# RADIATION SURVEY AND DECONTAMINATION OF CAPE ARZA FROM DEPLETED URANIUM

by

**Perko VUKOTIĆ[1], Tomislav ANDJELIĆ[2], Ranko ZEKIĆ[2], Milojko KOVAČEVIĆ[3], Vladimir VASIĆ[4], and Slobodan SAVIĆ[4]**

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**In the action of NATO A-10 airplanes in 1999, the cape Arza, Serbia and Montenegro was contaminated by depleted uranium. The clean-up operations were undertaken at the site, and 242 uranium projectiles and their 49 larger fragments were removed from the cape. That is about 85% of the total number of projectiles by which Arza was contaminated. Here are described details of the applied procedures and results of the soil radioactivity measurements after decontamination.**

*Key words: decontamination, depleted uranium, radiation survey*

## INTRODUCTION

On May 30, 1999, A-10 Thunderbolt NATO airplanes struck the cape Arza twice. The cape is located on the Luštica peninsula at the entrance of the Boka Kotorska bay. The armor piercing projectiles with depleted uranium penetrators were used. According to the data declared by NATO [1], the number of the projectiles fired at Arza was 480; 300 of them were with uranium penetrators and 180 with plain filling.

The cape Arza is stony; the ground consists of mainly red shallow soil which is somewhere brown or humus. The cape is overgrown with bushes and low vegetation with sparse trees. The terrain is slightly higher than the sea level (0 to 13 meters) and, at the back, the cape becomes a hill with dense, almost impassable vegetation (fig. 1). There are no water springs at Arza nor in its close surroundings. The complete precipitation flows into the sea. The cape is a touristic area with no agriculture or cattle raising activities.

Depleted uranium decontamination of the cape Arza was financed by the Government of Montenegro. The decontamination project was established in December 2000, and the preparatory actions for decontamination were performed during January 2001. The first phase of decontamination lasted from February 1, 2001 to mid June 2001. The campaign continued during April, May, November, and December 2002, with the engagement of 10 to 15 members of the expert team (7 civilians and 8 military officers) and about 10 people in logistics. The team was working effectively at the field 220 working days.

**Figure 1. Cape Arza site**

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Authors' addresses:
[1]Faculty of Natural Sciences and Mathematics
University of Montenegro
P. O. Box 211, 81001 Podgorica, Serbia and Montenegro

[2]Center for Ecotoxicological Research of Montenegro
Put R. Ivanovića 2,
81000 Podgorica, Serbia and Montenegro

[3]VINČA Institute of Nuclear Sciences
P. O. Box 522, 11001 Belgrade, Serbia and Montenegro

[4]Navy Command, Army of Serbia and Montenegro
85346 Zelenika, Serbia and Montenegro

E-mail address of corresponding author:
milojko@vin.bg.ac.yu (M. Kovačević)

## CONSEQUENCES OF THE ACTIONS

Immediately after the military actions, an nuclear, biologic, and chemic defense unit of the Navy of Serbia and Montenegro started the field work and found the traces of military activities performed by depleted uranium ammunition in the territory of the cape Arza. Several depleted uranium projectiles were found at the location as well as parts of blown-up jackets and the terrain contamination was determined. The places of the impact in the soil and in the stones could easily be determined. Before any work started, the terrain contamination measurements had been performed and the composition of the projectiles had been determined.

The length of the armor piercing bullet is 173 mm, and its diameter is 30 mm. The bullet is covered with the aluminum jacket, and there is a cone penetrator made of depleted uranium. The length of the penetrator is 95 mm, base diameter 16 mm, and mass 293 g. Isotropic analysis of the depleted uranium showed that the projectile consists of $^{238}$U (99.7-99.8)%, $^{235}$U (0.2-0.3)%, $^{234}$U 0.001%, and $^{234}$Th, $^{234}$Pa, and $^{231}$Th in traces. Isotopes $^{236}$U, $^{239}$Pu, and $^{240}$Pu, were also found in traces, which proved that the depleted uranium had been obtained by processing used reactor fuel [2, 3].

More detailed examination started a couple of months later when more detailed measurements of the terrain contamination were performed, and gamma-spectrometric analysis of the samples was carried out in the laboratory. The field measurements showed that contamination was local around the places of the impact in the diameter of several tens of centimeters. Outside those areas, radioactivity was on the level of natural radiation. The ground samples had wide spectrum of activities. Some of the samples had natural uranium ingredient, while the samples taken from the places of impact had the activities which were up to 20 kBq/kg.

## RADIATION SURVEY AND DECONTAMINATION

Detailed work on decontamination started almost a year and a half after the air force action. An expert team was formed to make a project of decontamination defining the work methodology, elements for people and environment protection, specific instrumentation *etc*.

### Instrumentation

At the moment when the work began, we had the following means at our disposal: Eberline's dosimetric system TOL/F, VICTOREEN 190 SI, BICRON Analyst, several domestic-made contamination monitors, KOMO-TL, KOMO-TM, and a well-equipped gamma-spectrometric laboratory. The basic detecting instrument used was KOMO-TL, which had been manufactured in the VINČA Institute. KOMO-TL is a contamination monitor with a GM tube. The GM tube S8, manufactured in the Russian Federation, is used for -radiation recording. The detector window is made of mica which is 14-17 m thick, and the effective area of the GM tube rate meter window is 27 cm$^2$. KOMO-TM is a monitor with a halogen GM tube with a window of 6 cm$^2$ effective area.

The dosimetric system TOL/F LB 132 consists of a central unit and a set of corresponding probe:

(a) The ionizing chamber LB 1321 is cylindric in shape with the active zone of 10 cm in length and 2.6 cm in diameter. The energy range is from 10 keV to 7 MeV. The measuring range is from 0.1 Sv/h to 100 Sv/h. The instrument has been licensed by PTB the German Federal Standard Bureau (Physikalisch-Technische Bundesanstalt).

(b) The LB 1231 probe is a proportional counter meter filled with xenon. The probe window is made of a titanium foil with density of 5 mg/cm$^2$. The count rate meter active area is 210 cm$^2$.

In addition, VICTOREEN 190 SI dosimetric system has 2 probes:

(a) Probe 489-120, with a NaI scintillator (2" 2"), has a window of 108 mg cm$^{-2}$ Al, with a sensitive area of 20 cm$^2$.

(b) Probe 489-110E RP1 has a halogen-quenched pancake GM tube as the detector (window of 15 cm$^2$). Probe detects -radiation above 3.5 MeV, -radiation above 35 keV, and -radiation above 6 keV.

BICRON Analyst is a portable count rate meter with a single channel analyzer and scintillation detector NaI(Tl) (3" 3").

### Radiation survey

Before the work began, the terrain had been secured physically, and the visitor access had been forbidden. A tent with the function of a sanitary-unit and of a place for changing clothes before and after work had been put up, the space had been prepared, and containers for depositing the uranium ammunition and contaminated soil had been placed. The tool and equipment room had been arranged, and the pumps for air sampling during the work had been positioned as well as the fire security systems (fig. 2).

The terrain of the cape Arza was divided into sections so that the detailed record and control of the work performed could be possible. The sections were mostly rectangular in shape, 10 m wide and 10 to 80 m long. Since the terrain was overgrown with dense vegetation which disabled the detailed radiological inspection, a team for clearing the terrain went prior to the others, cutting and carrying away

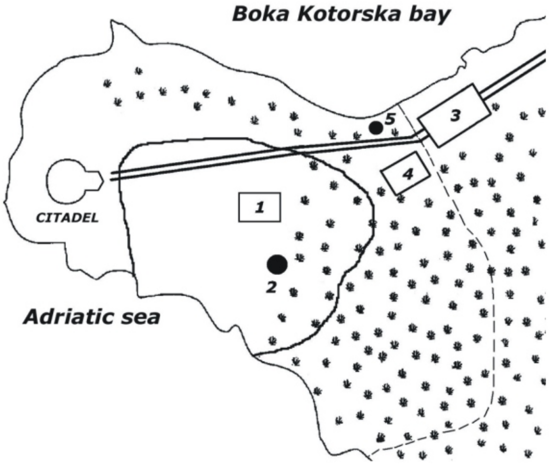


**Figure 2. Map of the cape Arza. Full and dotted lines mark the decontaminated and surveyed areas, respectively; 1 – radioactive material depot, 2 – air sampling pumps, 3 – sanitary passage, 4 – equipment and tool tent, 5 – water pumps**

the bushes. All full-grown trees were trimmed and preserved. In order to avoid the possibility that a section could be omitted or investigated better than the others, during the investigation all sections were divided by rope into transversal paths, each 10 m long and 0.7 m wide. The survey team consisted of 2 to 6 people, depending on the needs of organization, who performed visual investigation of a path first, and then detailed investigation with radiation monitors (fig. 3). Dosimetrists moved in a line, one by the other. The investigation was performed by KOMO-TL devices. During the terrain investigation, the sonde was held up to 5 cm above the ground and moved with the speed of 5-7 cm/s, with the stopping at the contaminated places. Especially long stopping occurred at the places where the signal rate was about or slightly higher than the upper limit of natural radiation. A dosimertist moved along a path with the average speed of 20 m/h. The natural level of radiation at Arza is recorded by KOMO-TL with 2 to 4 $s^{-1}$ at about 5 cm above the ground. At each location where the instrument showed the signal rate higher than 4 $s^{-1}$, a dosimetrist planted a flag, so that the decontamination team could later check whether it was a natural radiation variation or the real contamination by depleted uranium [4].

The checking of those places was performed with TOL/F -sonde, which was the most sensitive instrument at our disposal. The measurings by this instrument on Arza were within the relatively wide range of 15-25 $s^{-1}$, depending on whether the instrument was above the stony terrain, humus, or red soil.

The values of 20-25 $s^{-1}$ measured by this instrument above all types of terrain but the red soil definitely showed the contaminated places; however, if measured above the red soil, they were the result of the extremely high natural content of uranium in it, which could go up to 200 Bq/kg [5]. Not relying only on visual recognition of the type of soil in question, further determination whether the natural radiation or contamination was in question was done by taking away layer by layer of the soil with constant measurement of the signal rate with TOL/F. If the place was contaminated by depleted uranium, the signal rate was increasing with the increasing of depth; if the non-contaminated red soil was in question, the signal rate remained unchanged even after digging the hole of 10 to 20 cm.

## Decontamination method

The clearing was performed manually due to the characteristics of the contamination and the characteristics of the terrain itself. The places determined for decontamination by the investigation team were approached by the decontamination team. Parts of jackets and rocks as well as the contaminated soil were removed (fig. 4). The soil was layered with continuous measuring of contamination until a projectile was

**Figure 3. Survey team at work**

**Figure 4. Decontamination team at work**

**Figure 5. Uranium penetrator on the ground surface**

found [6]. Depending on the form of contamination, places of impact could be divided into several categories:

– *Places with a uranium penetrator on the ground surface*. At those places, intact uranium penetrators or their larger fragments were on the surface of the ground contaminating the surface layer of soil under and around them by oxides or by small uranium particles (fig. 5). Those projectiles and their fragments reached their locations by ricochet. During the investigation, 38 places with intact penetrators and 49 places with penetrator fragments on the surface of the ground were found.

– *A penetrator within the ground*. At those places, the signal rate grew rapidly in the depth of 5-7 cm underneath the surface. At the said depth, or 10-15 cm at the most, a dark gray cylindric aluminum jacket or its parts could be found (fig. 6). At the said depths, a rock or a stone with the visible place of impact of the uranium penetrator could be reached as well. The place of the impact was recognized by crashed stones in the diameter of 3-5 cm and by gray color (the oxide trace of uranium). At the depth of 20-30 cm, penetrator fragments were discovered, while penetrators were found at maximal depths of 100 cm. The immediate surrounding of a penetrator was yellowish, while the penetrator surface was yellow-green.

At those places, on the surface of the terrain around the impact of a penetrator, contamination usually spread within the area of 30-50 cm. There were 204 such places at the cape Arza.

**Figure 6. Aluminum jacket inside the ground**

– *The place of the impact visible, but without a penetrator.* Those places had the appearance and characteristics very similar to the places of the second category, differing in the fact that there was no uranium penetrator but only its minor fragments. In the majority of cases, at those places, the penetrator ricocheted off a rock or a stone under the ground and went up, out of the ground. The traces of uranium oxide indicated that the penetrator had perforated the ground and that a stone diverted its path. The characteristic of those places is a crater of 15-20 cm near the entering hole, presenting the place where the uranium penetrator went out of the ground.

– *A penetrator ricocheted off the ground surface*. This was the rarest case at the cape Arza. In this case, a penetrator with the jacket hit a rock on the surface of the ground and ricocheted off it. The rock surface had visible mechanical damages made by the impact and there were small oxidized uranium penetrator fragments or the oxide traces. At distances of about 15 m from those locations, usually in the direction of the fall of the projectile, there were several locations with surface contamination, sometimes with penetrator fragments or even with the penetrator itself.

## RESULTS OF CLEARING AND FINAL MEASURINGS

During the decontamination, 242 whole uranium penetrators and 49 larger penetrator fragments were removed, which were 75 kg of depleted uranium. There were also found many contaminated aluminum projectile jackets. About 200 kg of contaminated soil with the activity of $10^4$-3.5 $10^6$ Bq/kg and 6 $m^3$ of low active material (soil, pieces of rocks, fallen leaves and needles, *etc.*) were removed as well.

According to the data declared by NATO, the cape Arza was bombed with 300 uranium projectiles, so that about 85% of depleted uranium were found and removed by decontamination. On the basis of the strike direction of the A-10 airplanes and the fact that several penetrators were found in the rocks at the coast, we suppose that a few penetrators ended up at the bottom of the sea. This means that only few uranium penetrators have been left behind the decontamination process at the cape Arza, which is a far better result than the most optimistic one predicted at the beginning of decontamination.

**Table 1. Activities of analyzed soil samples**

| Sample No. | $^{137}$Cs Bq/kg | $^{226}$Ra Bq/kg | $^{238}$U Bq/kg | $^{235}$U Bq/kg |
|---|---|---|---|---|
| 1 | 125.14 | 202.53 | 46.13 | 8.64 |
| 2 | 234.93 | 147.87 | 43.43 | 6.92 |
| 3 | 238.63 | 116.17 | 45.93 | 4.57 |
| 4 | 155.27 | 168.77 | 37.63 | 3.84 |
| 5 | 271.94 | 102.54 | 52.38 | 6.43 |
| 6 | 282.29 | 226.28 | 114.43 | 8.88 |
| 7 | 377.11 | 179.81 | 64.91 | 4.35 |
| 8 | 225.66 | 93.72 | 64.55 | 3.38 |
| 9 | 262.36 | 102.31 | 53.88 | 4.30 |
| 10 | 241.38 | 188.73 | 116.07 | 9.65 |
| 11 | 300.84 | 189.07 | 117.58 | 9.77 |
| 12 | 260.66 | 135.16 | 80.44 | 5.28 |
| 13 | 299.38 | 88.24 | 110.94 | 7.21 |
| 14 | 299.75 | 118.23 | 67.36 | 8.30 |
| 15 | 214.43 | 106.19 | 70.91 | 3.22 |
| 16 | 220.30 | 143.20 | 100.72 | 6.84 |
| 17 | 208.13 | 94.27 | 83.84 | 5.78 |
| 18 | 185.59 | 78.68 | 56.19 | 4.95 |
| 19 | 228.90 | 98.62 | 61.66 | 5.04 |

The area of the clearing of the vegetation and the radiological control was broadening until the zone of about 30 m with no contamination and with no ricocheted penetrator fragments was obtained. The area of 18,000 m$^2$ was investigated and decontaminated. Radiological investigation was also performed outside the area. The detailed investigation of the sandy beach at the cape, which was divided into columns 0.7 m wide, was performed; the rocky coast was investigated visually and, where possible, dosimetrically. The best possible radiological investigation of the rest of the cape was performed as well, so that the whole radiologically investigated area was 45,000 m$^2$, comprising the part of the cape Arza most attractive for tourists.

### Gamma-spectrometric analysis of the ground samples

After the decontamination procedure had been completed, samples of the soil and biological material were taken. Composite soil samples from each section were made and analized to evaluate the successes of the work. A sample is cylindric in shape, 2.5 cm in diameter and 5 cm in length. Apart from that, soil samples from different depths were also taken. Soil samples from the area of 25   25 cm and depths of 0-5 cm, 5-10 cm, and 10-15 cm were taken. Biological material comprised moss and lichen from the ground, lichen from trees, tree bark, pine needles, and vegetation samples taken from above and near the places of impact. All samples were analyzed gamma-spectrometrically. On the basis of the measuring performed up to now, it can be concluded that decontamination has been performed successfully. The results of the measuring of the activities of composite soil samples taken from each section are given in tab. 1. Depleted uranium has been detected only in two samples, but the activities are almost negligible.

The official statment of the UNEP team report for depleted uranium that "the decontaminated area can be considered fit for unrestricted public access" [1], confirms that decontamination at the cape Arza has been performed with high quality.

## ARZA EXPERIENCES AND CONCLUSION

Clearing the contaminated area and organizing the work showed that:

– mutual positions of uranium penetrators and their aluminum jackets did not show any regularity,
– contaminated areas were discovered primarily by measuring   -radiation on the surfaces of the places of the uranium penetrator impact,
– projectiles which penetrated deeper into the ground could be detected with the help of gamma radiation at depths not bigger than 25 cm, and
– the best devices used for detection of contamination were GM count rate meters with the window which were sensitive enough for detection of   -radiation, and robust enough for outdoor measuring.

On the basis of the work done and measuring performed after the completion of decontamination, it has been concluded that:

The use of depleted uranium ammunition causes major contamination of environment.

By clearing of the contaminated areas, it is possible that those areas can be used without any restriction.

## REFERENCES

[1] ***, UNEP, Depleted Uranium in Serbia and Montenegro, Post-conflict Environmental Assessment, UNEP Geneva, 2002

[2] Šipka, V., Radenković, M., Paligorić, D., Djurić, J., Determination of Uranium and Plutonium Isotopes in the Soil and DU Penetrators, *Proceedings*, XXI Yugoslav Radiation Protection Symposium, Kladovo, Yugoslavia, October 10-12, 2001, pp. 69-72

[3] Harley, N. H., Foulkes, E. C., Hilborne, L. H., Hudson, A., Anthony, C. R., A Review of the Scientific Literature as it Pertains to Gulf War Illnesses – Vol. 7 Depleted Uranium, RAND, Washington, 1999

[4] Vukotić, P., Andjelić, T., Zekić, R., Kovačević, M., Vasić, V., Ristić, N., Decontamination of Cape Arza (Montenegro) from Depleted Uranium, *Proceedings*, European IRPA Congress, October 8-11, 2002, Florence, Italy, 132-R

[5] Vukotić, P., Borisov, G. I., Kuzmić, V. V., Kulakov, V. M., Antović, N., Dapčević, S., Mirković, M., Pajović, M., Svrkota, R., Fuštić, B., Djuretić, G., Background Gamma-Radiation in Montenegro, *Proceedings*, IRPA Regional Symposium on Radiation Protection in Neighbouring Countries of Central Europe, September 8-12, 1997, Prague, Czech Republic, pp. 477-479

[6] Andjelić, T., Vukotić, P., Kovačević, M., Zekić, R., Savić, S., Mišurović, A., Types of the Sites of Cape Arza Contaminated with Depleted Uranium and Results od Decsontamination, *Proceedings,* XXII Yugoslav Radiation Protection Symposium, September 29 – October 1, 2003, Petrovac, Serbia and Montenegro, pp. 353-358

**Перко ВУКОТИЋ, Томислав АНЂЕЛИЋ, Ранко ЗЕКИЋ,
Милојко КОВАЧЕВИЋ, Владимир ВАСИЋ, Слободан САВИЋ**

## ДЕКОНТАМИНАЦИЈА РТА АРЗА ОД ОСИРОМАШЕНОГ УРАНИЈУМА

У пролеће 1999. године, у нападу НАТО авиона типа А-10, рт Арза је контаминиран осиромашеним уранијумом. Деконтаминација рта је спроведена током 2001. и 2002. године при чему су уклоњена 242 уранијумска пројектила у целини и 49 већих фрагмената. То је око 85% укупног броја пројектила којима је Арза била контаминирана. У раду су детаљно описани предузети поступци деконтаминације и резултати мерења радиоактивности тла после деконтаминације.