NATURAL RADIOACTIVITY AND RADIATION SITUATION IN MANGYSTAU OBLAST OF WESTERN KAZAKHSTAN

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Introduction

When performing radio-ecological investigations and developing measures for lowering radiation risks for inhabited localities and territories subjected to impact of radiation-hazardous objects (RHO) one should pay special attention to the cases when several RHO's of different type contribute simultaneously into radiation situation in a region. A prominent example is the Aktau city in Mangystau oblast of Western Kazakhstan; radiation situation there has been formed under such factors as presence of Mangyshlak Atomic Energy Combine with BN-350reactor facilities, sites of underground nuclear explosions at Plato Ustyurt, uranium extracting and processing facilities and a bunch of operating there oil extracting companies. Previous investigations showed that situation in the city and its vicinity is quite complex and requires vast corrective measures to be immediately introduced. At the same time, separate narrow-scale programs related to improvement of radio-ecological situation in the region funded from different sources are uncoordinated and are not very effective for they have been developed without taking into account all the possible sources and mechanisms of radioactive contamination of the environment. In order to improve effectiveness of the measures aimed at lowering radiation risks it is necessary to perform preliminary investigations and estimate contributions from each RHO in the region. Institute of Nuclear Physics of National Nuclear Center (INP NNC RK) has been actively involved in a set of research and environment-preventing measures in Mangystau oblast for many years. Among the most noticeable projects on investigation of radiation situation at the territory of Mangystau oblast where INP took part or leaded are the following: assessment of radiation situation in places of underground nuclear explosions at Plato Ustyurt; over all investigation of sanitary-protection zone and monitoring zone of BN-350 reactor facilities; over-all investigation of ecological situation at toxic waste storage "Koshkar-Ata" and development of rehabilitation measures; inventory of industrial, solid domestic and radioactive waste, in Mangystau region; over all radio-ecological surveying of Aktau city and inhabited localities of Akshukur, Bayandy, Mangystau railroad station; radio-ecological surveying of spent uranium mines in vicinity of Aktau city. These works and their results demonstrate that there is a wide range of different-type radiation-hazardous objects each contributing to the general radio-ecological situation in Mangystau oblast. All the above named locations can be conventionally split up into two groups depending on radionuclide composition of generated radioactive waste and possible radioactive contamination of the environment. In the first group are places of underground nuclear explosions at Plato Ustyurt and BN-350 nuclear power reactor (fast neutrons type) that are potential sources of artificial radionuclides. Radio-ecological investigations performed at these locations are presented below.

BN-350 Reactor Facilities. In all environmental samples taken at the territory of sanitary-protection zone and monitoring zone of BN-350 reactor,the content of artificial radionuclides corresponds to average Western Kazakhstan levels of global fall-outs. The results presented in Tables 1 and 2 reliably demonstrate this [1]. Available retrospective data on releases also indicate that during whole operation period of reactor plant there was no annual environmental release of radioactive substances exceeding the acceptable levels .

Table 1. Content of artificial radionuclides in environmental samples

Radionuclide	Content in studied samples, Bq/kg	Global fall-outs level (in Western Kazakhstan), Bq/kg
^{137}Cs	<2.1 – 33.5	<0.5 – 50
^{90}Sr	<5 – 10.5	<5 – 30
^{152}Eu	< 1.4 – 2.5	Below determination threshold
$^{239+240}Pu$	<0.05 – 0.55	<0.05 – 5

Therefore, contribution of BN-350 to radio-ecological situation within the sanitary-protection and monitoring zones can be detected employing highly sensitive methods and this contribution is vanishingly small and does not change the quality of the environment. At those territories there were revealed no single case of exceeding regulatory allowable contamination of environment with artificial radionuclides.

Underground nuclear explosions. At near-mouth sites of the explosion wells at Plato Ustyurt that were have been used for peaceful nuclear explosions there were local areas of soil contamination with artificial radionuclides ^{90}Sr and ^{137}Cs. According to walk γ-surveillance, there is an insignificant area of less than 50 m^2 with registered Exposition dose rate (EDR) for γ-radiation of about 25-30 μR/h, the background values for that region being 8-10 μR/h. Since there are no inhabited places in the vicinity and the rate of radioactive contamination is low (within allowable limits), these sites do not impose considerable radiation hazard on the region. Natural radionuclides are of much more concern; their source is tailings from oil extraction and uranium industries.

Oil extraction facilities. Operation of oil-and-gas fields in Kazakhstan is accompanied with carrying out today surface of considerable amount of material with increased content of natural radionuclides. Amounts of radioactive materials accumulated at the fields are described in terms of thousands tons, activity of radionuclides delivered to human environment in dozens of Curies; up to 70% of the radioactivity is accumulated in pressure-compressor pipes (PCT) and other metal equipment. Such amount of radioactive materials increase natural background by orders of magnitude over a total area of several hectares and must be taken into account due to the hazard imposed on personnel and population.
Contaminated metal discard, particularly PCT, [2] is of highest hazard due to their possible unauthorized utilization by local population for water supply and construction. Such metal discard at oil extraction fields is completely accounted; rates of their contamination and related factors of radioactive hazard such as mass amount and activity are not determined for most of the cases.
Within the oblast following companies run commercial activities: public corporations “UMG”, “MMG”, “Karazhanbasmunai”, companies “TasbulatOilCorporation” Ltd., “OSC” Ltd., close corporation “KazTransOil”. At territories where oil-extracting companies operate 231 radioactive anomalies were registered [3], 192 of which were classified as man-caused technological radioactive contamination sites (TRCS). Most of the TRCS with their EDR for γ-radiation correspond to low-level waste of the 1^{st} category according to the SPORO-85 and State concept for handling of radioactive waste in the Republic of Kazakhstan EDR within 100–30,000 μR/h. Classification of TRCS based on EDR and their distribution within the oblast is presented in Table 2.

Table 2. Exposition dose rates for gamma-radiation in places of radioactive contamination at oil extraction fields of Mangystau Oblast.

№	Sites of radioecological investigations	Average back-ground, μR/h	Total number of anomalies	Total number of TRCS	TRCS within EDR		EDR, μR/h; main radiation sources
					100 – 300, μR/h	300 –30000, μR/h	
1	Novii Uzen	8-14	80	50	17	33	3000, ^{226}Ra
2	Zhetybai	8-12	40	33	7	26	3420 , ^{226}Ra
3	Southern-Mangyshlak area	13-18	3	2	1	1	950
4	Southern-Zhatybay area	13-16	2	2		2	2400
5	Kalamkas	8-10	106	101	55	46	10300
	Total for the sites of “Mangystaumunaigas”	8-14	231	188	80	108	

Actual source of radioactive contamination for all TRCS are stratal water in the zone of water-oil interface; primary source of natural radionuclides delivered to stratal water are the enclosing strata.

Stratal waters at oil fields contain highest concentrations of radium (10^{-8} – 10^{-11} %) compared to all other known stratum waters, except water from uranium fields.

Anomalous spots with masout soil cover areas of up to tens thousands square meters with EDR of 30 – 100 μR/h at natural background of 8–11 μR/h. Such soil is brown and usually covered with solid oil skin.

At places of extensive or multiple releases average level of radioactive contamination comprises for γ-radiation of 250–600 μR/h at territories of tens or hundreds of square meters; local maximal readings may be as high as 1000 – 2800 μR/h.

TRCS with oil-slime and salt on soil surface are most frequently presented as local clusters of a few to several dozens of square meters and EDR of 300 – 6000 μR/h.

Internal surfaces of equipment and tank bottoms keep sediment oil-slime and salts with high radionuclide content. Radioactivity of metal discard comprises at external surfaces of 400 – 10,000 μR/h.

At all oil extraction sites, mainly at intermediate and final stages of exploitation, technological equipment and pipelines are contaminated with natural radionuclides. Contamination type is the same as for TRCS of the third type; its source – stratal water circulating with oil.

Spent uranium mines. In 2002 specialists from INP performed overall radio-ecological investigation of two spent uranium mines [2]. These sites are located whithin 20 km of Aktau, accessible through railroad and automobile. Currently ore mining is not performed.

Not all the tails are covered what stipulates their negative impact on environment with direct radiation impact from gamma-radiation, radon emanation and aerosol-dust proliferation, transport of uranium and radium with periodical water flows into soil water horizons and local hydrological system.

One should note that along with natural factors contributing to radioactive contamination of the environment there is another, not less hazardous, scheme of radioactive contamination due to uncontrolled utilization of mining tailings in building or road construction that takes place in inhabited localities adjacent to stopped sites of geological prospecting and spent uranium mines.

Main contaminating factor is radionuclide containing dust proliferation. Intensity of this process to certain degree depends on weather-climate conditions. One can reliably determine contribution from this factor only upon monitoring investigations. At gamma-activities in an open-pit lodge of 0.3 – 0.6 μSv/h, and at naked ore body of up to 1.2 – 5 μSv/h, its value at external contour of musk stacks is 0.08 – 0.15 μSv/h that corresponds to background values. Radon concentration in atmospheric air at that lies within 2 – 5 Bq/m^3 that corresponds to world's average value.

Tailing Pool "Koshkar-Ata". In 2003 specialists from INP performed pilot monitoring of dusting from "Koshkar-Ata" radioactive and toxic waste storage [4]. This tailing pool was made in a closed hollow, covers 130 square kilometers and is located 7-8 km to the East from the Caspian Sea shoreline and 5 km to the North from Aktau. Amount of accumulated solid waste comprises ~104.8 mln. ton, including ~51.8 mln.ton of RAW with total activity of $41598.5 \cdot 10^{10}$ Bq. Main dose-forming radionuclides in the waste stored there are ^{238}U, ^{230}Th, ^{226}Ra and ^{222}Rn; concentration of ^{226}Ra changes from background values of 15 – 20 Bq/kg to 700 – 800 Bq/kg. There were revealed quite high concentrations of lead isotopes ^{210}Pb and ^{212}Pb.

Man-caused ecological hazard from the tailing pool is stipulated by two main factors: 1) air pollution and soil contamination with radionuclides and heavy metals adjacent to the tailing territories due to wind erosion from naked bottom sediments and, 2) contamination of underground water and possible proliferation of hazardous substances es dense saline solutions into the Caspian Sea.

Due to continuous decrease in water phase level of the tailing pool, area of exposed bottom sediments, a source of radioactive and toxic dust, increases. Water mirror covers 42.5 km^2. and shore exposed zone is as large as 34.5 km^2. A near-surface disposal of RW is located in the mouthpart of the tailing pool. Its detailed gamma-surveillance (covered 8,700 m^2) revealed that EDR reaches 700 μSv/h.

Waste accumulated in the tailing pool substantially influences soil and vegetation in adjacent territories. Directly at the site their impact is maximal on physical, chemical and biological parameters; waste completely covers the surface, makes soil more dense, with higher content of water-soluble salts and less microbial mass in it. At this territory vegetation is completely vanishing. At the tailing pool, total area subjected to such catastrophic change comprises about 70 km^2. Chemical and biological parameters of soils at significant distance from the pool have also worsened; this has been accompanied by vegetation degradation. There were registered exceeding contents of copper, zinc, nickel, gypsum and nitrates in the soil layer. In order to reveal the character of horizontal distribution for radioactive contamination over the shore-exposed zone of "Koshkar-Ata" tailing pool, walk gamma surveys wor performed. Data presented here are supported by gamma-spectrometric investigations and reveal non-uniform character of radioactivity distribution over the territory. Most of the radioactive waste is concentrated in exposed bottom sediments in the southern part of the tailing.

Radiation situation in that part of the tailing is also influenced by the near-surface radioactive waste disposal (NSRWD) located there; the situation becomes worse since previously radioactive waste were covered over, did not increase gamma-background and were isolated. Currently, local people intensively dig up the disposal trying to excavate and sell metal. Considerable part of RW becomes spread over the territory. Detailed gamma surveying of the NSRWD showed that pits and digs form intensive gamma-fields.

Content of radionuclides in soil is high. In a sample taken from 50-60 cm with EDR in the sampling point of 5.84 μSv/h concentrations of the isotopes were as follows: Pb-210 – 57300±410 Bq/kg, U-235 – 3960±68 Bq/kg, etc. There are considerable amounts of rare earth elements and heavy metals in soils there. Taking all that into account, it is reasonable to initiate rehabilitation actions from these lands, which impose the highest radio-ecological hazard on population and environment.

Proposals for rehabilitation of the "Koshkar-Ata" tailing pool territories. When estimated possible technologies for exposed shore zone rehabilitation at "Koshkar-Ata" cost is considered first because the cost of any traditional rehabilitation actions at sucha vast area (of 11 km^2) rises up to millions of US dollars, which currently is not acceptable for Kazakhstan. Traditional technologies isolation of shallow lands with some available and cheap local material, such as, clay or sand, or processing of soils in order to increase effective size of soil grains (such as processing with polymers).

Another promising way is to employ as isolating materials recrement or discards from local industries, particularly from local construction enterprises. That means solution of the problem is at "management and technology" level. In this case expenses related to extraction and delivery of isolating material are eliminated – these costs mainly determine rehabilitation expenses.

Conclusions

Radio-ecological investigations performed in Mangystau Oblast for many years (Table 3) revealed quite complex radiation situation in the region; some measures are tobe taken immediately.

Based on comparison of existing radio-ecological hazard sources and taking into account such "non-physical" parameters as population density in vicinity of a radiation hazardous site and site access control one can arive at the following main conclusions:

- first, radio-ecological problems of the BN-350 reactor facilities and sites of nuclear explosions are not of primary concern, in fact they attract unreasonable amount of attention;
- second, investigation should be focused on radio-ecological problems in the regions where transport and redistribution of natural radionuclides takes place due to commercial activity;
- natural radionuclides that come from uranium and oil-extracting industries are of the highest radiation hazard for population and environment. Therefore, priority environment protection measures directed to improvement of radio-ecological situation in these regions.

Table 3. Comparative radiation characteristics of main radiation hazards in Mangystau Oblast

№	Objects of radioecological investigations	Average background, μR/h	Total TRCS	Maximal area of TRCS	EDR, μR/h; main radiation sources	Notes
1	BN-350 reactor facilities	8–12	-	-	8–12; ^{137}Cs, ^{90}Sr	Continuous control over radiation situation is performed at the site and vicinity
2	Sites of underground nuclear explosions at Plato Ustiurt	8–12	-	-	25–30; ^{137}Cs, ^{90}Sr	No inhabited localities or industrial sites in the zone of potential impact
3	Oil extraction fields	8–14	192	$n{*}10^4$ m^2	up 10000; ^{226}Ra	Inhabited localities and camps are in the zone of possible impact; almost no radiation control at commercial activities is available
4	Spent uranium mines	13–18	3	$n{*}10^6$ m^2	2500; ^{226}Ra	Wing erosion of ore bodies is accompanied by radioactive dust proliferation
5	Tailing pool “Koshkar-Ata”	13–16	1	$n{*}10^7$ m^2	500; ^{226}Ra	The Caspian Sea and several inhabited localities including Aktau city are located within the zone of potential impact

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