial use. 2. Sending for processing. 3. Processing <i>in situ</i> . 4. Selling of secondary products.	▲	▲■	▲							■	0 0 100 100
	Pasty	1. Partial use. 2. Processing <i>in situ</i> . 3. Selling of secondary products.	▲	▲■								■	0 100 100

To solve the problem, several approaches and alternatives were considered: Strategy A – “Do nothing”; Strategy B – “Processing *in situ*”; Strategy C, Option C₁ – “One consolidated regional center” and Option C₂ – “Two regional centers”, which took into account the development of relevant infrastructures. Advantages and disadvantages of each strategy were assessed from the viewpoint of safety and expenses that enabled selection of a most acceptable alternative for the whole region (Table 4).

Table 4. Estimated cost for implementation of key phases of the strategies and options considered for toxic waste management in the region

Activities	Estimated cost by options, thousand euro								
	Strategy B “Processing <i>in situ</i> ”			Strategy C, Option C ₁ “One regional center”			Strategy C, Option C ₂ “Two regional centers”		
	Liquid	Solid	Pasty	Liquid	Solid	Pasty	Liquid	Solid	Pasty
Infrastructure development*	–	15600	–	–	5200	–	–	5200	–
	15200	15200	11500	5600	5700	11500	7800	9700	11500
	Subtotal: ~ 57500			Subtotal: ~28000			Subtotal: ~ 34200		
Transportation**	350 (auto transport)			3300 (auto), 12000 (water)			25 (railway), 150 (auto)		
Processing/year	420	1800	150	180	700	150	210	950	150
	Subtotal: ~ 2400			Subtotal: ~1000			Subtotal: ~ 1300		
Management***	Total ~ 61000			Total ~ 32000-41000			Total ~ 36000		

Comments: * - upper line – storage; bottom line – equipment and construction;

** - taking into account the cost for procuring motor transport and a special ship; *** - without the cost of TW-processing complex at city dump (estimated cost ~ 8000 thousand euro).

The data of Table 4 demonstrate that the Strategy B – “Processing *in situ*” is the most expensive. The development of infrastructure under Option C₁ is less expensive compared to Option C₂, however, unavoidable high cost of transportation - including procurement of moto vehicles and a special ship - equalizes the options C₁ and C₂ in between. In addition, long route of TW shipment to processing facilities

under Option C₁ increases the probability of emergencies (risks) during transportation. Thus, taking into account the indices of maximum safety and minimum expenses, the Option C₂ was selected for further consideration (Fig. 3).

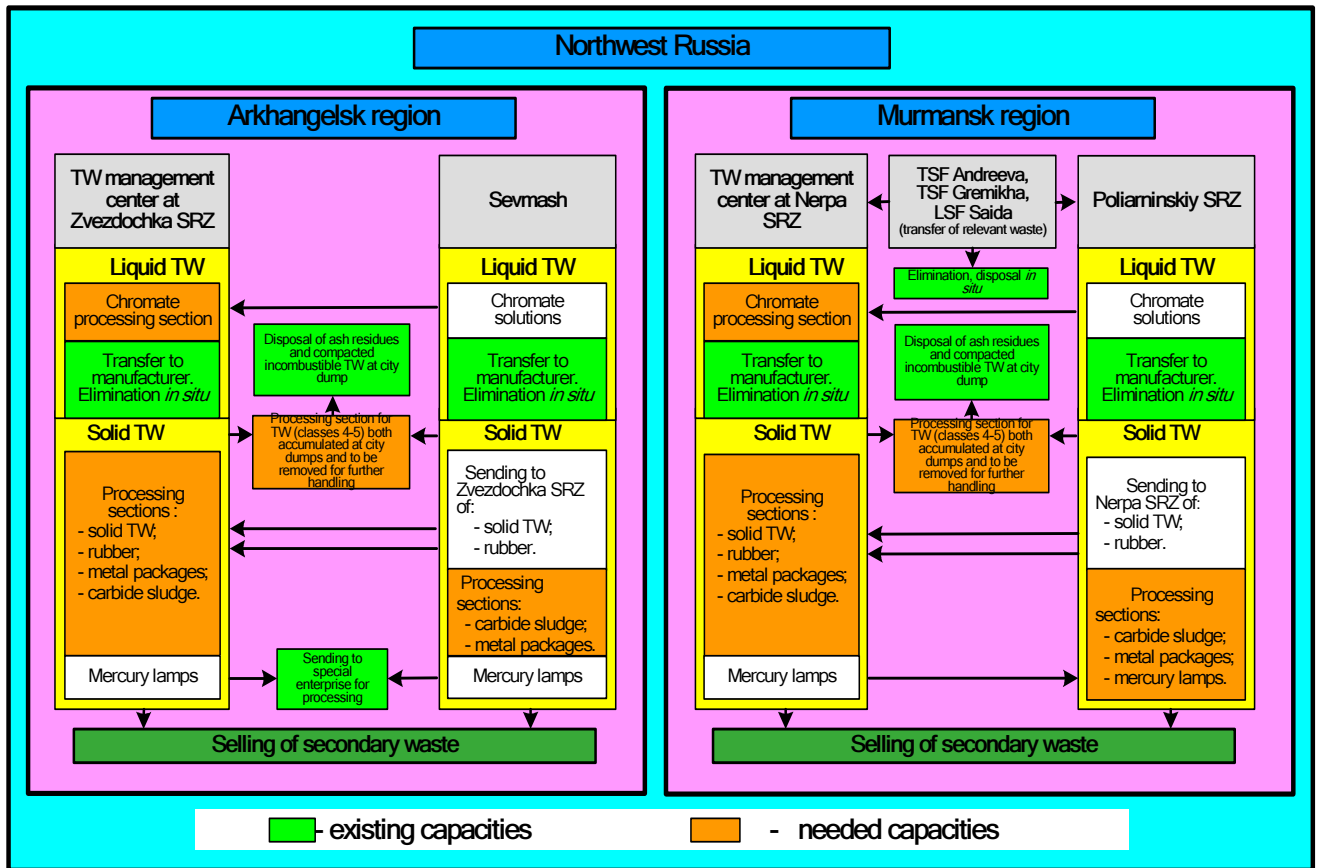


Fig. 3. Basic functional diagram for management of toxic waste produced during decommissioning and environmental remediation in Northwest Russia: Strategy C, Option C₂

Strategy C, Option C₂ provides for an independent and full-value operation of two TW-management centers located at about 1000 km from each other: at “Zvezdochka” Shipbuilding Centre (SC) in Arkhangelsk region and at “Nerpa” shipyard (SRZ) in Murmansk region. The strategy developed has general and particular approaches.

General strategic approach to TW management

1. The transfer from the actual practice of TW accumulation, temporary storage and uncontrolled removal to city dumps to its systematic processing and elimination with concurrent achievement of economic benefit (the end goal) is necessary.
2. To achieve the end goal, one needs to establish: -minimum-necessary unified infrastructure for handling all TW classes at decommissioning facilities and remediation sites - during the next 3 years; and -two centers for TW final processing and elimination enabling simultaneous handling of their own TW and TW of nearby decommissioning facilities and remediation sites - during 5 years.

3. Legal limitations for the duration of TW temporary storage at decommissioning facilities and remediation sites should be put in force as a motivation for TW processing and elimination.

Particular strategic approaches to TW management

Management of TW hazard class I

1. Establish infrastructure on gathering, assortment, containerization, temporary storage, processing and elimination.
2. Use TW processing-and-elimination capacities at outer enterprises.
3. Put secondary waste into reuse.

Management of TW hazard class II

1. Transfer to the owner.
2. Transfer to enterprises-producers.

Management of TW hazard class III

1. Establish infrastructure on gathering, assortment, containerization, temporary storage, processing and elimination.
2. Establish sections equipped with special incinerators to eliminate non-conditioned oil products.
3. Use the capacities of outer enterprises to process chladones (freons).
4. Put secondary waste into reuse.
5. Obtain supplementary heat energy from TW processing.

Management of TW hazard classes IV and V

1. Establish infrastructure on gathering, assortment, containerization, temporary storage, processing and elimination.
2. Put secondary waste into reuse and obtain supplementary heat energy.

The integration approach to solution of the TW-management problem consists in the following (see Fig. 3):

- once two TW processing-and-elimination centers are established (at “Nerpa” SRZ and “Zvezdochka” SC), the problem of TW management at decommissioning facilities and remediation sites of the region may be solved in full, and the hazard of TW storage and inflow to city dumps in the towns of Snezhnogorsk, Poliarnyi and Severodvinsk may be reduced;
- before TW processing-and-elimination centers are established, decommissioning facilities and remediation sites will continue the use of existing capacities on gathering, assortment, storage, incineration *in situ*, transfer for processing to other enterprises and removal of authorized TW classes to city dumps;

- once unified infrastructure elements are put into operation at decommissioning facilities and remediation sites, such facilities and sites will organize their own work on TW safe and secure storage, processing and elimination of individual TW types;
- once TW-processing center is put into operation at “Nerpa” SRZ, TW non-processed earlier at Poliarninskiy SRZ, TSF Andreeva, TSF Gremikha and “Saida” Long-term Storage Facility (LSF) will be sent to “Nerpa” SRZ (save for mercury lamps from TSFA, TSFG and LSF “Saida” to be sent to Poliarninskiy SRZ). In Arkhangelsk region “Zvezdochka” SC will accept TW from Sevmash;
- the responsibility for remediation of city dumps (industrial waste only) will be placed on “Nerpa” SRZ in the Murmansk region and on “Zvezdochka” SC in the Arkhangelsk region;
- the following end states of TW management in the region are provided for: processing, elimination *in situ*, return to the owner/producer for reuse, selling of non-toxic products, use of heat energy etc. and removal of only not hazardous non-processible and non-reusable TW to city dumps for ultimate disposal.

The proposed strategy has the following **key provisions**:

- selection of an optimal approach to hazard (risk) reduction from TW including the activities on appropriate gathering, safe temporary storage, processing/elimination using technologies enabling reuse of secondary resources and ultimate disposal of non-toxic products resulting from TW processing instead of the current practice of TW accumulation at decommissioning enterprises, remediation sites and city dumps;
- as the first step, unified infrastructure has been developed and is proposed for implementation. Such infrastructure provides minimum-necessary TW-management stages at each decommissioning enterprise and remediation site and will allow limiting TW storage at enterprises and sites as well as TW inflow to city dumps;
- establishment of regional centers at “Nerpa” SRZ and “Zvezdochka” SC will enable processing of their own TW and that of nearby enterprises and facilities involved into the decommissioning programme in 3-5 years;
- to reimburse the expenses for TW processing and elimination, the use of TW-elimination technologies allowing obtaining secondary non-toxic products or commercially-usable heat energy is proposed;
- the actual standard and legal documents regulating the duration of TW temporary storage at decommissioning enterprises should be amended via introducing time limitations in order to motivate TW transfer to safe condition for the sake of environmental risk reduction;
- the actual practice of TW (classes 4-5) disposal at city dumps should be ceased and optimized via processing/elimination, disposal and reuse (non-toxic secondary products only).

Stages of implementation. For lack of integrated approach to TW management and due to low efficiency of related activities based on the principle of ensuring minimum-acceptable occupational safety, both modernization of infrastructure at involved enterprises/sites and establishment of appropriate regional infrastructure to guarantee safety of workers, population and the environment is the barest necessity.

The logic of such infrastructure establishment provides for step-by-step development of individual TW-management substructures at each enterprise and at major sites (such as TSFs) taking account of their specificity and industrial capabilities. At presents all enterprises/sites need the following minimum-necessary structural elements: special pads with appropriate equipment for gathering, assortment, compacting and temporary storage of liquid and solid TW in certified containers enabling TW shipment to the nearest TW processing-and-elimination centers. There are presently no certified containers at any enterprise/site of the region.

At the next step building up of local (enterprise/site-level) infrastructures is provided for via construction of complexes to process and eliminate individual TW classes *in situ* and concurrent construction of the following regional centers:

- “Zvezdochka” SC – at the existing TW temporary-storage pad (its partial reconstruction has been already performed); and
- “Nerpa” SRZ – at free areas within the enterprise site.

Both burnable and non-burnable TW produced in the course of nuclear submarine dismantling at Sevmash and Poliarninskiy SRZ will be transferred for processing to “Zvezdochka” SC and “Nerpa” SRZ, respectively. To this end, the following should be done at “Zvesdochka” SC:

- establish a section to process water solution of potassium chromate/bichromate. For this purpose manufacturing of an adequate-capacity installation based on the existing pilot installation is necessary;
- reconstruct temporary-storage pad providing for the arrangement of an incineration plant (IN-50.4 M-type incinerator [19]), a compacting installations for mixed TW (HSM 12 Gigant-type press [20]) and single-use cans (HSM FP 3000-type press [21]); and
- establish a rubber-processing section with special processing line using the “ozone knife” (OK) technology.

The establishment of similar infrastructure elements is proposed at “Nerpa” SRZ as well:

- a section to process water solution of potassium chromate/bichromate;
- a pad with arrangement of an incineration plant (IN-50.4 M-type incinerator), a compacting installations for mixed TW (HSM 12 Gigant-type press) and single-use cans (HSM FP 3000-type press);
- a rubber-processing section with special processing line using the OK technology.

Pasty TW-processing sections should be established at all involved enterprises of the region: “Zvezdochka” SC, Sevmash, “Nerpa” SRZ and Poliarninskiy SRZ. Another important task is the construction of assortment-and-processing complexes («TYRANNOSAURUS»-type [23, 24] including

ECHUTO 150.07-type incinerator [25]) at city-dumps of Severodvinsk, Poliarny and Snezhnogorsk that will enhance safety of the population and the environment.

A rather detailed justification of the selection of equipment and its elements are provided in Ref. [18]. Projects which implementation will enable establishment of a safe TW-management infrastructure in the region in accordance with C₂ option with indication of tentative duration and cost estimates are listed in Table 5.

Table 5. Projects which implementation will enable establishment of an adequate TW-management, processing and elimination infrastructure in the region

Enterprise, site	Project		Duration, month	Cost, thousand euro
“Zvezdochka” SC (TW-processing center)	1	Reconstruction of TW temporary storage pad	48	5200
	2	Establishment of processing line for chromium-containing water solutions	30	2000
	3	Establishment of processing line for single-use can compacting	18	200
	4	Establishment of rubber-processing line	30	3800
	5	Establishment of carbide-sludge processing line	36	2500
Sevmash (TW-processing section)	6	Establishment of carbide-sludge processing line	36	1200
	7	Establishment of processing line for single-use can compacting	18	200
“Nerpa” SRZ (TW-processing center)	8	Construction of TW temporary storage pad	48	8700
	9	Establishment of processing line for chromium-containing water solutions	30	2000
	10	Establishment of processing line for single-use can compacting	18	200
	11	Establishment of rubber-processing line	30	3800
	12	Establishment of carbide-sludge processing line	36	2500
Poliarninskiy SRZ (TW-processing section)	13	Establishment of carbide-sludge processing line	36	1200
	14	Establishment of processing line for single-use can compacting	18	200
TSF Andreeva (TW-processing section)	15	Establishment of processing line for single-use can compacting	18	250
TSF Gremikha (TW-processing section)	16	Establishment of processing line for single-use can compacting	18	250
For the sake of all involved enterprises/sites	17	Development of project documentation and manufacturing of containers for TW storage and shipment	12	50
Severodvinsk, Snezhnogorsk, Poliarny	18	Construction of a complex on assortment and processing of solid TW accumulated at city dumps	24	8000
	19		24	8000
	20		24	8000
TOTAL:	-	TW-management infrastructure in the region	~ 48	~ 58000

Comments. Reconstruction of TW temporary storage pad at “Zvezdochka” SC is being conducted by Rosatom’s order. So far the work has been performed by 70 % but suspended for lack of financing.

By way of conclusion it should be mentioned that, despite the completion of nuclear submarine dismantlement over the next 3-5 years, complex decommissioning of NPSS and NMS ships and nuclear icebreakers along with environmental remediation of TSF Andreeva and TSF Gremikha will continue beyond this period. Until recently management of TW caused by complex decommissioning of nuclear submarines has been mostly reduced to TW accumulation, and this major problem is not still solved in full, the end state of TW-management activities being uncertain.

To reduce increasing environmental risks, an optimum TW-management infrastructure should be established during the next 4-5 years. Such infrastructure developed under the Strategic Master Plan and proposed for individual enterprises/sites and the whole region enables environmentally safe completion of complex decommissioning and environmental remediation of former nuclear- and radiation-hazardous naval facilities in Northwest Russia.

It is worthy of note that the establishment of a processing installation for chromium-containing water solutions at “Zvezdochka” SC should be considered as a first-priority project directly connected with NS-decommissioning activities. The situation topicality is due to the fact that in 2008 dismantling of a nuclear submarine housing 52 t of liquid TW hazard class I began at “Zvezdochka” SC, however, such TW cannot be processed or placed into appropriate containers for lack of adequate processing capacities and containers. To prevent slowdown of NS dismantling paces in future, chromium-containing water solutions should be kept within biological-shielding tanks of reactor units and stored afloat or on shore at “Zvezdochka” SC’s site until the problem of such TW processing is solved. There is presently no way of transferring reactor units with such TW to LSF “Saida” for lack of its own appropriate TW-processing and storage facilities and no plans for their construction in the future.

REFERENCES

1. Danilyan, V.A., Vysotskiy, V.L., Nikitin, V.S., *et al.* (2001) *Environmental Effects of Nuclear Submarine Decommissioning at the Russian State Nuclear Shipbuilding Center*, Preprint IBRAE n°12-2001, IBRAE, Moscow, P.42 (in Russian).
2. Nikitin, V.S. (2003) *An Assessment of Radiation and Chemical Risks while Dismantling “Kursk” Nuclear Submarine*, Sudostroenie Publishers, SPb, C.115 (in Russian).
3. Vasiliev, A. P. (2003) *A Comparison of Chemical and Radiation Risks during Complex Decommissioning of Nuclear Submarines*, RF Minatom’s International Environmental Safety Center, Moscow, P.12 (in Russian).
4. Sivintsev, Yu.V., Vysotskiy, V.L. and Danilyan, V.A. (2003) A comparative assessment of the impact of chemical and radiation factors on workers and population while dismantling nuclear submarines, *J. Atomnaya Energiya (Atomic Energy)*, **95(3)**, pp. 222-238 (in Russian).
5. Zhikhar’, S.A., Batrakov, V.N., Pnichko, E.P., *et al.* (1994) Hygienic characteristic of dust-gas releases generated during gas cutting of naval scrap metal, *J. Hygiene & Sanitation*, **2**, pp. 11-13 (in Russian).

6. Gerchikov, M.Yu., *et al.* (2005) *Strategic Environmental-Impact Assessment for the Strategic Master Plan*. Canada. Performed under Contract № C14073REV with EBRD. Registration number NNC: 12124/TR/002, April 2005, P.213 (in Russian).
7. *Sanitary Regulations on Defining Hazard Class of Industrial and Domestic Toxic Waste* (2003), SP 2.1.7.1386-03, Moscow (in Russian).
8. *Toxic Waste Categorization Criteria by Classes of Environmental Hazard* (2001), RF Ministry for Environmental Resources, Approved by Order № 511 of 15.06.2001, Moscow (in Russian).
9. *The Federal Classification Toxic Waste Catalogue* (2003) RF Ministry for Environmental Resources, Approved by Order № 786 of 02.12.2002 with Supplements approved by Order № 663 of 30.07.2003, Moscow (in Russian).
10. GN 2.1.6.1338-03 (2003) Maximum Permissible Concentrations of Air Pollutants in Populated Areas, in: *Russian Register of Potentially Hazardous Chemical and Biological Substances* Russian Ministry for Health, Moscow, P.57 (in Russian).
11. GN 2.2.5.1313-03 (2003) Maximum Permissible Concentrations of Noxious Substances in the Air of Work Areas, in: *Russian Register of Potentially Hazardous Chemical and Biological Substances*, Russian Ministry for Health, Moscow, P. 268 (in Russian).
12. GN 2.1.5.1315-03 (2003) Maximum Permissible Concentrations of Chemical Pollutants in Water Bodies Used for Drinking-water Supply, Domestic and Recreational purposes, in: *Russian Register of Potentially Hazardous Chemical and Biological Substances*, Russian Ministry for Health, Moscow, P.111 (in Russian).
13. GN 6229-91 (2003) Maximum Permissible Concentrations and Approximate Permissible Concentrations of Chemical Substances in Soils. in: *Russian Register of Potentially Hazardous Chemical and Biological Substances*, Russian Ministry for Health, Moscow P.6 (in Russian).
14. *Fish-industry Standards: Maximum Permissible Concentrations and Approximate Safe Levels of Noxious Substances in Water Bodies Used in Fish-industry*, Moscow (in Russian).
15. Sarkisov, A.A., Vysotskiy, V.L., Nikitin, V.S., *et al.* (2004) *Strategic Approaches to Decommissioning of Russian Retired Nuclear Fleet in Northwest Russia*, IBRAE RAS, NIKIET, RRC KI, Moscow, P. 523. (in Russian).
16. Sarkisov, A.A., Vysotskiy, V.L., Kulikov, K.N., *et al.* (2006) *Strategic Master Plan for Decommissioning of Retired Nuclear Fleet and Environmental Rehabilitation of Its Supporting Infrastructure in Northwest Russia*, IBRAE RAS, Moscow, P. 365 (in Russian).
17. RF Law “*On Industrial and Domestic Waste*” (editions of 29.12.2000 №169-FL; of 10.01.2003 № 15-FL; of 22.08.2004 № 122-FL (edition of 20.12.2004); of 09.05.2005 № 45-FL; of 31.12.2005 № 199-FL), Moscow (in Russian).
18. Vysotskiy, V.L., Kulikov, K.N., Ivanov, S.A., *et al.* (2007) *Development of the Concept on Management, Elimination and Ultimate Disposal of Toxic Waste Produced during Complex Decommissioning of Nuclear Submarines and Environmental Remediation of Temporary Storage facilities for Spent Nuclear Fuel and Radioactive Waste*, IBRAE RAS–NIPTB “Onega”, Moscow, P.230 (in Russian).
19. IN-50.4 M-type Incinerator: <http://www.turmalin.ru/index.php/page=musor67>.

20. HSM 12 Gigant-type press manufactured by HSM Company (Germany).
21. HSM FP 3000-type press manufactured by HSM Company (Germany).
22. Rubber-processing line using the “ozone knife” technology developed by OK Tech Alliance Ltd. (UK)
23. Industrial Toxic Waste Neutralization and Disposal Ground. Design Fundamentals. Sanitary Regulations (SNIIP) 2.01.28-85, Moscow (in Russian).
24. “TYRANNOSAURUS”-type waste-crushing machine manufactured by BMH Company (Finland).
25. EChUTO 150.07-type incinerator manufactured by “VP-Service” Company (Moscow, Russia).