# YUGOSLAVIA'S NUCLEAR LEGACY: SHOULD WE WORRY?

**by Andrew Koch**

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Recent problems at a relatively unknown nuclear research institute in the former Yugoslavia highlight the myriad of security and environmental concerns associated with nuclear facilities in economically and politically troubled states. A series of articles published by the industry journal *NuclearFuel* have raised safety and nonproliferation concerns about the Vinca Institute of Nuclear Sciences near Belgrade, Serbia.[1] The articles list Vinca's problems storing nuclear waste and providing physical security for its fissile material, and allege that Yugoslavia had a nuclear weapons program under former President Jozef Broz Tito. Although the articles may overstate the nonproliferation aspects of the Yugoslav program, they help focus public attention on a potentially serious environmental problem. This report seeks to explain the Yugoslav nuclear program's current troubles and to chronicle its past.

## HISTORICAL SUMMARY

Yugoslavia's nuclear program had its origins in the period immediately following the Second World War. The country's first nuclear research center, the Vinca Institute of Nuclear Sciences, was established 12 kilometers (km) from Belgrade in 1948. The Jozef Stefan Institute, a nuclear physics research-and-development center in Ljubljana, Slovenia, was founded soon after; construction of the institute was completed in 1954.[2] The Rudjer Boskovic Institute, the last of three institutes and their affiliated laboratories that formed the core of Tito's nuclear program, was established in 1950 in Zagreb, Croatia.[3] Subsequent Yugoslav nuclear-related research-and-development facilities included: the Institute for Application of Nuclear Energy in Agriculture, Veterinary Science, and Forestry in Zemun (1959); the Research Development Center for Thermotechnics and Nuclear Technology in Sarajevo (1961); the Institute for Geological and Mining Investigation and Exploration of Nuclear and Other Raw Materials (responsible for uranium exploration); the Energoinvest Research and Development Center for Heat and Nuclear Engineering; the International School of Elementary Particle Physics; and the Dr. Drogomir Karajovic Institute of Occupational and Radiological Health in Belgrade.[4] Yugoslavia also built several nuclear fuel cycle facilities, culminating in the completion of the Krsko nuclear power plant in 1983.[5] At the height of its nuclear program, Yugoslavia had an estimated 1,300 to 2,000 engineers and scientists and 600 to 1,000 technicians working in the nuclear field.[6]

Tito's government is suspected of having attempted to acquire the capability to build nuclear weapons. As early as 1954, Yugoslav scientists were aware of, and concerned about, Tito's intentions with regard to nuclear weapons. Stevan Dedijer, the head of Vinca from 1952 to 1955, was critical of Tito's unofficial objectives for the institute, namely to produce a Yugoslav nuclear weapon.[7] This view was reinforced by a January 23, 1954 report from the U.S. Army attaché in Athens, Greece,

which explicitly said that, "the Yugoslavs have commenced a program to produce atomic weapons."[8] The program was allegedly supervised by the Yugoslav Federal Nuclear Energy Commission, established in 1955 under the leadership of Aleksandr Rankovic.[9] Rankovic, as Secretary for the Secretariat of Internal Affairs, was also head of the Yugoslav secret police.[10]

Yugoslav scientists investigated both uranium enrichment and plutonium reprocessing technologies. The country's first nuclear reactor, the RB heavy water zero-power critical assembly completed in 1958, was built to acquire reactor technology if Yugoslavia were to pursue the reprocessing option.[11] The reactor burns 80 percent enriched uranium, is under International Atomic Energy Agency (IAEA) safeguards, and is still in operation. Yugoslavia continued research on heavy water reactor technology, completing in 1959 the 6.5 megawatt thermal (MWt) heavy water RA research reactor that burns 80 percent enriched uranium fuel.[12] The Soviet Union provided the heavy water and enriched uranium fuel for both the RA and RB reactors.[13] The fuel was not originally subject to IAEA safeguards and ownership of it transferred to Yugoslavia upon delivery.[14] The Yugoslavs also conducted research into heavy water production technology at a lab in Vinca's Chemistry Division.[15]

The nuclear program's focus changed following an accident at the RB research reactor in 1958 that killed one worker and seriously injured six.[16] The Yugoslav nuclear program was re-oriented toward light water reactor technology, although efforts to acquire heavy water technology continued.[17] Less than two years later, construction of the 250 kilowatt (kW) TRIGA Mark II light-water research reactor began at the Jozef Stefan Institute.[18] The U.S. firm General Atomics provided the TRIGA reactor with 20 percent enriched uranium fuel under a nuclear cooperation agreement.[19] Although the fuel was put under IAEA safeguards, ownership of it transferred to Yugoslavia upon delivery.[20]

In conjunction with the reactor program, Vinca's Department for Spent Fuel Reprocessing was established in 1956 to investigate plutonium reprocessing and separation technology, according to institute documents.[21] A laboratory-scale plutonium reprocessing facility at Vinca, which was reportedly built with Norwegian and Czechoslovak assistance, operated from 1966 until 1977-78.[22] The facility was equipped with four hot cells and reprocessed spent uranium metal fuel from the RA reactor using the Purex process.[23] Unnamed officials at Vinca have admitted that they reprocessed plutonium during the 1970s, but said it was "only a few grams for experimental purposes."[24] According to Vinca officials, the reprocessing program ended in the late 1970s, its equipment was removed, and all the facilities were placed under IAEA safeguards.[25] There is, however, insufficient open-source evidence to demonstrate that Yugoslavia was able to acquire more than a rudimentary reprocessing capability.

Tito's scientists also worked on uranium enrichment technology. Vinca's Laboratory of Physical Chemistry housed a calutron and the Rudjer Boskovic Institute housed a 16 megaelectronvolt (MeV) cyclotron, both of which were used to research uranium enrichment using the electromagnetic isotope separation technique.[26] Scientists at Vinca have also studied uranium enrichment using chemical, ion exchange, and laser isotope separation methods.[27] However, there is little evidence that any of these efforts ever proceeded beyond the research stage.

Yugoslavia had research facilities studying the entire nuclear fuel cycle. There was a pilot-scale uranium mine at Zletovska Reka, and a larger one at Zirosky that began mining in 1968, but was shut down in Jume 1990.[28] Belgrade also operated the Kalna uranium mine and mill from 1963 to 1966, producing at total of 900 kilograms (kg) of uranium dioxide (UO2) and 400 kg of uranium metal.[29] The uranium was acquired in preparation for enrichment or to fuel the country's reactors. Vinca's Laboratory for Reactor Materials was created in 1962 and conducted research on metallic and oxide nuclear fuel fabrication technology.[30] The lab developed the capability to fabricate uranium oxide fuel elements for the RA research reactor in conjunction with the Atomic Energy Commission of Czechoslovakia.[31] Due to turbulent relations with the Soviet Union, Tito wanted an independent source of uranium fuel for the RA reactor, which was outside Soviet control.

Although Yugoslavia ratified the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1970, there were indications by Belgrade in the 1970s that the government had reconsidered the nuclear option. In 1975, an article in the Communist Party newspaper *Borba* hinted that Yugoslavia might need nuclear weapons for defensive reasons. The article said that, "today the possibility exists—both in the East and in the West—of manufacturing nuclear weapons costing a few hundred dollars, instead of a few hundred million dollars as in the past. Cheap and easy manufacture of 'mini-nuclear'

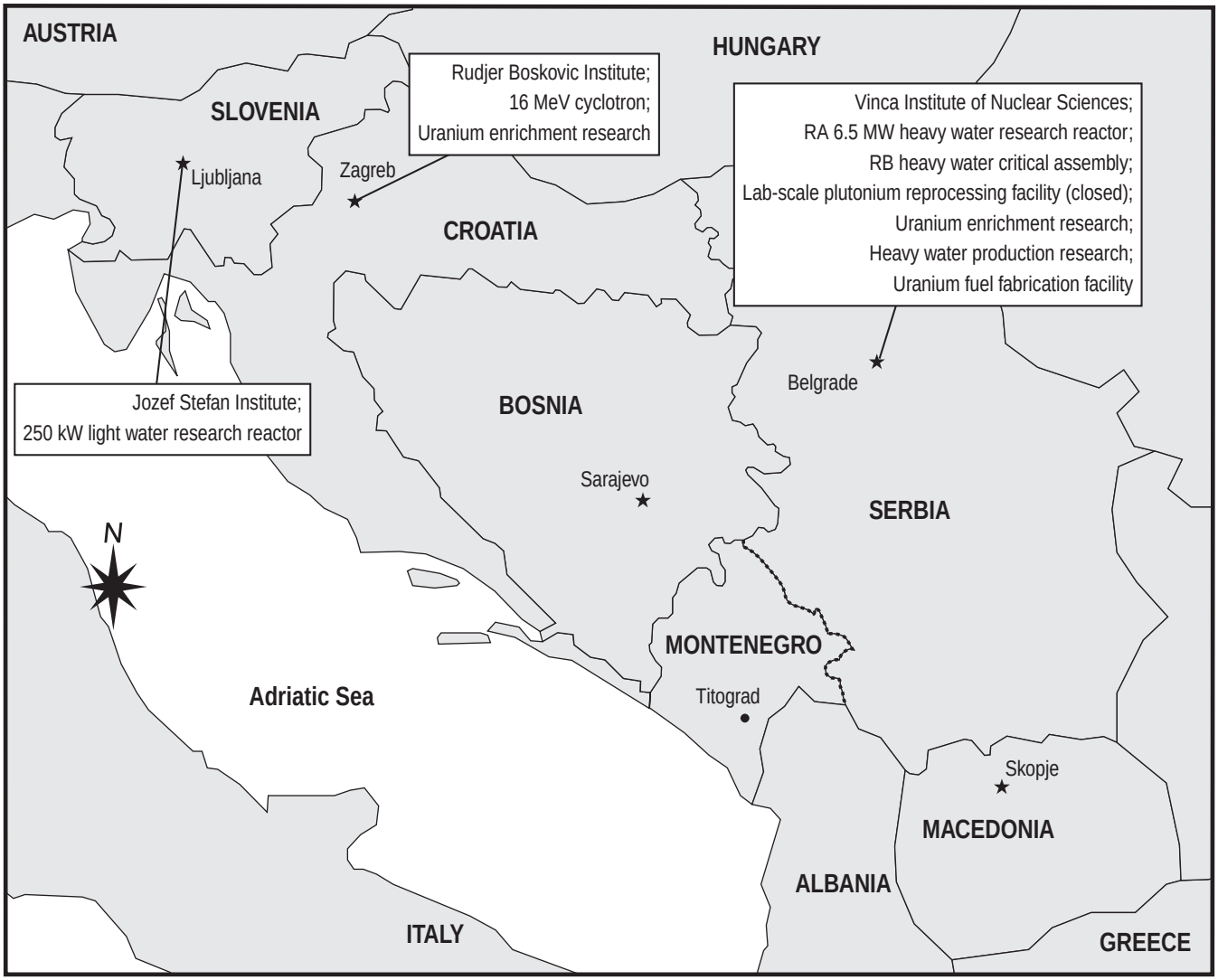


***Figure 1: Key Former Yugoslav Nuclear Research and Development Sites***

weapons, capable of destroying entire units or headquarters of the aggressor, would have a sobering effect on anyone contemplating invasion of our country."[32] In an interview less than a year later, Colonel-General Ivan Kukoc hinted that although Yugoslavia did not have nuclear weapons at that time, Belgrade could reconsider its status as a non-nuclear weapon state if the nuclear powers did not disarm.[33] Kukoc, a member of the Executive Committee of the Yugoslav League of Communist Central Committee presidium, said that "we have been advising and are still advising against any monopoly which member countries of the so-called club nuclear powers are seeking to establish. It depends the least upon us whether Yugoslavia will be obliged to consider her A-bomb or even to begin her production."[34] This view was in response to the perceived discrimination Yugoslavia faced in the civilian nuclear field and because some Yugoslav military officers believed that nuclear weapons would be an effective deterrent vis-à-vis the Soviet Union.[35]

The Yugoslav nuclear program was in decline by the time Tito negotiated to buy the Krsko nuclear power plant in the late 1970s. The 664 MW pressurized water reactor (PWR) was completed in 1983 by the U.S. firm Westinghouse, which also supplies the nuclear fuel.[36] By that time, the perceived economic and technical benefits of nuclear power were diminishing. Furthermore, segments of the Yugoslav nuclear bureaucracy were disappointed that reprocessing facilities were not offered as part of the Krsko contract.[37] With the closure of the lab-scale reprocessing facility at Vinca and no new re-

processing plant being offered, Yugoslavia's potential nuclear aspirations were abandoned by the early 1980s.

## A SMUGGLING CASE WAITING TO HAPPEN?

Attention was focused on Vinca's nuclear facilities in early 1997 because of fears the institute may house inadequately protected weapons-useable fissile material. Articles in *NuclearFuel* suggest that, due to the deteriorating political and economic situation in rump Yugoslavia [Serbia/Montenegro], highly enriched uranium (HEU) stored at Vinca could be stolen or diverted.[38] According to the articles, the government of Slobadan Milosevic has recently expressed its concern to the IAEA over the physical security of the HEU.[39] Unnamed diplomatic sources quoted in the *NuclearFuel* reports said Serbian officials have discussed with the IAEA and the U.S. government the removal of the HEU from the country.[40] Officials at Vinca have subsequently denied making any such request.[41]

Questions have been raised about the physical security of fresh highly enriched uranium dioxide fuel, supplied by the USSR after 1976 and stored in the reactor building.[42] The fuel, packed in sealed aluminum containers, is comprised of 5,056 fresh fuel elements totaling 48.2 kg of 80 percent enriched uranium.[43] While the site may not have the degree of physical protection afforded by corresponding facilities in the West, it does have security measures in place. Armed guards patrol the storage facility's entrance and unarmed guards are stationed inside the perimeter, protected by a barbed-wire fence.[44] The IAEA recently upgraded security at the site, installing a "round circuit" TV monitoring system which allows constant electronic surveillance of the facility.[45] Furthermore, the IAEA conducts monthly inspections of the HEU as part of its safeguards efforts.[46] Although the effectiveness of these measures in preventing the diversion or theft of nuclear materials can not be guaranteed until actually tested, U.S. and IAEA officials seem satisfied with them, at least for the moment.[47]

## SAFETY CONCERNS

At the request of the Serbian government, the IAEA sent inspection teams to Vinca in November 1995, October 1996, and February 1997. A trip report from the 1995 IAEA inspection found that "the research reactor RA presents a serious nuclear safety problem."[48] Spent fuel rods from the Soviet-designed research reactor, shutdown indefinitely in August 1984, are stored in a pool under dangerous conditions.[49] The spent fuel storage pool holds 6,656 two percent enriched uranium fuel elements and 884 eighty percent enriched uranium fuel elements, which contain a total of 5.2 kg of plutonium if reprocessed.[50] Some of the two percent enriched uranium spent fuel was repacked in 30 hermetically sealed aluminum barrels which may be over-pressurized due to a build-up of hydrogen gas caused by corrosion of the aluminum fuel cladding.[51] Safety officials at Vinca believe that most, if not all, of the storage drums are dangerously over-pressurized and could rupture, spreading radioactive material into the waste storage building.[52]

Leaking rubber seals on the barrels may have permitted built-up gas to escape, but this has led to a second problem, radioactive materials leaking into the spent fuel storage pool.[53] The pool, muddied by the presence of sludge and suspended corrosion products, has only a primitive and inoperable system for purifying the pool water.[54] Since 1995, the radioactivity in the pool water has increased by a factor of two.[55] The radioactivity threatens to exacerbate corrosion of the spent fuel and is a safety hazard itself.

Initially, the IAEA articulated other concerns as well, although these now seem to be temporarily mitigated. IAEA spokesman David Kyd said there was a danger that highly flammable uranium hydride gas could have accumulated inside the aluminum containers, in addition to the hydrogen gas.[56] Uranium hydride gas, produced by corrosion of the uranium metal fuel elements, could potentially rupture the barrels or catch fire underwater, causing a serious radioactive leak into the building housing the spent fuel storage pool. Even worse, because the structural integrity of the building can not be guaranteed, a radioactive cloud could be released into the atmosphere. However, recent visual inspections of random spent fuel samples have largely alleviated this concern. The IAEA inspections revealed that, while there is wide-spread corrosion of the aluminum containers and spent fuel cladding, the uranium metal has not been uncovered, reducing the possibility that uranium hydride could have been produced in sufficient quantities to pose a hazard.[57]

## REMEDIAL ACTION

Several steps for remedial action need to be taken to ensure the safety of the spent fuel. In particular, the spent fuel needs to be repacked and stabilized, the drums need to be vented, and the pool water needs to be cleared and

purified.[58] The Vinca institute currently has programs under way to measure and release the over-pressurized drums, and the Russian firm ENTEK has agreed to conduct much of the storage safety activities.[59] In addition to the corroded canisters, the steel structure of the pool is highly corroded, raising the fear that it could collapse during the venting process.[60] Vinca personnel also plan to remove sludge from the bottom of the spent fuel pool, purify the pool water, and install a new system for pool water purification, all of which will take at least six months.[61]

However, even if these steps are taken, they are only temporary solutions. The best long-term solution would be to either transfer the spent fuel back to Russia or to build a dry-storage facility for it in Serbia, which could take several years. Such steps are possible because the fuel supply contract says that Russia should take back the spent fuel. The Russian Ministry of Atomic Energy (Minatom) has thus far been unwilling to do so, especially without financial incentives. Returning the unused HEU to Russia is also a possibility; Serbian officials have expressed a willingness to address the fresh fuel issue. Vinca Director Miroslav Kopecni said the uranium could be returned to Russia, "but only under the condition that we receive in exchange a corresponding quantity of low-enriched uranium."[62] Again, Russia may be willing to accept the fresh fuel, but only with financial incentives.

To date, the safety issues at Vinca have not been addressed due to a lack of funding. Financial support is needed because the government in Belgrade does not have the resources to address these serious issues. The Serbian government has promised to provide funding to improve the safety of the spent fuel, Kopecni wrote in a letter to the IAEA.[63] It is not certain, however, when the estimated $215,000 to $300,000 will be given.[64] The IAEA has allocated only $50,000 for the Vinca project and has said an additional $100,000 will be needed from outside the agency. To date, Italy has offered assistance, but has not provided it yet.[65] U.S. State Department officials said that because the United States and the United Nations do not recognize the Milosevic government, the provision of additional assistance by the United States and IAEA is unlikely.[66] Despite the lack of diplomatic recognition, the IAEA could provide additional assistance if the site were declared a "nuclear emergency."

## CONCLUSION

This report has reviewed past and present security and environmental concerns surrounding Yugoslavia's nuclear program. Recent allegations and past fears aside, there is a lack of open-source information to verify that Yugoslavia ever had a serious "nuclear weapons program." While Tito likely aspired to have a nuclear weapons production capability, and did conduct research into both plutonium reprocessing and uranium enrichment, these activities do not appear to have reached a level of technical competence nor to have involved enough weapons-related research to be considered a "nuclear weapons program."

The presence of HEU at Vinca has raised nonproliferation fears that the fissile material stored there could be diverted or stolen. In response to its own concerns, the IAEA upgraded the facility's physical security measures last year and is satisfied with the safeguards status, at least for the moment. Whether these measures are adequate to prevent nuclear smuggling from the site, remains to be seen.

The attention Vinca has received highlights the facility's serious environmental safety problems. This attention has helped raise public awareness about problems with the spent fuel storage pool, and could lead to IAEA emergency assistance for the necessary remedial action. A long-term solution for the safe disposition of the spent fuel, does not, however, seem likely. As in many countries, Yugoslavia does not have a facility designed to permanently store spent fuel, and the chances that one will be built are remote. Return of the spent fuel to Russia is also unlikely, unless Moscow is provided with financial incentives.

[1] Mark Hibbs, "Vinca Wants Fresh HEU Removed in View of Growing Serbian Unrest," *NuclearFuel*, February 10, 1997, pp. 1, 8-9; Mark Hibbs, "IAEA Sends Mission to Belgrade: Fuel Removal is 'Hazardous, Costly'," *NulcearFuel*, February 24, 1997, pp. 2-3.

[2] "Jozef Stefan Institute," (http://www.ijs.si.html); Slobodan Nakicenovic, *Nuclear Energy in Yugoslavia* (Belgrade: Export Press, 1961), p. 35.

[3] "Rudjer Boskovic Institute," (www.irb.hr/Engleski/povijest.html).

[4] James P. Nichol and Gordon L. McDaniel, "Yugoslavia," in James Everett Katz and Onkar S. Marwah, eds., *Nuclear Power in Developing Countries* (Lexington, Massachusetts: Lexington Books, 1982), p. 346.

[5] Nuclear Engineering International, *World Nuclear Industry Handbook 1996* (London: Reed Business Publishing, 1995), p. 31.

[6] Nichol and McDaniel, "Yugoslavia," p. 346.

[7] Jan Annerstedt and Andrew Jamison, "Stevan Dedijer: An 'Elitist Egalitarian'," in Jan Annerstedt and Andrew Jamison, eds., *From Research Policy to Social Intelligence: Essays for Stevan Dedijer* (London: MacMillian Press,

1988), pp. 2-3.
[8] Declassified U.S. State Department Memorandum from Oliver Marcy, Bureau of Canadian and European Affairs, to U.S. Secretary of State, March 18, 1954.
[9] "Scientific and Industrial Research and Technological Advance," Declassified Foreign Service Dispatch from U.S. Embassy Belgrade to U.S. Department of State, May 12, 1955.
[10] *Ibid*.
[11] Sava P. Milovanovic, "Vinca: Energy Division," (http://rt270.vin.bg.ac.yu:80/~savam/eng_vinca/energy.html).
[12] The RA research reactor used two percent enriched uranium metal fuel prior to 1976. See Nuclear Engineering International, *World Nuclear Industry Handbook 1996*, p. 109; "Research Reactor RA at the Institute of Nuclear Sciences VINCA: Belgrade", in *International Atomic Energy Agency Division of Nuclear Power and the Fuel Cycle Travel Report*, October 30-November 2, 1995, Appendix 1.
[13] "International Nuclear Safety Center Database: R-A and R-B," (www.insc.anl.gov/cgi-bin/nr…_all&qvar=nre_geni.refid&qval=7585 and 7586).
[14] Nichol and McDaniel, "Yugoslavia," pp. 348-349.
[15] Sava P. Milovanovic, "Vinca: Chemistry Division," (http://rt270.vin.bg.ac.yu:80/~savam/eng_vinca/chemistry.html).
[16] Nichol and McDaniel, "Yugoslavia," p. 347.
[17] Interest by the United States and Soviet Union in light water reactor technology was also a factor. During the 1970s, nuclear power was thought of as a promising technology. See Nichol and McDaniel, "Yugoslavia," p. 347.
[18] Nakicenovic, *Nuclear Energy in Yugoslavia*, p. 35.
[19] J.E. Matos, "Foreign Research Reactors in the EIS," (http://www.td.anl.gov/RERTR/FRRSNF/EISREACT.html); Nichol and McDaniel, "Yugoslavia," p. 349.
[20] Nichol and McDaniel, "Yugoslavia," p. 349.
[21] Milovanovic, "Vinca: Energy Division."
[22] Nichol and McDaniel, "Yugoslavia," p. 356.
[23] *Ibid*.; The Boris Kidric Institute of Nuclear Sciences Brochure (Belgrade: The Boris Kidric Institute of Nuclear Sciences, publication date unknown).
[24] Dejan Anastasijevic, "Belgrade on Barrel of Uranium," *Vreme*, March 15, 1997, pp. 23-25; in FBIS-EEU-97-065 (15 March 1997).
[25] Anastasijevic, "Belgrade on Barrel of Uranium;" Hibbs, "Vinca Wants Fresh HEU Removed in View of Growing Serbian Unrest."
[26] The Boris Kidric Institute of Nuclear Sciences Brochure; Nakicenovic, *Nuclear Energy in Yugoslavia*, pp. 41-42.
[27] The Boris Kidric Institute of Nuclear Sciences Brochure.
[28] Nuclear Engineering International, *World Nuclear Industry Handbook 1996*, p. 111; Nichol and McDaniel, "Yugoslavia," p. 354.
[29] The Kalna uranium mine and mill were closed for financial reasons. The Yugoslav government believed that it already had a sufficient stockpile of uranium to meet its research and fuel needs. See Nichol and McDaniel, "Yugoslavia," p. 355.
[30] The Boris Kidric Institute of Nuclear Sciences Brochure.
[31] *Ibid*.
[32] Dimitrije Seserinca Gedza, *Borba*, December 7, 1975; reprinted in "Yugoslavia and Nuclear Weapons," *Survival* 18 (May/June 1976), pp. 116-117.
[33] "Interview with Col.-Gen. Kukoc," *Nin*, March 13, 1977; reprinted in *Survival* 20 (May/June 1977), pp. 127-129.
[34] *Ibid*.
[35] Lewis Dunn, *Controlling the Bomb: Nuclear Proliferation in the 1980's* (New Haven, CT: Yale University Press, 1982), p. 62.
[36] Nuclear Engineering International, *World Nuclear Industry Handbook 1996*, pp. 30-31.
[37] Nichol and McDaniel, "Yugoslavia," p. 351.
[38] Mark Hibbs, "Vinca Wants Fresh HEU Removed in View of Growing Serbian Unrest."
[39] *Ibid*.
[40] *Ibid*.
[41] Anastasijevic, "Belgrade on Barrel of Uranium."
[42] "Research Reactor RA at the Institute of Nuclear Sciences VINCA: Belgrade," Appendix 1.
[43] *Ibid*.
[44] Interview with International Atomic Energy Agency officials by Center for Nonproliferation Studies staff member, Vienna, April 2, 1997.
[45] *Ibid*.
[46] Hibbs, "Vinca Wants Fresh HEU Removed in View of Growing Serbian Unrest."
[47] Interviews with International Atomic Energy Agency and U.S. State Department officials, April 2, 1997.
[48] "Research Reactor RA at the Institute of Nuclear Sciences VINCA: Belgrade," Appendix 1.
[49] Due to the political and economic troubles in Serbia, combined with poor maintenance of the reactor, it is doubtful that the RA facility will be restarted. The reactor probably will not be fully decommissioned because the costs of fully decommissioning it and disposing of the spent fuel are higher than mothballing the reactor. However, staff at Vinca are hoping to restart the reactor someday, which has not yet lived-out its full operation-life. See "Remedial Action at Vinca," *International Atomic Energy Agency Newsbriefs* 12 (January/February 1997), p. 5.
[50] "Research Reactor RA at the Institute of Nuclear Sciences VINCA: Belgrade," Appendix 1.
[51] *Ibid*.
[52] M.V. Matausek, Z. Vukadin, R. Pavlovic, and N. Marinkovic, "Current Activities on Improving Storage Conditions of the Research Reactor 'RA' Spent Fuel," paper delivered to 1st International Meeting on Research Reactor Fuel Management held in Bruges, Belgium, on February 5-7, 1997.
[53] *Ibid*.
[54] *Ibid*.
[55] *Ibid*.
[56] Rob Edwards, "Spent Nuclear Fuel Festers in Serbia," *New Scientist*, March 22, 1997, p. 7.
[57] Matausek, Vukadin, Pavlovic, and Marinkovic, "Current Activities on Improving Storage Conditions of the Research Reactor 'RA' Spent Fuel."
[58] "Remedial Action at Vinca," p. 5.
[59] Matausek, Vukadin, Pavlovic, and Marinkovic, "Current Activities on Improving Storage Conditions of the Research Reactor 'RA' Spent Fuel;" Interview with International Atomic Energy Agency officials by Center for Nonproliferation Studies staff member, May 11, 1997.
[60] Ann MacLachlan, "Vinca Spent Fuel Problem Might Be on the Road to Resolution," *NuclearFuel*, April 21, 1997, pp. 12-13.
[61] Matausek, Vukadin, Pavlovic, and Marinkovic, "Current Activities on Improving Storage Conditions of the Research Reactor 'RA' Spent Fuel."
[62] Anastasijevic, "Belgrade on Barrel of Uranium."
[63] MacLachlan, "Vinca Spent Fuel Problem Might Be on the Road to Resolution."
[64] *Ibid*.
[65] "Remedial Action at Vinca," p. 5.
[66] Author's interview with U.S. State Department officials, April 10, 1997.