Information about remediation activities

According to the principles of radiation safety, decontamination must ensure a reduction of doses, radioactive contamination density and radionuclides concentration in the air of inhabited places and in the areas of an adjoining protective zone.

The necessity of separating decontamination works for populated areas is explained by the following reasons:

- Significant non-uniformity of radioactive contamination even within the borders of one individual farm;
- Variety of decontaminated surfaces within the borders of one object (roof, walls, fences, road covers, gardens, etc.);
- Presence of the population and industrial activity on decontaminated territories;
- Absence of experience with complex decontamination of populated areas;
- Absence of effective technical means of decontamination of the populated areas.

The industrial methods of decontamination and their efficiency can be compared with the methods used for decontamination of populated areas on purpose to fulfill investigations. However, one cannot help but notice that the significant volume of decontamination works executed in the inhabited locality for the first two years after the accident (1986-1988) by military junctions has shown their very low efficiency and economic weakness.

The experience of works after the Chornobyl accident has shown that decontamination of the populated areas must be carried out in a complex manner, using various methods for vertical decontamination (crowns of trees, roofs, walls of houses, fences) and horizontal decontamination (territory).

In estimating the significance of decontamination works, one should take into account, that reduction of radioactive contamination levels of objects can take place both due to decontamination and due to radioactive decay and such external factors as atmospheric fall-outs, air flows, etc. Also, it should be mentioned that it is impossible to evaluate the decontamination works without considering such measures, as dust removal and putting populated areas in good order.

Decontamination works in the Ukrainian inhabited localities

Tables 1 and 2 review the volumes of the complex works on decontamination that were carried out in the Ukrainian inhabited places during the period of 1986-1989.

Table 1. Volumes of both decontamination and dust-suppression works in the inhabited places in 1986.

Name of works	**Quantity**
Decontamination:	
Dwelling-houses and municipal buildings	22 570
Courtyards	over 1500
Schools and children's establishments	455
Stock-farm premises	about 300
Streets in the inhabited places, km	over 10 000
Removal of contaminated ground, m^3	over 300 000
Covering with asphalt for dust-suppression:	
roads, km	387
road-sides, km	37
territory (in Prypiat and Polissky), km^2	38 000
Treatment of roads and road-sides with dust-suppression materials, km	2377

Table 2. Volume of complex works fulfilled together with decontamination of inhabited places in 1986-1989.

Name of works	**Indications**
Replacement of roofs on houses and buildings	14077
Wrecking and disposal of ramshackle houses, buildings	2145
Replacement of fences, km	590
Decontamination of houses and within doors	7300
Decontamination of wells	2143
Transportation of contaminated ground and rubbish, th m^3	447,5
Delivery of clean ground, th m^3	312,3
Sanitary cleaning on the area, mln km^2	1,4
Building of hard-paved roads, km	567
Transmission line wiring, km	776
Water communication setting, km	570

Reduction of internal irradiation doses can be achieved mainly by Administrative-Organizing measures being carried out. It is possible to classify them as:

- Delivery of clean food products;
- Radiation control for the local food production;
- Cultivating of "steady" against the radionuclides in their mass accumulation products [provision of stable elements to reduce accumulation of the radioisotopes?];
- Inculcation of safe methods for growing, preparing and processing agricultural products received from personal farms.

Since all the actions for reduction of internal irradiation doses come to elimination of polluted food products from use and to radiation control of their quality, the main efforts ought to be directed toward decreasing external irradiation doses.

As a result of radioactive fallouts, spreading of the contamination had occurred for ecosystem elements and for inhabited and subsidiary constructions, roads, pastures, etc. These fallouts form the external irradiation dose.

Analysis of the radiation situation and dose loads for the population shows that choice of methods for decontamination and radioactive waste management are defined mainly by means of technical facilities available and by material and human resources balance. So the choice of decontamination technology presents by itself a compromise problem of minimizing two parameters: material outlay and risk for population health from remaining contamination of decontaminated territory.

Farmstead territory together with all complexes of buildings is taken as a conditional unit of populated area decontamination. Agricultural activity is a component part of human life; therefore to achieve radiation contamination control levels which ensure the possibility of getting products fit for food without limitations is the final goal of decontamination.

For yard subsidiary buildings and wooden barriers for farmsteads, if their contamination level exceeds the fixed level (Table 3) they are not subjected to decontamination. Instead, the intent is to replace them.

Replacing the roofs of dwelling houses and buildings attached to them is stipulated by the project for the condition of beta-activity exceeding more than 200 part/cm^2/min).

The most polluted areas of farmsteads are buildings for public use (farms, enclosures, workshops and others); the most polluted objects of public service are blind areas and drains.

According to the radiometric survey, some areas of farmsteads and kitchen gardens of public use in the villages were found as the most contaminated places.

The project provided in detail for removal by hand of contamination from blind areas around the houses and buildings of public use, as well as polluted soil places in some narrow

parts, with further loading into containers. Soil and builders' refuse must be loaded from containers in the backs of cars and transported to LSWD (Local Site Waste Disposal) locations. Moreover, waste of organic origin is transported separately, since it is expected to require some different technology for its disposal.

Table 3. Control power levels from gamma-radiation exposure and surface contamination with beta-radiation radionuclides.

	Objects of contamination	**Level of contamination by beta-particles part./cm^2/min**
1.	Pre-school institutions for children, schools, medical and preventive establishments and equipment inside, food shops, enterprises of food industry and public food and equipment: Within the premises Territory and equipment	 20 20 50
2.	Objects of cultural-mass purpose, sport buildings and complexes: Within the premises Territory and equipment	 30 50
3.	Inner surfaces of dwelling premises and subjects of personal use	50
4.	Inner surfaces of service premises and outer surfaces of equipment inside	50
5.	Open surfaces of the city territory and outer surfaces of buildings	200
6.	Transport means and mechanisms: Inner surfaces Outer surfaces Internal surfaces external surfaces	 50 100

On the completion of removal and transport of contaminated soil and materials from the courtyards and places of public use, ploughing ought to be done, or manual re-plough, if it is impossible for mechanisms to be fitted. Lime (5 t/ha, according to the calculation) is inserted simultaneously and potassium - phosphoric fertilizers (by 125 kg/ha) of each type.

The final stages of decontamination of populated areas included improvement of the farmsteads and places attached to them as well as places of common use, including delivery of clean soil for the blind area hollows, gravel (crushed stones) and asphalt for blind areas and courtyards, covering with asphalt, making barriers, recovering of roofs and taking down of constructions, grass sowing aimed at making a turfy layer on the places of common use, as well as turfing of waysides.

Decontamination of Soil

Dust particles, rain drops and flow, and contaminated leaves obey the principles of gravity which lead them to reach the soil at the final stage of natural transport. The soil around houses, yards, roads and pavements was found to be a significant contributor to the doses.

Skim and burial ploughing In the urban environment, the application of skim and burial ploughing would be restricted to large areas, such as parks. The plough skims off the topmost layer of soil (about 5 cm) and buries it at a depth of some 40-50 cm without inverting the intermediate layer. Hence the name 'skim and burial plough'. The removal of only about a 5 cm layer of topsoil rarely affects the fertility of the land, and poorer quality subsoil is not brought to the surface. Overall, the skim and burial plough greatly reduces radiation levels at the ground surface, the resuspension hazard is eliminated, most of the contamination is made inaccessible to plant roots, and soil quality is unaffected. The effect of the procedure, which has been tested in the former USSR, has been found to be a reduction of the dose-rate by some 94%, but in very sandy soils it may be difficult to achieve the objective with this method.

Triple digging Triple digging is an excellent method to reduce the dose to people, both where the uptake to plants is considered, and for external dose reduction. This method can be used in gardens and other places where it is impossible or expensive to use skim and burial ploughing. It can be seen that if the initial contamination is in the uppermost 10 cm of soil, then the dose reduction factor will range from 0.08 to 0.5, depending on the size of the plot and the initial distribution.

The sequence of decontamination work fulfillment will be dictated, as a rule, by the actual conditions of locality, by weather conditions, and it ought to be determined by the standard order for realization of decontamination works on populated areas. The order of priorities for works to be fulfilled is represented in Table 4.

Table 4. Sequence of decontamination work fulfillment

No.	Name of works to be fulfilled	Order of work priorities
1	Interim technological site setting-up in the populated areas for the road engineering to be localized, and determination of routes for the waste resulting from decontamination to be transported away	I
1	Decontamination of populated area 500-m protected zone	II
2	Decontamination of village inhabited area zone (except courtyards)	III
3	Fence disassembling	III
4	Roof dismounting	III
5	Pulling down of ramshackle and neglected buildings	III
6	Digging out of soil under the drains	IV
7	Digging out of soil with 40 mkR/hr exposure rate	IV
8	Cleaning of wells	IV
9	Infield spading by hand	IV
10	Infield ploughing	IV
11	Clean soil delivery	V
12	Setting up the blind areas	V
13	Courtyard covering with asphalt	V
14	Trimming of streets and inside roads with their planning simultaneously	VI
15	Digging out of radiation-contaminated soil along the streets and inside	VII

No.	Name of works to be fulfilled	Order of work priorities
	roads	
16	Ploughing of street surfaces, inside roads and adjoining areas	VIII
17	Accomplishment of streets (covering with asphalt and sod)	IX
18	Decontamination and re-cultivation of verified routes for the waste to be transported away	X
19	Assessment of radiation situation on the inhabited area territory	XI
20	The surface treatment with dust-coupling solutions	Operation is carried out before the work fulfillment

In the early stages, when there were still many short-lived gamma emitters, the following were carried out on the most heavily contaminated land:

- removal of the top layer of soil on the most contaminated plots of land and in the places most frequented by people;
- decontamination of buildings;
- resurfacing (repaving) of roads, etc.

Decontamination works cost 28×10^6 rubles for 4 years (in scale 1990). In 1987-1990 the next countermeasures were carried out:
washing of walls, roofs, houses (2127 yards) - 95%;
removal of contaminated soils (450 yards - 3100m^3) - 14%;
changing of roofs - 81%;
changing of fences (13.4 km) - 13%;
repaving of roads - 12%.
In 1987, 1560 workers using more than 90 units of technics made works of decontamination in Polesskoe.

Tables 5 and 6 summarize the volumes of materials remediated and waste removed during the decontamination efforts.

Table 5. The list of waste volumes at realization of decontamination-remediation works.

No.	Name of works	Volume of works		Volume of waste		Technical support
		units	quantity	units	quantity	
1	Contaminated soil 0,2 m depth to be taken away under the drains by hand	m^3/t	4798/6717	m^3/t	4798/6717	Means of small mechanization (shovels, barrows, containers, etc.)
2	Contaminated soil 0,2 m depth with ≥ 4,0 μSv/h), of exposure rate to be taken away Including by hand by cleaners	 m^3/t m^3/t m^3/t	 2383/3336 300/420 2083/2916	m^3/t	2388/3336	 Means of small mechanization Bulldozer. Loader pneumatic-wheel
3	Cleaning of the contaminated silts from wells by hand	m^3/t	34/61	m^3/t	34/61	Means of small mechanization (shovels, hoist, bins, barrows, containers, etc.)
4	Some separate plots digging out by hand (gardens, small fruit plantations, etc.) with introducing simultaneously: Chalk - 5,0 t/ha potash salt – 0,125 t/ha superphosphate - 0,125 t/ha	 ha t t t	 19,88 99,4 2,485 2,485			By hand
5	Surface treatment by 10% SSD solution when replacing the fences, digging out the soil, replacing the roofs, taking down ramshackle houses, ploughing (1,0 L/m^2 is a specific discharge of 10%-solution)	T	1800			Street-flushing car
6	Fence disassembling and setting	100 lm m^3/t m^2	226 1011/809 18705	m^3/t	1011/809	Auto-crane, Pneumatic-wheel loader
7	Roof dismounting	m^2/t	189/268	m^3/t	179/268	Auto-crane
8	Roof setting up	m^2/t	18705/266			Auto-crane
9	Pulling down of ramshackle and					Auto-crane,

No.	Name of works	Volume of works		Volume of waste		Technical support
		units	quantity	units	quantity	
	neglected buildings	m^3/t	70/56	m^3/t	70/56	Tip-lorry, bulldozer
10	Clean ground bringing	m^3/t	7181/10053			Tip-lorry, bulldozer
11	Blind area setting up Crushed stone delivery Asphalt delivery	m^2 m^3/t m^3/t	24350 2435/4357 730,5/1314,9			Tip-lorry, bulldozer, pneumatic-wheel roller, machine for covering with asphalt, hand road-roller
12	Covering courtyards with asphalt Crushed stone delivery Asphalt delivery	m^2 m^3/t m^3/t	35300 3530/6330 1059/1906,2			Tip-lorry, bulldozer, pneumatic-wheel roller, machine for covering with asphalt, hand road-roller
13	Infield ploughing for 0,3 m depth by T-4A tractor with introducing simultaneously: chalk - 5,0 t/ha potash salt - 0,125 t/ha superphosphate - 0,125 t/ha	ha t t t	81,85 413,85 14,52 14,52			Tractor, arrangement for additional fertilizing to be applied
14	Transportation of contaminated soils and building rubbish over 10 km distance	m^3/t	8475/11247			Dump-truck, dust-cart
15	WASTES Including organic waste			m^3/t m^3/t	8475/11247 1171/999	

Table 6. Decontamination of protected zone, territories for general use.

No.	Name of works	Units	Volume	Technical support
1	Ploughing of protected zone (500 m) 0,3 m depth by T-4A tractor (96 kWt) with introducing to soil: chalk - 5,0 t/ha potash salt - 0,125 t/ha superphosphate - 0,125 t/ha	ha t t t	270 1350 33,75 33,75	ULP-8 arrangement for additional fertilizing to be applied
2	Ploughing 0,3 m depth of territories for general use by T-4A tractor (96 kWt) with introducing to soil: chalk - 5,0 t/ha potash salt - 0,125 t/ha superphosphate - 0,125 t/ha	ha t t t	40 200 5,0 5,0	ULP-8 arrangement for additional fertilizing to be applied
3	Cleaning 0,2 m depth of reservoir-sides from contaminated soils (silts)	m^3/t	2480/3968	Tractor. Excavator pneumatic-wheel
4	Contaminated soil digging out 0,2 m depth from the ditches near roads	m^3/t	3660/5124	Excavator pneumatic-wheel
5	Transportation of contaminated soils to the point of waste disposal over 10 km distance	m^3/t	6373/9418	Dump-truck
6	Contaminated soil digging out 0,2 m depth and 1,0 m wide under the drains near the buildings of public use (farms, stock-houses etc.)	m^3/t	233/326	By hand (shovels, hoist, bins, barrows, containers and etc.)
7	Delivery and setting of soil layer 0,2 m depth for reservoir-sides and river-sides etc.	m^3/t	2480/3968	Dump-truck, bulldozer
8	Transportation of disassembled fences to the place of disposal over 10 km distance	m^3/t	332/266	Dump-truck
9	Road slopes sodding with grass-mix introducing	t	0,3	Seeding machine

The most radical way for reduction of exposure dose in the school and pre-school establishments is realisation of the decontamination process. Decontamination was made by removal of the top soil layer to the depth of 20 cm manually and with the help of a bulldozer. The removed soil was transported to be disposed of in the RW Disposal Point. The radionuclide content in this soil did not exceed 400 Bq/kg. In detail the technology of decontamination procedures for the schools and the volumes of fulfilled works are represented in Table 7.

Table 7. Technology of decontamination procedure for the schools.

No.	Operation	Unit	Number
1	Removal of the contaminated soil layer by hand	m^3	60
2	Removal of the contaminated soil layer by bulldozers and transportation for a distance of 10 m	m^3	131
3	Per extra 10 m	m^3	191
4	Loading of the soil into vehicles by excavators (0.25 m^3)	m^3	191
5	Transportation of the soil to the burial ground for a distance of no more than 5 km	ton	306
6	Uncontaminated soil exploitation by bulldozers in pits and transportation for a distance of 20 m	m^3	130
7	Loading of the soil into vehicles by bulldozers	m^3	130
8	Transportation of the soil for a distance of 1 km	ton	203
9	Strewing of the soil between trees by hand	m^3	40
10	Transportation of the soil by bulldozers for a distance of no more than 30 m	m^2	90
11	Vegetable soil exploitation by excavators and loading of the soil into vehicles	m^3	13
12	Transportation of the vegetable soil for a distance of no more than 1 km	ton	16
13	Strewing of the vegetable soil between trees by hand	m^3	13
14	Roller compaction of the soil	m^3	143
15	Mechanical land leveling	m^2	1190
16	Disassembling of asbestos-cement roof coverings	m^2	253
17	Replacement of asbestos-cement roof coverings	m^2	253
18	Loading of the roof coverings disassembled	m^3	5
19	Transportation to the burial ground for a distance of no more than 5 km	ton	6
20	Dosimetry	m^2	1419