The Consequences of NATO Bombing on the Environment in Serbia

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Abstract. During the air strikes in 1999 NATO used ammunition with depleted uranium (DU) in FRY. It is known that the DU has a long time of semi-disintegration; actually its effect is ever lasting. More than few years after the end of conflict, particles of DU dust can be detected in a soil samples, as well as in some air samples. Also DU was found in the sensitive bio-materials. In this material cytogenetic and clinical laboratory investigations in persons, who lived in Southern Serbia (Vranje) and on the Kosovo have been presented. The changes have been detected in the blood cells and chromosomes. There were not found disorders in the bone marrow. The examinations included general clinical assessment, blood count, ratio percentage of individual leukocyte line elements, morphological changes of the blood cells in the stained capillary smears observed under microscope, leukocyte enzyme activity. Incidence of the chromosomal aberrations in our series evidenced the results characteristic for individuals occupationally exposed to ionizing irradiation for the prolonged period of the time. The difference in number of aberrations and aberrant cells in the exposed and unexposed subjects is statistically significant. Future environmental investigations are needed, as well as awareness-raising for the local population and other risk groups. The contamination should be prevented by clean up of DU particles and stop its entry into the food chain. The population of the contaminated regions should be subjected to annual screenings according to the program of the targeted examination aimed at detection of internal contamination in order to enable early diagnosis and treatment of the diseases. The particular attention should be paid to children and pregnant women, due to their increased radio-sensitivity.

1. Introduction

NATO bombing of the FRY from March 24 to June 10, 1999, caused environmental degradation with immediately regionally and long terms locally consequences. Large quantities of substances with cancerogenic, allergenic, terratogenic, mutagenic, toxic and other dangerous characteristics with negative consequences on people, plants and animals were emitted into the environment. Cumulative and synergetic effects of different kind of pollutants are especially danger. This paper will be focused on the consequences of using of depleted uranium (DU) ammunition on the environment and human health in Serbia caused by NETO bombing.

2. Depleted uranium (DU) environmental assessments

During the air strikes NATO used ammunition with DU at more than 112 locations, dominantly on the Kosovo and Metohija Provinces, five locations few times in Southern Serbia and one location in Montenegro. Scientists and state authorities of FR Yugoslavia many times have informed public and international community about using of DU ammunitions and their consequences on the environment and human health.

United Nations Environment Program (UNEP), Balkan Task Force in October 1999 has reached the conclusions related DU findings of preliminary fact-finding mission:

- Lack of official information from NATO confirming that DU was or was not used during the Kosovo conflict distorted the prerequisites for the group's work.

- With the given conditions and assumptions, the significant risks are restricted to a limited area around the target. If the DU is dispersed to larger areas, the corresponding risks are reduced.
- If contaminated vehicles and apparent accumulations of uranium pieces and dust are removed from the target area, the possible risks of significant exposures are related to a few specific circumstances that could be avoided by provision of adequate information and instruction.
- The possible contamination of land from DU is not an obstacle to moving back to those villages and regions that were affected by attacks and at which DU ammunition may have been used, providing that certain recommendations are taken into account.
- During and immediately after any attack where DU was used, some people in the immediate vicinity may have been heavily exposed to DU by inhalation. The extent to this possible problem might be verified by special health examinations. This is applicable also to potentially affected individuals who are no longer in the area.
- The results of these analyses are general in nature and, therefore. Applicable not only to Kosovo but also to other areas targeted during the conflict.
- A more thorough review is required of the health effects of medium – and long-term exposure to DU (1).

Based on the scientific assertions Yugoslavian authorities in February 2000 concluded next:

- During air strikes by NATO forces on targets in FR Yugoslavia, a special type of 30 mm DU ammunition was used that was fired by guns on A-10A aircraft, which is a crime against humanity sanctioned by international military law.
- The core of these arms is of DU 238 and as such is radioactive waste. Owing type of weapon is made of radioactive waste. Owing to the presence of radioactivity, it is considered a radiological weapon and its use for purposes of warfare cannot be justified for reasons of either a military or political nature. Arguments can be put forward to support the claim that the primary goal of using such arms was to reduce stocks of hazardous radioactive waste that are expensive to store and safeguard.
- The effects of using DU are fatal for military personnel and the civilian population since they cause long-term genetic and carcinogenic changes owing to radioactive contamination. Contact with fragments of projectiles by inexperienced persons, owing to the presence of radioactivity, causes visible changes to the skin that appear in less than 80 hours.
- According to international standards and our own, uranium-238 belongs to the second group of radionuclides that have very high radioactivity and toxicity, and its use in weapons against military and civilian infrastructures and facilities is absolutely inhuman owing to both the momentary effects, and particularly the long-term contamination that is practically unlimited (2).

In November 2000 UNEP organized the DU Assessment Mission in Kosovo and Metohia. Results of that mission were made public in April 2001. On the and of October and beginning of November 2001 UNEP organized the DU Assessment Mission on the South of Serbia and Cape Arza in Montenegro. Report was published in March 2002. UNEP conduct similar DU assessment in Bosnia and Herzegovina in October 2002. DU Report was published in March 2002. In the mentioned report findings from the Kosovo and Serbia/Montenegro missions shortly have been summarized[1]:

- In Kosovo, the mission did not find any widespread contamination of the soil or ground surface, though some localized points of contamination were identified at some of the sites where the use of DU had been reported. The major part of ground contamination was found in the upper 10-20 cm directly below a penetrator. No DU contamination of water or domesticated cow mil was found during the mission and subsequent laboratory testing, and there was no evidence to suggest any immediate health problems. However, it was concluded that there could be future risk of DU contamination of groundwater. Analyses of bio-indicators (i.e. lichen, bark, moss and grass) at four sites indicated that DU had been used at these sites, but did not uncover any conclusions about aerosolisation of DU or airborne contamination.
- In the subsequent Serbia and Montenegro mission, all the sites investigated had previously been visited, cleaned, fenced-off and assessed by the FRY authorities. This had not been the case in Kosovo. UNEP could not find any significant contamination of the ground surface or the soil except at localized points of concentrated contamination. Nine penetrators and 13 contamination points were identified. The penetrators were removed and the contamination points marked for later decontamination by the FRY authorities. However, laboratory analyses of soil samples enabled contamination to be detected several meters from contamination points. DU contamination was found in some soil samples within the fenced areas (i.e. the target areas). With the exception of Cape Arza, none of the soil samples collected outside the fenced areas showed any DU contamination. Thus, there was no indication that DU had spread outside the fenced areas or over a large distance. Importantly, however, the

[1] All three DU missions were donated by the Swiss Agency for Development and Cooperation.

contamination levels inside the fenced areas were of such a low level that they were considered insignificant from the human health point of view.

- In terms of groundwater contamination arising either from DU at contamination points or from more widespread ground contamination, the possible consequences in Serbia and Montenegro were insignificant. The general conclusion for the five sites investigated in Serbia was that there was no remaining on the surface in the areas that were searched by UNEP. However, at some sites there were indications that penetrators (and contamination points) were present outside the searched areas and might be present outside the areas fenced-off by the FRY authorities in Serbia. There were good reasons for believing that most of the DU rounds fired against targets at the investigated sites did not fragment, but instead entered the ground more or less intact. In this case, the buried penetrators constitute a source of uranium that might, in the future, influence the concentration of uranium in drinking water. During the mission and subsequent laboratory testing, there was no detectable DU in any of the water samples.
- Two of the sites showed a clear indication of DU in the air sampled. However, digging for penetrators was undertaken at the same time as the operation of the filters used for air sampling, making it difficult to find an unequivocal explanation for this finding.
- As was found in the 2000 Kosovo mission, lichen appeared to be a reliable indicator of air-borne DU contamination. Of the lichen samples taken in Serbia and Montenegro, only those obtained from four sites showed any significant indication of DU (3, 4, and 5).

Four new and significant findings are contained within the UNEP report - Depleted Uranium in Bosnia and Herzegovina – Post-Conflict Environmental Assessment:

- First, detailed laboratory analyses of surface soil samples revealed low levels of localized ground contamination. At most, local ground contamination could be detected around contamination points at distances below 200 meters, but usually much closer. None of the sites showed widespread contamination, meaning a contamination over large surface in the range of a couple of hundred meters. Ground surface DU contamination detectable by portable beta and gamma radiation detectors was typically limited to areas within 1-2 meters of penetrators and localized points of contamination caused by a penetrator impact.
- Second, penetrators buried near the ground surface and recovered by UNEP had decreased in mass by approximately 25 % over 7 years. Based on this finding, correlated with those penetrators studied in UNEP's earlier studies, a DU penetrator can be fully oxidized to corrosion products (e.g. uranium oxides and carbonates) in 25 to 35 years after impact. Following time period, no more penetrators – metallic DU – will be found buried in the Balkans soil. In contrast, penetrators lying on the ground surface showed significantly lower corrosion rates.
- Third, for the first time, DU contamination of drinking water could be found at one site. DU could be clearly identified in one drinking water sample. A second drinking water sample from well also showed traces of DU. But was detectable only through the use of mass spectrometric measurements. Contamination of the well water may be due to the fact that the well is positioned in what would have been the line of attack by planes. The concentrations are very low and the corresponding radiation doses are insignificant for any health risk. This is also true considering the toxicity of uranium as a heavy metal. However, because the mechanism that governs the contamination of water in a given environment is not known in detail, it is recommended that water sampling and measurements should continue for several years, and that an alternative water source should be used if DU is found in the drinking water.
- Finally, the presence of DU in air was found at two sites, including air and certain surface contamination inside two buildings at two different sites. Resuspension of DU particles due to wind and/or human activities from sources such as contamination points, corroded penetrators or fragments laying on the surface are the most likely cause. The concentrations were very low and resulting radiation doses are minor and insignificant. However, as some of these buildings are currently under use by the civil population or by military, UNEP considers exposure to such a source unnecessary. Therefore, Precautionary decontamination and clean-up steps for these buildings are recommended (5).

Depleted uranium (DU) human health impacts

The question on environmental and health impacts originated from the use of DU ammunition has, after several conflicts, become a much debated issue. Since there has been very little scientific fieldwork with proper measurements as well as laboratory work outside of the military community, until recently it has been difficult to come t any significant conclusions (5).

DU is a by-product from the process used to enrich natural uranium ore for use as fuel in nuclear reactors and nuclear weapons. It is distinguished from natural uranium by differing concentrations of certain uranium isotopes. DU is an unstable, radioactive heavy metal that emits ionizing radiation of three types: alpha, beta and gamma. Because of its radioactivity, the amount of uranium in a given sample decreases continuously but the so-called “half-life” (the period required for the amount of uranium to be reduced by 50 per cent) is very long, 4.5 billion years in the case of the isotope uranium-238 (U-238 or ^{238}U). Therefore, the level of radioactivity does not change significantly over human lifetimes (5).

DU is toxic for humans and animals. Although it is considered less radioactive than natural uranium, its toxicity is high due to high linear energetic transfer (LET) irradiation, tissue deposition (bones, kidneys, blood, lungs) and elimination time (5,000 days). Radiation limit depends on the quantity and contamination time, including also other factors, such as age, sex, previous health status, exposure to other materials, genetic predisposition and radio-sensitivity, diet and stress (6). Each upper radioactive doses than natural can produce biological effect. Biomarkers of effects and radio sensitivity are blood cells, especially lymphocytes and chromosomes (7, 8). Identified initial effects of DU on sensitive tissues can be used like biomarkers for early disclosure of possible disease as well as for recommendation of appropriate therapy.

Subjects and Methods

Chromosome aberration analyses have been performed from 1999 until 2002 on two referent population groups (RP1 and RP2), as control, and the tested populations (TP) from selected regions that were contaminated by DU during the Kosovo conflict.

The first control group (Referent population RP1) included 33 residents of the central Serbia (Belgrade, Valjevo and Niš) exposed by natural level of radiation only. Special control group (Referent population RP2) had been compound by 46 workers occupationally exposed to X-ray (Referent population RP2) with damaged cells containing chromosomal aberrations and lesions due to absorbed dose range 1.45-19.82 mGy (or mSv), in average 7.90 ± 4.95 mSv, measurement by thermo-luminescent personal dosimeter (TLD).

Tested population (TP) comprised a selected sample of the residents from DU contaminated regions: on the south of Serbia, in vicinity of Vranje and Bujanovac (Pljačkovica, Pržar, Borovac, Bratoselce; Group 1 – N = 29); one enclave in Kosovo (Štrpce; Group 2 – N = 21); and TV technical workers from Pljačkovica and Pržar (vicinity of Vranje; Group 3 – N = 19.

The environmental investigation included measurement of environmental radioactivity in south and central Serbia during 2001 and 2002 in the following areas: Belgrade, Valjevo, Niš, Vranje, Bujanovac, Pljačkovica, Borovac, and Bratoselce. The measurements have performed samples of air, soil, ground, plants (grass, lichen, moss, and rose hip), drinking water, dairy products and other food products that are characteristic for nourishment of the population in the regions.

The methods of measurement have been. The strength of the absorbed airborne gamma irradiation dose was measured, as well as total alpha and beta activities and specific gamma activity in water, specific radionuclide activity in samples of soil, plants and food products, using gamma spectrometry and alpha spectrometry. Food radioactivity produced and consumed from the village households from the region of Vranje and Bujanovac was specially analyzed.

Examined subjects from the region of Vranje - Bujanovac and Valjevo (control) have been underwent to the following radioactivity analyses: Gamma-spectrometric evaluation of 24-hour urine for the presence of natural uranium and K-40 and artificial radio nuclides (Cs-137; J-131) in Bq per liter of urine (9, 10); Alpha-spectrometric analysis of the total urine content and activity ratios of the present uranium isotopes, in mass units, i.e., in activity units per liter of urine (11).

The examinations included: general clinical assessment; complete blood count; ratio-percentage of individual leukocyte line elements; morphological changes of the blood cells in the stained (Giemsa) capillary smears observed under microscope; presence of immature forms or blasts (12) and leukocyte_enzyme activity (alkaline phosphatase – APL) using modified Koplow cytochemical methods (13). Lymphocytes were particularly assessed, with respect to their absolute number, percentage of the stimulated lymphocytes, the so-called large lymphocytes, and particularly their karyotype and its chromosomal aberrations.

Chromosomal alterations have been observed in metaphase on 200 mitoses, in lymphocytes of peripheral blood, by microscopic examination of the stained preparations under immersion (14, 15). Total number, frequents chromosomal aberrations (dicentrics, acentrics, rings), chromosomal lesions (chromatid breaks, chromatid exchanges), damaged cells (cells containing aberrations and lesions), and rogue cells (multi-damaged cells) have been investigated (16, 17).

With aim to use parametric analytical methods, the distribution analyses of the observed variables have been performed by Kolmogorov-Smirnov congruence test. For the results analysis Student's t-test has been used for parametric data, and Mann-Whitney's test of the rank sums for comparison of differences between two groups of non-parametric data per one characteristic. For the test of significant diferences of chromosomal aberations frequencies Poisson's regression model with logarithmic link function, with the confidence of 99 % , has been used.

Student's T-test has been used for processing of the clinical laboratory results, and Mann - Whitneyev test to analyze chromosome aberrations. For sum rank comparison non-parametric tests have been used (Weall – Coxon, Kruskal Wallis, and Fischer). For assessment analyzes more characteristics parameter or non-parameter analyze of variant quotient by Kruskal – Wallis and Fisher. Testing hypothesis was that all population groups are identical, using Poisson regression. This statistical analyzes have been based on Wilcoxon rank sum test. The significance was $p<0.01$ for testing the null hypothesis, that gives confidence of 99%. Parameter estimates and confidence intervals for Poisson distribution (alpha = 0.01).

Results

Mean annual value of the absorbed airborne gamma irradiation dose in Serbia (including south region) is 0.09 micro Gy/h. Gamma-spectrometric analysis of the composite air samples shows presence of low levels of natural radio-nuclides, while cesium 137 activities is below limit of detection. Presence of uranium was evidenced in two samples of air, obtained immediately above the ground in the Vranje region.

In the Vranje region, in addition to natural radio-nuclides, radio-cesium 137 had been found in the soil samples, with its concentration widely ranging from 0.9 – 68 Bq/kg, depending on sampling site, however the values were within those evidenced in other regions of Serbia as a consequence of the Chernobyl accident and prolonged half life. Uranium 235 and 238 isotopes had been found, as well as their imbalance in favor of the DU 238. Presence of uranium, which is its isotopes as natural radio-nuclides, when its ratio is approximately 1, is normal. However, values exceeding 200,000 Bq were evidenced in several samples obtained in the south region. Contamination of the soil has been found, as well as plants contamination (Table 1). Values between 100 and 200 and even above 3,000 Bq had been found in certain plant. It means that transfers of the DU from the soil into the plants has taken the process, and indicate risk of its entrance into food chain. It was also influenced by natural characteristics of the terrain, moist and abundance of ground waters, resulting in corrosion of ammunition and consequential release of DU, its solubility and absorption. In 2002 activity had been considerably low at the same locations, and it can point out movement (or overflowing) of contamination. Uranium isotope values determined in different samples of drinking water, dairy products and other foods were minimal, increased levels of DU have not been detected (Table 1).

Gamma-spectrometric urine analysis (Table 2) evidenced radio cesium 137 and radio iodine 131 below 1Bq/liter, while alpha-spectrometric analysis evidenced proportion changes between uranium 235 and uranium 238 in 3 cases (0.16, 0.21 and 0.76, respectively).

Clinical examinations of all subjects did not reveal any chronic disease associated with influence of ionizing irradiation. Difference of the mean values of blood element counts between the studied groups was not significant. Capillary smears obtained from the residents of the contaminated regions were characteristic (Table 3).

Toxic granulations in the neutrophilic granulocytes, nuclear segmentation disorders, karyorrhexis, stimulated – large lymphocytes and virocytes were present. Nuclear and cyto-plasmatic changes (toxic granulations) have been evidenced in 85% subjects from Kosovo, as well as in 62% subjects from Vranje, while only in 15% subjects from Pljačkovica. As for the control group, toxic granulations in the cytoplasm have been evidenced in 15 % of subjects. The most noticeable nuclear changes have been evident in the Kosovo group, while lymphocytes and virocytes had been presented between 10 to 50 % in both groups (Bujanovac, Štrpci). These morphological changes almost have not been evident at the other subjects. Alkaline phosphatase activity score in the granulocytes was 35 IU (International Units), while in the control group it was 56 IU (significant difference for $p<0.05$; Kruscal-Walis test).

In 10 subjects from south region APL – score was below the lower limit of 20 IU. There was not significant difference between subjects from Kosovo and those from Vranje. In none of the cases APL was inhibited i.e. 0 IU. Leukemia blasts were not observed (Table 3). Development of large stimulated Ly was present in the smear up to 50% (usually up to 10%). Virocytes – large monocytes with a nucleolus and monocytes with large fused granules and vacuoles was present in the smear up to 50 %. Morphological changes of the immunocytic line (lymphocytes and monocytes) were found in every other subject from Kosovo and from the region of Vranje (toward 12% in control group), but in the TV workers on the Pljačkovica (Group 3) have not been found (Table 3). Basophilic granulocytes have been found in 100 elements in the smear in several sporadic cases from the Štrbce, while increased percentage of eosinophiles had been found in 2 subjects from the region of Vranje (Table 4). This data are not significant. In the investigated group of workers on Pljačkovica increased percent of neutrophilic granulocytes and monocytes have been found as well as monocytes with occurrence of younger precursors, while percent of lymphocytes had been reduced.

Chromosomal aberrations as dicentrics, acentrics and rings are aberration typical for ionizing irradiation effects, infrequently found in general population. Professionally exposed workers have had on 9,200 cells 145 aberrations, and frequency average was 0.016 (1.6%), significantly more than in all investigated groups ($p<0.05$). It was evident linear correlation of the chromosomal aberrations frequency with showed doses on the personal dosimeter (coefficient of correlation 0.39; $p<0.01$). Additional variables, as age, sex, working period, smoking, had no impacts (variance analyze “ANOVA” $p<0.01$). Non-characteristic changes, such as chromosomal lesions (chromatid breaks, chromatid exchanges) have been found in both exposed and unexposed subjects, and they may be the result of other causes of lower mutagenic potentials (toxins, viruses, infections, and smoking). Lesions frequency in the professional exposed group was 0.015 or 1.5 %. There was not significant difference regarding to the investigated group of the south of Serbia (Vranje-Bujanovac), while it was significantly higher than other investigated groups from the south and central Serbia (Table 5).

Multi-damaged cells, rogue cells, have been the most evident in first investigated group on the south of Serbia and they have the biggest incidence, one rogue cells on 566.6 all cells (Table 5). In the control investigated group from central Serbia they did not found. Because of small X-rays doses incidence was 1 in 4,600. Multi-factorial variance analyze has shoved that investigated variable (age, sex, smoking, duration of exposure) had not significant impact in any of five groups (p>0.01).

Logarithm function of Poisson regression (confidence 99 %) has showed that group 2 (Kosovo) and 3 (Pljačkovica) on the south of Serbia and control group from central Serbia have been identical. It means that aberrations frequency risk is similar in the interval 0-1 on 200 cells. Group 1 from the region Vranje-Bujanovac has increased frequency risk, in the interval 1-2 chromosomal aberrations per 200 cells. Group is not statistically equivalent with control group. The biggest risk for aberrations occurrence have professionally exposed workers (3 aberrations per 200 cells). Although the logarithm function forms of the aberrations frequency was similar, group 1 and group of professionally exposed workers have not been identical. Investigated persons from the regions Vranje and Bujanovac have had bigger frequency of chromosomal changes than investigated persons from other regions, but significantly less than workers exposed to X-rays.

Discussion

Uranium 238 in the soil, plants and sporadically even in urine of certain individuals, from the region Vranje-Bujanovac (Bratoselce) have been evidenced. Radioactive contamination level was low, within the small dose range, incapable to produce evident clinical picture of the irradiation disease. The risk of the continuous effects of the low doses includes accelerated ageing and greater probability of development of mutations that may be cause of certain diseases or malformations, leading to reduced life expectancy of the population in the contaminated region.

DU chemical toxicity and radioactivity in a professional exposition cause kidney damage, lung and bones cancer, and damages of radiosensitive tissues. It is possible to conclude that DU can cause leukemia and lymphoma, as well as secondary myelodysplastic syndrome what precede cytogenetic anomaly karyotipe haematopoiesis cells, long time period without characteristic deviations in a peripheral blood. Also kidney damages, spermatogenesis, as well as extrapyramidal and behavior zones of the brain (18, 19, 20, 21).

Denaturation of the leukocytic lysosomes (toxic granulation) leading to APL inhibition may be a consequence of ionizing irradiation effects, or other toxic materials (chemicals, heavy metals, etc). Nuclear segmentation disorders are indicative of bone marrow lesions. Concomitant nuclear and cytoplasm lesions may suggest maturation disorders leading to haematopoiesis insufficiency regardless of its cause. Cells with more types of characteristic aberrations are called multi-aberrant cells or rogue cells. Increased frequency of aberrations, lesions, damaged cells, multi damaged cells – rogue cells, under the impacts of small doses of radiation, had been found at the professionally exposed workers. It is visible increased incidence rogue cells to the workers in the region of Vranje and Bujanovac.

According to examination results, DU did not reach the food chain, but it has been on the surface of the soi. In a case of long time stay in contaminated regions it can be taken in a body by inhalation, or through the skin and gastrointestinal system (22, 23). Exposition to low level dose over three years can cause cumulative biological effects, damaged DNA, and haematopoietic cells (24).

Conclusions

One examined group from DU contaminated region had certain changes in blood cells, mainly morphological, in cytoplasm, nucleus and chromosomes. Some samples of urine of mentioned group were contaminated with DU. However, comparison of the examined group and group of X-rays workers, point out that examined persons in the DU contaminated regions have had certain risk of cells damages, but it is not bigger than risk of the persons from the group of X-rays workers. Direct influences on human health have not been expected, but subsequent consequences can not be excluded. This is reason why longer and bigger scientific investigation should be necessary.

REFERENCES

1. United Nations Environment Program / United Nations Centre for Human Settlements (Habitat), *The Kosovo Conflict – Consequences for the Environment & Human Settlements.* First published in Switzerland by UNEP/UNCHS, p. 62-63, (1999).
2. Federal Ministry for Development, Science and the Environment, *FR Yugoslavia Report – The Consequences of NATO bombing for the Environment in FR Yugoslavia*. Belgrade, (2000).
3. United Nations Environment Program, *Depleted Uranium in Kosovo – Post Conflict Environmental Assessment*, First published in Switzerland by the UNEP, (2001).
4. United Nations Environment Program, *Depleted Uranium in Serbia and Montengro – Post Conflict Environmental Assessment*, First published in Switzerland by the UNEP, (2002).
5. United Nations Environment Program, *Depleted Uranium in Bosnia and Herzegovina – Post Conflict Environmental Assessment*, First published in Switzerland by the UNEP, (2003).
6. Duraković, A., *Medical effects of internal contamination with uranium.* CMJ, 40 (1), 1-18, (1999). (www.mefst.hr/cmj/1999.htm).
7. Timbrell, J.A., *Introduction to toxicology*. 3rd ed. London: Taylor Francis, (2001).
8. Harvey, L., Berk A., Zipursky, S.L., Matsudaira, P., Baltimore, and D., Darnell, J., *Molecular cell biology*. 4th ed. USA: W. H. Freeman and Company, Media Connected, (2001).
9. Muck, K., Roth, K., Gerzabek, M.H., and Oberlander, H.E. *Effective half-lives of I- and Cs-isotopes in grassland shortly after fallout.* J. Environ. Radioactivity, 24, 127-143, (1994).
10. Milačić, S., Jovičić, D., and Kovačević, R., *Cytogenetic and clinical laboratory investigation of participants in the decontamination of depleted uranium- contaminated terrain in Serbia and Montenegro.* Central European Journal of Occupational and Environmental Medicine, 8 (4), 270-276, (2003).
11. ICRP *Uranium in: Individual monitoring for intakes of radionuclides by workers: desingua and interpretation.* Annals of the ICRP, l9 (3), 141-154, (1996).
12. Milačić, S., and Panov, D., *Influence of small doses of ionizing radiations on haematopoiesis in conditions of occupational exposure.* Series symposia, Radiation Protection, advances in Yugoslavia and Italy, Udine, Italy, June 22-24, 1988, 79-82, (1988).
13. Milačić, S., and Minić, M. *The importance of leukocytes cytochemical analyses for evaluation of the ionogenic irradiation effects in occupationally exposed persons - Radiation protection selected topics.* Paper presented at Int. Symposium, Dubrovnik, 2-6 October 1989, 198-201, (1989).
14. Moorchead, P.S., *Chromosome preparation of leukocytes cultured from human peripheral blood.* Exp Cell Res. 20, 613-616, (1960).
15. Rozgaj, R., Kašuba, V., and Šimić, D. *The frequency of dicentrics and acentrics and the incidence of rogue cells in radiation workers.* Mutagenesis, 17 (2), 135-139, (2002).
16. Rozgaj, R., Kašuba, V., and Peric, M. *Chromosome Aberrations in Operating Room Personnel.* American Journal of Industrial Medicine, 35, 642-646, (1999).

17. Pfeiffer, P., Goedecke, W., and Obe, G. *Mechanisms of DNA double-strand break repair and their potential to induce chromosomal aberrations.* Mutagenesis, l5 (4), 289-302, (2000).
18. Hu, Q.Y., Zhu, S., *Detection of DNA damage in spermatogenic stages of mice treated with enriched uranyl fluoride by alkaline elution.* Radiat Environ Biophysics, 29, 161-167,(1990).
19. ICRP *Genetic susceptibility to cancer.* Publication 79, Annals of the ICRP, 28 (1-2), 1-157, (1999).
20. Cedervall, B., *Technical and medical aspects of the use of depleted uranium in the Kosovo conflict.* Rapport T-SEKT 06/2001. Swed Power, 1-9, (2001).
21. Cedervall, B., Edgren, M., and Lewensohn R., *X-ray induced DNA double strand breaks in mouse L1210 cells.* Radiation Res. 159, 495-501, (2003).
22. IAEA, *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environments*, Technical Reports Series No. 364, (1994).
23. ICRP, *Uranium in: Individual monitoring for intakes of radionuclides by workers: desingua and interpretation.* Annals of the ICRP, l9 (3), 141-15,4 (1996).
24. Wones, R., *Do persons living near a uranium processing site have evidence of increased somatic cells gene mutations - A First Study.* Mut Res Environ Mutagen. Related Subjects, 335 (2), 171-184, (1995).

TABLES:

Table I. Radio-activity (range) at 2 contaminated sites in south of Serbia

Type samples	Year 2001 (Bq/kg; Bq/l)				Year 2002 (Bq/kg; Bq/l)			
	Pljačkovica (Vranje)		Bratoselce (Bujanovac)		Pljačkovica (Vranje)		Bratoselce (Bujanovac)	
	U-238	U-235	U-238	U-235	U-238	U-235	U-238	U235
Soil	69-14958	2,3-119	148-182	4,9-5,7	70-149	3.7-4,9	157-336	5,6-13,2
Ground	32-216700	4-1700	148-21556	4,9-210	70-2272	3,7-20	96-296	2,8-10,5
Plants	109-3467	2,7-38	102-834	4,7-27	16-48	0,7-4	10,5-102	0,7-7,4
Drinking water	<0,11	<0,006	<0,05	<0,003	<0,08	<0,07	<0,03	<0,003
Dairy products	<1,7	<0,06	<0,35	<0,09	<1,3	<0,07	<2,8	<0,16
Vegetables, fruits, meat	<1	<0,01	<1	<0,01	<1	<0,01	<1	<0,01

Table II. Radioactivity at urine of the persons living in Serbia 1999-2002

Urine- Samples	Number Of samples	By alpha-spectrometric (range)		By gamma-spectrometric (average)	
		U-238 (mBq/l)	U-238/U-235	Cs-137 (Bq/l)	J-131 (Bq/l)
Samples from contaminated area	22				
Contaminated urine-samples	3	1-30,4	0,16-0,76	<0,80	<0,63
Non contaminated urine-samples	19	0,5-1,81	1,01-1,45	<0,90	<0,67
Samples from non contaminated area	20				
Control group	20	below det.	below det.	<0,60	<0,52

Table III. Clinical laboratory investigation of capillary blood smears of persons living on the contaminated and non contaminated area

Area	Number of persons	Morphological changes				APL (IU)		Blast cells
		Toxic granulation No. (%)	Karyorrhexis No. (%)	Large Ly No. (%)	Virocytes No. (%)	<20 No.	>80 No.	No.
Contaminated area suth of Serbia								
Bujanovac – Vranje	29	18 (62)	6 (20)	17 (58)	3 (10)	6	6	0
Kosovo – Strpci	21	18 (85)	9 (42)	11 (51)	2 (9)	4	3	0
Pljackovica – Przar	19	3 (15)	2 (10)	0	0	0	0	0
Non-contaminated area central of Serbia								
Belgrade-Valjevo (CG)	33	5 (15)	1 (3)	4 (12)	0	0	0	0

APL (IU) = leukocytes alkaline phosphatases (international units)
CG = control group

Table IV. Clinical laboratory investigation white blood cells of the persons living on the contaminated and non contaminated area

Area	**No. of persons**	**Differential count (%)**						**Number of persons**				
		NG	**Ly**	**Mo**	**Eo**	**Bs**	**Y**	**NG <50%**	**Ly,Mo >50%**	**Ly <30%**	**Mo >6%**	**Eo >6%**
Contaminated area South Serbia												
Bujanovac – Vranje	29	56	35	5	4	0	0	4	1	1	6	2
Kosovo – Strpci	21	54	40	3	2	1	0	1	1	0	0	0
Pljackovica – Przar	19	60	32	6	1	0	1	19	0	12	6	0
Non-contaminated area Central Serbia												
Belgrade-Valjevo(CG)	33	54	39	4	3	0	0	0	0	0	0	0

NG = neutrophilic granulocytes
Ly = lymphocytes
Mo = monocytes
Eo = eosinophilic granulocytes
Bs = basophilic granulocytes
Y = young cells (immature cells)
Differential count (%) = number of white blood cells on 100 counted in the blood smears
CG = control group

Table V. Cytogenetic analysis in the lymphocytes of the differenced group from south and central Serbia

Region	No. of persons	With CA	With CL	TCI	DC	RC and incidence	Total CA	Frequents CA (%)	Total CL	Frequents CL
Contaminated area south Serbia										
Bujanovac-Vranje	29	16	28	5100	44	9 1/566,6	39	0.007 (0.7%)	76	0.014
Kosovo-Strbci	21	5	6	4200	13	4 1/1050	14	0,003 (0.3%)	10	0.002
Pljackovica-Przar	19	6	0	3800	7	1 1/3800	8	0.002 (0.2%)	0	0
Non-contaminated area central Serbia										
Control group	33	6	15	6600	24	0	6	0.0008 (0.08%)	18	0.002
Occupational exposed workers	46	46	30	9200	15 2	2 1/4600	145	0.016 (1.6%)	145	0.015

CA - Chromosomal aberrations = dicentrics, rings, acentrics
CL - Chromosomal lesions = chromatid breaks, chromatid exchanges
TCI- Total cells investigated
DC - Damaged cells = Cells containing aberrations and lesions
RC - Rogue cells = Multi-damaged cells

Table VI. Frequency chromosomal aberrations of the differenced group (age, sex, smoking) from south Serbia

Predictors	**Group 1 No. (Fr.CA)**	**Group 2 No. (Fr.CA)**	**Group 3 No. (Fr.CA)**	**Control group No. (Fr.CA)**
Age (year)				
18-39	17 (0.006)	0	2 (0)	27 (0.0007)
40-70	12 (0.010)	21 (0.003)	17 (0.002)	6 (0.0016)
Sex				
Female	12 (0.010)	0	1 (0)	13 (0.0004)
Male	17 (0.006)	21 (0.003)	18 (0.002)	20 (0.0125)
Smoking				
Smokers	18 (0.010)	12 (0.001)	8 (0.0006)	14 (0.0010)
Non-smokers	11 (0.008)	9 (0.005)	11 0.0031	19 (0.0008)

Group 1 = Bujanovac-Vranje
Group 2 = Kosovo-Srbci
Group 3 = Pljackovica-Przar
Fr.CA = Frequency chromosomal aberrations