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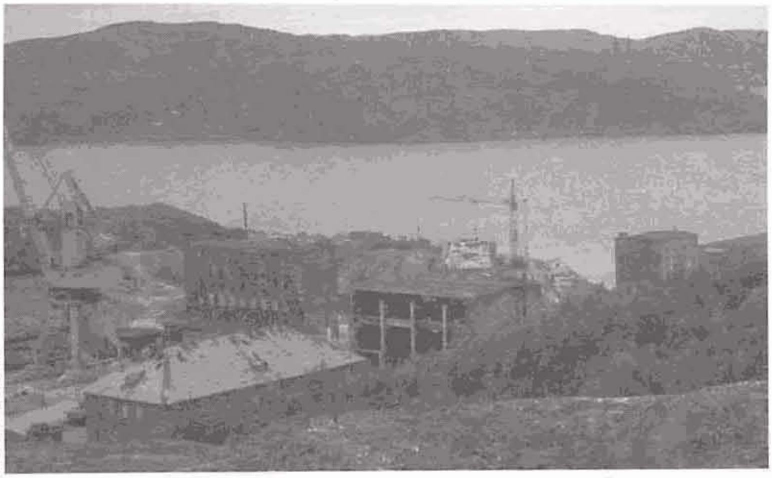
Liquid Radioactive Wastes in Russia



SOURCE: BELLONA

Naval radioactive waste facility at Andreeva Bay in northwestern Russia, the Northern Fleet's largest storage facility for spent nuclear fuel assemblies and solid and liquid radioactive waste.

A Problem Without End

BY VALERY BULATOV[1]

Against a backdrop of positive declarations from the Russian Ministry of Atomic Energy (Minatom) about the prospects for nuclear power and stabilization of the environmental situation in the nuclear energy complex, there is increasing public concern in Russia about the growing problems connected to nuclear wastes. Several years ago, under strong pressure from scientists, environmentalists, and those living near nuclear facilities, some information about the volume and activity of irradiated fuel and other radioactive wastes was released.

These official data, including those concerning liquid wastes, are shown in Table 1 on page 16. They represent wastes located at facilities overseen by a number of government agencies. Most are the result of the long-term production of nuclear weapons, operation of nuclear power stations, and reprocessing. As can be inferred from the data in Table 1, liquid wastes, both in volume and activity, constitute 85–90 percent of all wastes at Minatom sites; at Ministry of Defense sites they make up 50–60 percent of all wastes by volume and 20 percent by activity. Under the Ministry of Transport and the State Committee on Defense Industries (Goskomoboronprom), liquid wastes are 60–70 percent of the total volume.

However, there are a few important omissions from the table. Wastes from uranium mining and at the "Radon" facilities (where low- and medium-level wastes are stored) are not broken down between solid and liquid. In addition, there is little information about wastes connected to underground nuclear explosions. Also excluded from the table are liquid wastes that have been injected into three underground facilities. Minatom has also tended to refuse responsibility for the most dangerous portion of its nuclear inheritance from its predecessor Minsredmash (the Ministry of Medium Machine-Building), including wastes stored in tanks and in open reservoirs and pools.[2]

The diversity of liquid wastes—both in their activity and

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GUEST OPINION

Nuclear Dangers in Light of the Balkan Crisis

BY VLADIMIR IAKIMETS[1]

Since the start of the North Atlantic Treaty Organization bombing of Yugoslavia on March 24, 1999, global nuclear dangers, notably US-Russian nuclear dangers, have become intertwined with the Balkan crisis. To avoid any political speculation let me just outline nuclear weapon-related developments in Russia that were induced by this war:

- According to the Russian News Agency ITAR-TASS, several Russian politicians stated that Russian tactical nuclear weapons could be re-deployed in Belarus (March 25)
- The Ukraine parliament called for reversal of the country's non-nuclear weapons status in response to NATO attacks on Yugoslavia (March 26)

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INSIDE

BALKAN CRISIS

FROM PAGE 1

- The United Nations Security Council rejected a Russian-sponsored resolution for the immediate cessation of the use of force against Yugoslavia and the urgent resumption of negotiations (March 26)
- A few days after the bombing started, Russia officially announced suspension of its cooperation with NATO by recalling Russian representatives from Brussels and asking NATO representatives to leave Moscow
- Anatoly Kvashnin, Chief of the General Staff, declared, "If the question of Russia's continued existence is raised, then everything that the Armed Forces possesses, including nuclear weapons, should be used" (March 31)
- Chairman Roman Popkovich of the Defense Committee of the Russian Duma proposed including the possibility of a first nuclear strike in the national security policy (March 31)
- Igor Sergeyev, Russian Defense Minister, stated, "In the developing situation, Russia will have to revise its plans for further reductions of the armed forces," Itar-TASS (April 7)
- The Russian Duma supported the idea of the unification of Russia with Yugoslavia, as proposed by Yugoslavian counterparts (vote 293 to 54) (April 16)
- Russia boycotted the NATO Summit (April 22–23)
- "You have to understand that if we want to cause you a problem over this, we could. Someone, we don't know who, could send up a missile from a ship or a submarine and detonate a nuclear weapon high over the United States. The EMP [electromagnetic pulse that destroys electronic and computer equipment] would take away all your capability," Vladimir Lukin, Chairman of the Duma Committee on Foreign Relations, late April (as stated by U.S. Congressman Curt Weldon in an May 18 speech)
- At a top-secret meeting of the Russian Security Council, President Yeltsin signed a decree committing to develop, deploy and use tactical weapons (April 29)
- "Just let Clinton, a little bit, accidentally, send a missile. We will answer immediately. Such impudence! To unleash a war on a sovereign state. Without Security Council. Without United Nations." Boris Yeltsin, *Washington Post* (May 7)

It is clear that the NATO decision to bomb Yugoslavia without a UN Security Council mandate has aggravated a nuclear situation that was retrogressing rapidly from the hopeful early years after the end of the Cold War. This nuclear crisis has become so serious so suddenly because the bypassing of the UN Security Council comes on top of a series of adverse developments. Several of these involve NATO and/or US commitments either under treaties or given to Russia as part of the winding down of the Cold War, as they have been and continue to be understood by Russians in and out of government.

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Editor: Lisa Ledwidge

Deep Underground Storage in France?

BY MARY BYRD DAVIS[1]

In December 1998, the French government announced its decision to develop two "laboratories" to study geological disposal of nuclear waste. This decision is the outcome of a very long and controversial process.

The first round in the search for a repository site began in May 1987, when French national authorities identified four zones in France with geologic characteristics favorable for deep underground storage of highly-radioactive and long-lived waste. The zones were the granite formation of Neuvy-Bouin (also known as Deux-Sèvres); the clay to the north of Sissonne (in Aisne); the salt in the vicinity of Ain (also known as St Julien sur Rouyssouze); and the shale to the southwest of Segré (also known as Maine et Loire). Between mid-1987 and the end of 1990 these four areas were to be studied and a site for an underground "laboratory" chosen. Around 1995, after the laboratory would have been constructed and presumably found suitable, authorization to turn it into an actual storage facility would have been requested. All going well, authorization to place waste in the facility would have been granted around 2000.[2]

All did not go well. Following the Council's 1987 announcement, protest organizations sprang up in each of the four proposed zones. Opposition was not limited to petitions, studies, and peaceful marches. For example, in November 1988, at Ain, protesters seized an excavator and audiovisual equipment, raided and walled up the offices of the Agence nationale pour la gestion des déchets radioactif (ANDRA—National Waste Management Agency), and in a public square burned the documents they had seized. The same day 1,000 people staged a march. The mayor described the activities to the press as "a natural reaction" to ANDRA's program. Officials, farmers, and business people in Ain feared that a waste site would damage the reputation of Bresse chicken, traditionally marketed as the finest in France.[3]

Citizens were still expressing their "natural reaction" December 20, 1989, when access routes to ANDRA's site were blocked, and 30,000 liters of pig litter were spread on the exploratory area.[4] At Neuvy-Bouin, ANDRA had to survey by helicopter because demonstrators had systematically cut ground survey lines. The agency told a nuclear industry meeting in October 1988 that it had lost more than 48 percent of its work time at the site that year because of the activities of protesters.[5]

The most serious protests occurred in Maine et Loire. In December 1989, demonstrations involving thousands of people led to violent clashes with gendarmes (police officers). As at other sites, ANDRA property was damaged and destroyed. On January 20, 1990, 15,000 people, including representatives of groups from the three other study sites, marched in Angers. At this point, as a parliamentary report noted, "the Prime Minister, in order to prevent these incidents from claiming victims, had to decide to interrupt work for at least a year."[6] Prime Minister Michel Rocard declared a moratorium on work at all three sites in February 1990 and asked an independent advisory body to examine the waste question and turned over decision-making to the parliament.[7]

With a law passed December 30, 1991, the French Parliament gave the waste program a new start. The

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EXISTING AND PROPOSED NUCLEAR WASTE STORAGE SITES IN FRANCE

SOURCE: *Atlas of the World*, Sixth Edition (Oxford University Press, Inc.: New York), 1998; ANDRA, *Inventaire Nationale des Déchets Radioactifs*, Édition 1996.

FRANCE

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law requires the government to approach the problem of what to do with highly-radioactive and long-lived waste by simultaneously:

- conducting research on the separation and transmutation of long-lived isotopes;
- studying the possibilities of reversible or irreversible deep underground storage, in particular by establishing underground laboratories; and
- studying procedures for packaging and storing these wastes above ground.

Laboratory sites were to be chosen in consultation with local officials and the public, and the transformation of a laboratory into an actual storage site would require additional legislation. No more than fifteen years after the promulgation of the law, by the end of 2006, the government must send to parliament a report evaluating the research and, if appropriate, a bill that would authorize creation of an underground storage facility.[8]

In December 1992, the government appointed Deputy Christian Bataille of the Office Parlementaire d'Evaluation des Choix Scientifiques et Techniques (Parliamentary Office for the Assessment of Technological Options) to identify candidate sites for laboratories. Each community hosting a laboratory would receive 60 million francs (about $10 million) a year for fifteen years and be given priority for government investments in infrastructure. Furthermore, communities with candidate sites were given numerous, expensive gifts.[9]

Some thirty departments (regions) volunteered, and after geologic evaluations, Bataille narrowed the number of candidates down to ten, each of which he visited.

In a report to the government made public January 5, 1994, Bataille named four departments as finalists: Gard, Haute-Marne, Meuse, and Vienne. The General Council in each had voted unanimously or virtually unanimously in favor of a laboratory. His criteria in selecting the four had been based on "economic" and "social" considerations—in other words, departments which would benefit the most from a high technology installation.[10]

The number of sites was reduced to three, as a site which became known as the "Est de la France" was chosen on the boundary between the Haute-Marne and Meuse regions.[11] The Gard and Est de la France sites are clay; the Vienne is granite.

Opposition to each of the sites immediately manifested itself and continues at the sites now chosen, although so far without the threat of violence. In the

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RADIOACTIVE WASTE CATEGORIES IN FRANCE

France's Commission nationale d'evaluation has characterized three categories of waste, according their level of activity, their nature, and the half-lives of the isotopes contained in the waste. Government agencies generally follow these categories in conduct and oversight of waste management activities.

Category A: low- and mid-level wastes which contain principally only short- or medium-lived beta- and gamma-emitters, and alpha emitters in small quantities (not more than 3.7 gigabecquerel(GBq)/metric ton [0.1 curies/metric ton] of alpha activity after 300 years).

Category B: low- and mid-level wastes which contain long-lived radionuclides, notably alpha-emitters in significant quantities (more than 3.7 GBq/t [0.1 Ci/t] of alpha activity, but less than 370 GBq/t of beta and gamma activity).

Category C: high-level wastes containing large quantities of fission products, activation products, and actinides. This is mainly vitrified wastes. Spent fuel is also considered a high-level waste (without upper limit).

Category A wastes are destined for surface storage in France. ANDRA operates two of these: the Centre de stockage de la Manche, which has been filled; and the Centre de stockage de l'Aube, which is currently receiving wastes. Category B and C wastes are placed in interim storage, awaiting geologic disposal. They are kept on site, or in several interim storage facilities, notably a facility for alpha-emitting wastes at Cadarache.

Treatment of substances with an activity of less than 100 Bq/gram for artificial radionuclides or 500 Bq/gram for natural radionuclides (called very low-level wastes) is essentially unregulated at the present time. The Direction de la sûreté des installations nucléaires (Nuclear Installation Safety Directorate) is currently in the process of elaborating more precise definitions for waste categories than those currently in use, to consist of four levels: "very low-level, low-level, mid-level, and high-level." Each level is divided into "short-lived" and "long-lived."

SOURCES: Mary Byrd Davis, *La France nucléaire: matières et sites* (WISE-Paris, 1997); Commission nationale d'evaluation, *Rapport d'evaluation no. 1*, June 1995.

ROCK TYPES FOR A RADIOACTIVE WASTE REPOSITORY

Rock Type	Advantages	Disadvantages
Crystalline (e.g., Granite)	• High mechanical strength • High thermal stability • Often resistant to chemical change • May retard radionuclide transport	• May be highly permeable and porous • Brittle under tensional stress • Numerous fractures and joints • Often complex geology
Clay	• Low permeability • Plastic (self-sealing) movement • Few fractures • May retard radionuclide transport • Easy to excavate	• Most suitable clays are near the surface • Adjacent sediments provide pathways • May be hydrocarbon source rocks
Salt	• Low Permeability • Dry • Plastic (self-sealing) movement • Few (if any) long-lived fractures • High thermal stability • High thermal conductivity • Easy to excavate	• May contain corrosive brines • May be an economic resource • Salt formation may be mobile • Accidental flooding could remove all salt

Reprinted with permission from *Radioactive Waste—Where Next?* (London: Parliamentary Office of Science and Technology, November 1997), p. 77.

FRANCE

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Gard, the Syndicat Général des Vignerons (Union of Wine Growers) des Côtes du Rhône is campaigning against a laboratory for fear it will damage the reputation of their wine. They refer to a study carried out under the aegis of the Chamber of Agriculture, which concludes that there is a major risk that a laboratory could damage the image of the wine, with potentially serious economic consequences.[12]

Deep disagreements continue over both the process and the goal of developing a geologic repository in France.

The findings of two official groups of French scientists and engineers have buttressed some of the arguments of opponents to radioactive waste burial. The 1991 law required that a Commission nationale d'evaluation (CNE—National Evaluation Commission) be set up to assess the status of research on management of highly radioactive and long-lived waste and to make annual reports to the government for transmission to Parliament. In a June 1998 special report on reversible and irreversible storage, the CNE recommended that low- and medium-level alpha-contaminated waste be placed deep underground but that highly radioactive waste be stored above ground or just below the surface for a long period of time.[13]

Furthermore, a 1996 CNE report expressed strong reservations about the granite site in Vienne, because it judged that a risk exists that fluids will circulate between the granite that would hold the high-level waste and aquifers from which water for drinking and irrigation is drawn.[14] In its 1997 report, the CNE states that the negative aspects of the site "appear today to be uncircumventable and cause the Commission to go beyond the reservations that it expressed in report no. 2."[15] Bataille disagreed with this view and in a report of the Parliamentary Office criticized the CNE for overstepping what he considers to be its role.[16]

The Institut de protection et de sûreté nucléaire (IPSN—Institute for Nuclear Protection and Safety) has found a fractured zone in the Tournemire Tunnel in Aveyron where it is studying the suitability of clay as a burial medium. Researchers have been able to see water flowing in certain of these fractures. The IPSN 1997 annual report notes that the transfer mechanism in clay is not understood.[17]

The authorities held public inquiries on each of the three proposed laboratory sites in 1997, and construction of a laboratory at each site was officially found to be within the public interest. The government was then obligated by law to choose two sites. In December 1998, the site in Meuse was chosen for development of a laboratory to study clay sites. Researchers will explore to a depth of 400 to 500 meters, and the laboratory is slated to be finished by the end of 2002. The Gard is to be studied as the location of a subsurface storage site. No granite site was chosen because the Vienne site was deemed unsuitable, and the search is beginning for a new site.

Deep disagreements continue over both the process and the goal of developing a geologic repository in

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For example, it is Russia's firm understanding, buttressed by Western sources, as the former US Ambassador to Russia Jack Matlock wrote in *The New York Times* in April 1999, that former Soviet President Mikhail Gorbachev was given an understanding that NATO's borders would not be expanded to the East if Germany were allowed to unite with West Germany and a unified Germany were to stay in NATO. Yet NATO was enlarged without Soviet opposition after Germany was peacefully re-united.

Further, during debates on NATO enlargement, Russia was assured that NATO was a defensive transatlantic organization that would never undertake offensive military action against any sovereign country without a UN mandate (it was said by NATO officials that such an offensive action is constitutionally impossible). However this happened in the Yugoslavia case.

These developments have made it impossible for anyone in Russia to lend credibility to commitments given by NATO. Therefore, while NATO has stated several times it has no plans to station conventional or nuclear forces in the territories of new members, such assurances carry little, if any, weight in Russia.

NATO expansion has been especially troubling to Russians because about 150 US nuclear bombs and their associated bombers are still stationed in non-nuclear weapons states in Europe (see Table, this page). The fact that there is no formal agreement that would prevent these weapons from being moved into the territories of NATO's new members, much closer to the borders of Russia, has greatly increased Russian concerns. The stationing of these bombs in non-nuclear states is also questionable under Articles I and II of the Nuclear Non-Proliferation Treaty (NPT), which prohibit nuclear weapons states from sharing nuclear weapons with non-nuclear states. (See page 9 for the text of Articles I and II of the NPT.) The potential extension of nuclear sharing to new NATO members is especially objectionable under the NPT. How would the United States government react if Russia were to begin nuclear sharing agreements with other countries, especially if these agreements also included possible actions against third parties without any United Nations Security Council mandate?

All of these developments are further complicated and aggravated by the often-stated US desire to deploy a national missile defense (NMD) system. These are provocative in the context of a world full of nuclear weapons because they can be considered part of a first strike strategy. Given that US verbal assurances now mean next to nothing in Russian political discourse, the US movement toward NMD deployment is especially de-stabilizing. If carried out without the explicit assent of Russia, an NMD system deployment that violates the 1972 Anti-Ballistic Missile treaty in Russia's eyes could have nuclear repercussions every bit as serious as those of the NATO decision to bomb Yugoslavia without a UN mandate.

Those of us who have advocated nuclear disarmament in a climate that was already very difficult prior to March 24 now find the ground cut out from under our feet. Given the lack of any significant Russian conventional force capacity, NATO expansion and NATO's bypassing of the UN Security Council, there is little that anyone can do in Russia to roll back the new and larger role for Russian nuclear weapons unless the West takes initial steps that would be reassuring not only for the Russian government, but also for the Russian people.

A first step in that direction would be for the United States to remove the nuclear bombs that it has stationed in Europe back to its own territory. This would make the NATO expansion that has already occurred less threatening to Russia and create a new reality that would instill some confidence that there may be a desire on the part of the United States and its European allies to work with and not against Russia. This minimal step is necessary for the sake of nuclear safety and for the world's security. I hope that the United States will carry it out expeditiously.

[1] Vladimir Iakimets, Ph.D. is a staff member of the Institute for Systems Analysis of the Russian Academy of Sciences in Moscow. This paper expresses his personal views.

NUMBER OF U.S. NUCLEAR WEAPONS IN EUROPE

Belgium	10
Germany	45
Greece	10
Italy	30
Netherlands	10
Turkey	15
UK	30
Total	**150**

SOURCE: William Arkin et al., "Taking Stock: Worldwide Nuclear Deployments 1998," Natural Resources Defense Council, Washington, DC, March 1998.

UPDATE ON NUCLEAR TREATIES

Nuclear dangers have been rising rather than declining, due in no small part to the direction that some nuclear-related treaties are taking. The following provides an update to the compilation of nuclear-related treaties published in the October 1998 double issue of *Science for Democratic Action*.

NATO summit

Status: The NATO summit was held in Washington, DC, April 22–24, 1999 during the NATO-Yugoslavia war. NATO members and all "partners," except one, participated. NATO "partner" Russia boycotted the meeting. NATO members and partner countries are shown the accompanying map (page 8). A new Strategic Concept was issued at the summit. Quotations below are from this document.

Main nuclear implications: (i) NATO decided that it may undertake operations that go beyond the defense of borders of its member states. (ii) NATO toned down the language indicating that it is less likely to use nuclear weapons by stating (para 64):

> ...NATO's ability to defuse a crisis through diplomatic and other means or, should it be necessary, to mount a successful conventional defence has significantly improved. The circumstances in which any use of nuclear weapons might have to be contemplated by them are therefore extremely remote....NATO will maintain, at the minimum level consistent with the prevailing security environment, adequate [nuclear] sub-strategic forces based in Europe.

(iii) NATO did not rule out basing nuclear weapons in new member states that are closer to Russian borders. (iv) The US will maintain nuclear weapons in Europe (Para 42) "The presence of United States conventional and nuclear forces in Europe remains vital to the security of Europe, which is inseparably linked to that of North America." (v) NATO retained the option to use nuclear weapons first in any conflict (para 46):

> To protect peace and to prevent war or any kind of coercion, the Alliance will maintain for the foreseeable future an appropriate mix of nuclear and conventional forces based in Europe and kept up to date where necessary, although at a minimum sufficient level....[T]he Alliance's conventional forces alone cannot ensure credible deterrence. Nuclear weapons make a unique contribution in rendering the risks of aggression against the Alliance incalculable and unacceptable. Thus, they remain essential to preserve peace.

Comments: NATO's decision on out-of-area operations has heightened US-Russian tensions, notably in the context of the NATO decision to bomb Yugoslavia without first presenting the case for humanitarian intervention to the Security Council. Three NATO partners (Kazakhstan, Tadjikistan, and Kyrghyz Republic) share borders with China. Various events, including NATO action in Yugoslavia, have heightened US-Chinese tensions. The retention of first use option and the high value given to nuclear weapons by NATO has increased concerns that other countries would see this as a message that nuclear deterrence is a desirable security policy, thereby undermining non-proliferation.

REFERENCES: The US government's NATO summit web site is: http://nato50.gov. The quotes above are from NATO's new Strategic Concept, which can be found at http://nato50.gov/text/99042411.htm.

Nuclear Non Proliferation Treaty

Status: The NPT Preparatory Committee (PrepCom) meeting was held in New York in May 1999 with the objective of preparing for the review of the NPT to be held next year by its 186 signatories. (All countries except Cuba, India, Israel, and Pakistan have signed and ratified the NPT.) The 107 or so countries that participated in the PrepCom agreed on some procedures for the Review Conference, which will take place in New York from April 24 to May 19, 2000.

Main nuclear implications: The participating countries failed to achieve consensus on an agenda for the Review Conference. Specifically, there was no agreement on whether and how to discuss the nuclear disarmament obligations of the five nuclear weapons states that are parties to the NPT and on the issue of a nuclear weapons free zone in the Middle East. In the aftermath of the NPT PrepCom, the discussions on nuclear disarmament at the United Nations Conference on Disarmament continue to be stalemated. Further, there has been no progress towards a treaty banning the production of fissile materials for nuclear weapons purposes. China and Russia want the Conference on Disarmament to establish an ad hoc committee on the "prevention of an arms race in outer space," which the United States opposes. The Yugoslavia war demonstrated, among other things, the use of satellite-assisted targeting of non-nuclear weapons and precision-guided non-nuclear weapons, which are part of the Pentagon's "Revolution in Military Affairs" (see *SDA*, double issue on disarmament, vol. 6 no. 4 and vol. 7 no. 1, October 1998).

Comments: The failure so far of the preparations for the review of the NPT to lay the framework for agreement on its nuclear disarmament provision (Article VI) bodes ill for the non-proliferation regime. NATO's insistence on retaining nuclear weapons in

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TREATIES

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Europe as part of its "deterrence" strategy, despite the overwhelming and demonstrated dominance in the non-nuclear arena, raises more insistently an old question. If nuclear weapons make a "unique" contribution to NATO deterrence strategy, why should other countries continue to forgo them? This question becomes especially relevant when considered in light of the failure of the United States, Russia, Britain, and France, as well as NATO, to provide firm assurances that they will never threaten to use or use nuclear weapons against non-nuclear weapons states that are parties to the NPT. These "negative security assurances" had been promised to the non-nuclear states in 1995 as part of the process of the indefinite extension of the NPT in that year. The crisis in non-proliferation is being intensified by the fact that, of the nuclear weapons states, only China has explicitly recognized the World Court's advisory opinion that the NPT requires the nuclear weapons states to actually achieve nuclear disarmament in all its aspects.

According to Rebecca Johnson of the Acronym Institute, the "inability [of the NPT PrepCom] to adopt any meaningful recommendations reflect the deepening crisis in international relations and arms control. The PrepCom proceedings also served to highlight the growing chasm between the aspirations and ideas coming from a wide section of non-nuclear-weapon States (NNWS) and the five NPT nuclear-weapon States (NWS)...."

REFERENCES: See the Acronym Institute's home page and Disarmament Diplomacy issue No. 37 at http://www.acronym.org.uk/ for documents and Rebecca Johnson's commentary about the PrepCom.

Comprehensive Test Ban Treaty

Status: Of the nuclear weapons states, only Britain and France have ratified it. India, Pakistan and North Korea have not signed it. A conference to accelerate ratification will be held in fall 1999. All five NPT nuclear weapon states as well as India are pursuing some form of "stockpile stewardship" programs (see *SDA* double issue, vol. 6 no. 4/vol. 7 no. 1, October 1998). The United States and France are building huge laser fusion facilities designed to create thermonuclear

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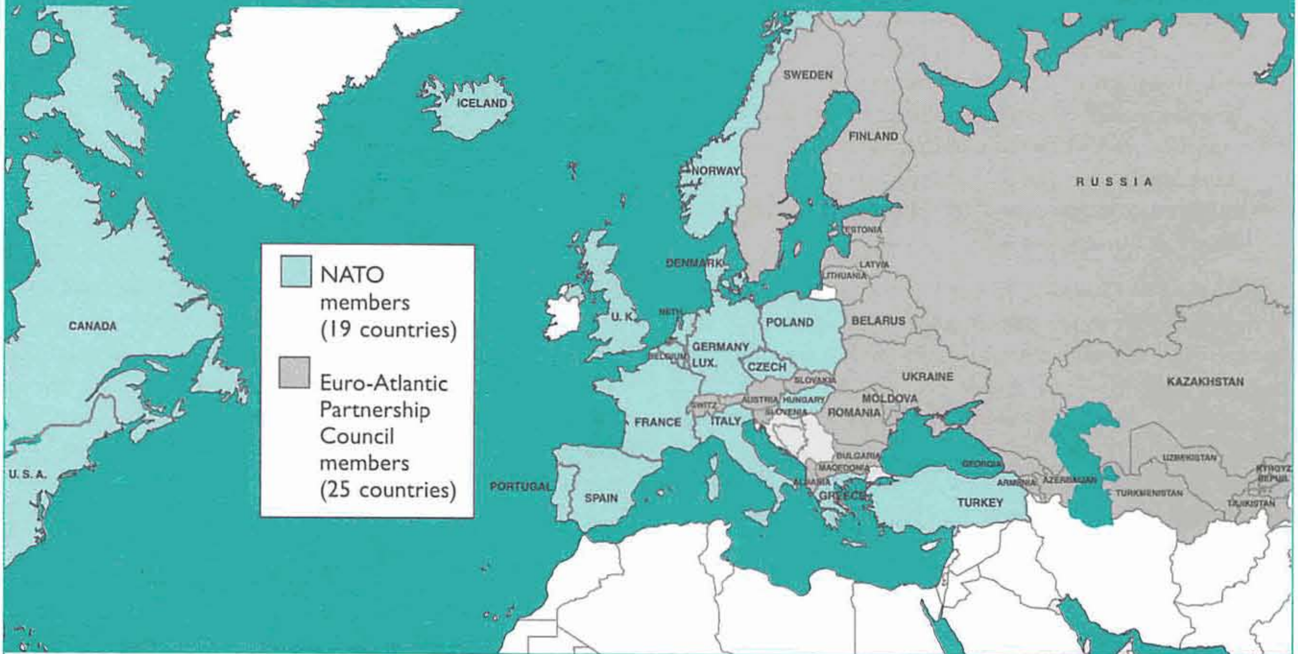
NATO MEMBER AND PARTNER COUNTRIES



19 member countries of NATO

Belgium	Luxembourg
Canada	Netherlands
Czech Rep	Norway
Denmark	Poland
France	Portugal
Germany	Spain
Greece	Turkey
Hungary	United Kingdom
Iceland	United States
Italy	

25 Euro-Atlantic Partnership Council Member Countries

Albania	Kazakhstan	Slovakia
Armenia	Kyrghyz Republic	Slovenia
Austria	Latvia	Sweden
Azerbaijan	Lithuania	Switzerland
Belarus	Macedonia	Tadjikistan
Bulgaria	Moldova	Turkmenistan
Estonia	Romania	Ukraine
Finland	Russia	Uzbekistan
Georgia		

SOURCE: NATO Official Homepage, http://www.nato.int

OTHER NUCLEAR TREATIES AND ISSUES

Item	Status	Implications	Comments
START II	Not ratified by Russia	Contributes to impasse on arms reductions	US started bombing Iraq and Yugoslavia just prior to Russian Duma consideration of ratification.
Arms cuts beyond START II	US-Russian agreement reached in principle	Would further mutual confidence since Russia cannot afford to maintain a large arsenal	A failure to achieve quick progress on further arms reductions is increasing nuclear dangers due to deteriorating command and control infrastructure in Russia. US-Russian talks are to be resumed.
Fissile Materials Cut-off Treaty	Stalled in the Conference on Disarmament	Failure to achieve treaty allows weapons states to continue producing fissile materials	Fissile materials talks are mired in procedural disagreements that mask more profound disagreements. All five NPT weapons states and India, Israel, and Pakistan are participating.
US-Russia fissile materials cooperation	Has been funded by the US. Progress in achieving security is slow, but work is continuing	Continued joint work is among the few bright spots in the nuclear security picture	The collapse of the ruble in August 1998 and concomitant worsening economic conditions have affected progress.
ABM Treaty	US is pressuring Russia to accept modifications of this treaty. President Yeltsin has agreed to consider this but there is much resistance in Russia.	Modification to allow ballistic missile defenses would have serious negative consequences for the prospects for nuclear disarmament.	Ballistic missile defenses are regarded as dangerous since they can provide a first strike capability to the possessor. China is especially vulnerable since it has fewer than two dozen strategic warheads that can reach the US (compared to 6,000 US warheads that can reach China). Though this is a US-Russian treaty, its breach or modification would cause negative repercussions for US-Chinese relations and possibly US-Russian relations.

TREATIES

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explosions, even though Article I of the CTBT bans all nuclear explosions and obliges parties to prevent nuclear explosions within their jurisdictions. The ratification of the CTBT in the United States has been linked to implementation of an extensive stockpile stewardship program.

Implications: Failure of the CTBT to enter into force, continued pursuit of stockpile stewardship programs that involve design capability for new weapons, and the construction of laser fusion facilities designed to create explosions that would violate Article I are all undermining a long sought and hard won goal that is essential to achieving both enduring non-proliferation and nuclear disarmament.

Comments: Stockpile stewardship programs as well as the delay of many countries, including the United States, in ratifying the CTBT is further eroding confidence that nuclear weapons states will meet their nuclear disarmament obligations.

REFERENCES: See the websites of the Coalition to Reduce Nuclear Dangers (http://www.crnd.org) and IEER (http://www.ieer.org).

TEXT FROM THE NUCLEAR NON-PROLIFERATION TREATY

Article I: "Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear-weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices."

Article II: "Each non-nuclear-weapon State party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices."

Ecological and Health Implications of NATO Bombing in Yugoslavia

Since the start of the NATO-Yugoslavia war on March 24, 1999, IEER has received numerous inquiries about the ecological and health effects of the NATO bombing of industrial facilities and power transformers, which resulted in toxic chemical compounds being released into the air, soil, and water. One example is the bombing of the Pančevo chemical complex, located on the Danube River (see map). IEER has no independent data on the types and amounts of chemicals present at Pančevo or other facilities that have been bombed, but has compiled the best available information to respond to these queries. The information sources we have used include news reports, chemical industry data, health and environmental data on the chemicals, and claims of Yugoslavian authorities. The latter claims were checked against industry data in the United States for reasonableness to ensure that the types of chemicals alleged to be present would be found at the types of facilities that were bombed. The industrial uses of the chemicals reportedly present at Pančevo and their potential health effects are detailed in Table 2, along with effects of PCBs which were present in electrical transformers struck by NATO.

Pančevo

The Pančevo complex, a combined petrochemical, fertilizer and polyvinyl chloride manufacturing complex, was bombed repeatedly in April 1999. Chemical storage tanks there reportedly released into the air, soil, and water large amounts of ammonia, ethylene dichloride, and vinyl chloride (see Table 2, pp. 12–13). Also reportedly released were 100 tons of mercury, 800 tons of hydrochloric acid, 3000 tons of caustic soda, and 250 tons of liquid chlorine. (*The New York Times,* July 14, 1999, p. A1)

The burning of chlorinated chemicals creates other toxic byproducts, such as dioxins. Traces of phosgene, a highly dangerous World War I chemical warfare agent also used as a common industrial chemical, were also reportedly found. It is unclear whether phosgene was stored at the plant or whether it was the by-product of the combustion of other chemicals.

The bombing of the plant sent toxic fumes into the air of the city of Pančevo and nearby areas. Favorable winds appear to have prevented large-scale immediate casualties. The plant premises are apparently so contaminated that western journalists who inspected the rubble more than a month after the bombings "became violently sick from breathing in the Pancevo air" (May 24 National Public Radio report). *The New York Times* reported on July 14 that people in Pančevo have suffered a "surge of unexplained symptoms," like headaches, skin rashes and increasing miscarriages.

Since toxic fumes from large fires typically travel quite far, they could affect a wide region, including some of the member countries of NATO. Further, since the fires can last for hours or days, the spread of the toxic fumes would likely be along many wind directions, rather than in one elongated pattern in a single principal direction characteristic of a short-term accidental release.

In order to prevent large-scale poisoning of the air in the area, the plant authorities released some of the chemicals, including highly toxic ethylene dichloride, into a nearby channel that flows into the Danube River. As of May 24, the ethylene dichloride was at the bottom of the canal and had not yet entered the river (ethylene dichloride is insoluble in and denser than water). The Danube is the source of drinking water for millions of people downstream in Yugoslavia, Romania, Bulgaria, and Moldova. Pollutants in the river water may also cause increased damage to ecosystems in reservoirs downstream created by two dams, known as Djerdap Dam I and Djerdap Dam II. The generating systems are partly owned by Yugoslavia and partly by Romania.

Transformers and Depleted Uranium

NATO bombed electrical transformers in Yugoslavia as a way of disrupting that country's power system. Some of these transformers contained polychlorinated biphenyls (PCBs). Because of their persistent toxicity, the manufacture and use of PCBs are now widely banned.

NATO used armor-piercing depleted uranium (DU) munitions in Yugoslavia. DU munitions were also used in Iraq. Depleted uranium is a radioactive and toxic heavy metal. DU munitions can catch fire and be converted to an aerosolized oxide. The oxide powder could be breathed in by people in the vicinity resulting in radiation doses to their lungs. In both Yugoslavia and Iraq, DU munitions were used in the context of chemical pollution. About one-seventh of the US armed forces personnel who served in the 1991 Gulf War have been afflicted with one or more of the complex of symptoms, collectively called Gulf War Syndrome. While all these symptoms could not have been caused by depleted uranium alone, DU may have played a role. The combination of contaminants, including potential synergistic effects between chemicals and between combinations of chemicals and depleted uranium, is worrisome.

Nuclear Safety and Proliferation

The NATO bombing also increased nuclear safety and proliferation risks. First, a small nuclear research institute located near Belgrade has two research reactors (the larger one has been shut for years) and significant quantities of stored nuclear waste (see Table 1, this page). An errant bomb could have had serious environmental and public health consequences if it hit the site, particularly the waste storage area. Furthermore, weapons-usable highly enriched uranium (HEU) is still present at the site. During the bombing, the International Atomic Energy Agency (IAEA) suspended inspections of the facility which are conducted to ensure that the approximately 60 kg of HEU (enough for one or two nuclear bombs, depending on design) are not diverted.

The second nuclear danger is associated with the six nuclear power reactors in Bulgaria. The Kozloduy station is downriver from Yugoslavia along the Danube (see Tables 3 and 4 on page 14 for information about Bulgaria's nuclear power program). There exists the potential for operational problems due to contaminants in the Danube interfering with the condenser cooling systems of the power plant. For instance, ethylene dichloride could foul the reactor's cooling water intakes or pumping systems. Four of the reactors are of an older design (VVER 440-230) that is especially vulnerable to accidents. The National Academy of Sciences noted in a 1995 report that the VVER 440-230 reactors

> … do not have containments, a major difference in safety from international standards. The early models (VVER 440-230) were not designed to withstand major earthquakes or the level of cooling water losses which Western reactors are designed to survive, have less redundancy in their safety systems, lack emergency operating procedures and training simulators to assist operation in responding to upset conditions, and otherwise fall far short of internationally accepted safety

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TABLE 1. SPECIFICATIONS OF YUGOSLAVIAN RESEARCH REACTORS IN BELGRADE

Type of reactors	one 6.5 MWt Research Reactor one Zero-power research reactor
Moderator/Coolant	Heavy Water (D_2O)
Criticality Date	28-Dec-59 (Research Reactor) 29-Apr-58 (Zero-power Reactor)
Current Status	Shutdown in 1984 (Research Reactor) Operating (as of 1997) (Zero-power Reactor)
Fuel	Highly Enriched Uranium (6.5 MWt reactor converted from LEU in 1976)
Enrichment Level	80%
Fuel Source	USSR
Amount of HEU in unirradiated fuel	50 kg
Amount of HEU in slightly irradiated fuel	10 kg
Number of LEU/HEU spent fuel elements	5000
Safeguards	International Atomic Energy Agency

SOURCES: US Department of Energy, Argonne National Laboratory, International Nuclear Safety Center (http://www.insc.anl.gov); David Albright, "What about Yugoslavia's Nuclear Explosive Material?" ISIS Policy Paper. Institute for Science and International Security (ISIS). April 21, 1999 (http://www.isis-online.org); Judith Miller, "Crisis in the Balkans: Nuclear Security," *New York Times*, p. A12, May 5, 1999.

TABLE 2. CHARACTERISTICS OF SOME OF THE CHEMICALS AND BY-PRODUCTS REPORTEDLY PRESENT OR RELEASED AS A RESULT OF THE NATO BOMBING OF ELECTRICAL TRANSFORMERS AND THE PANČEVO PETROCHEMICAL COMPLEX IN YUGOSLAVIA*

Chemical	Uses	Properties	Health Effects	Regulations, U.S.†
Ammonia, NH_3 (Synonyms: anhydrous ammonia, aqua ammonia) *Amount reportedly released from Pančevo: 15,000 tons*	Used in fertilizers, synthetic fibers, plastics, and explosives	• Flammable, corrosive, colorless gas with a pungent odor • Water-soluble	• Exposure can cause extensive permanent damage to mucous membranes of the eyes, nose, mouth and respiratory system, including severe pulmonary and gastrointestinal irritation, and buildup of fluid in the lungs (lung edema) which can cause death • Ammonia has not been tested for its ability to cause cancer in animals or to affect reproduction	• OSHA PEL: TWA 50 ppm • NIOSH REL (in air): TWA 25 ppm; ST 35 ppm • NIOSH IDLH: 300 ppm
Ethylene dichloride, $C_2H_4Cl_2$ (Synonyms: 1,2-dichloroethane, 1,2-ethylene dichloride, dichloroethylene, ethane dichloride) *Amount reportedly released from Pančevo: 1,400 tons*	Used to make vinyl chloride and other chemicals and to dissolve grease, dirt, and glue. Removes lead from leaded gasoline	• Highly flammable, explosive, clear, oily, man-made liquid with a pleasant odor and sweet taste • Slightly water soluble • Poisonous gases produced in fire, including hydrochloric acid, vinyl chloride, and phosgene.	• The U.S. Department of Health and Human Services has determined that 1,2-dichloroethane may reasonably be anticipated to be a carcinogen • Exposure can irritate the skin, eyes, nose, throat, and lungs and may cause nausea, vomiting, dermatitis, headaches, dizziness, and lung edema • Ingesting or breathing in high levels causes damage to heart, central nervous system, liver, kidneys, and lungs. Long term effects not known • Animal studies show exposure causes nervous system damage, kidney disease, reduced immune function and cancer of the stomach, lung, and breast	• OSHA PEL: TWA 50 ppm; C 100 ppm; 5-minute maximum in any 3 hours 200 ppm • NIOSH REL (in air): TWA 1 ppm; ST 2 ppm • NIOSH IDLH: Potential occupational carcinogen 50 ppm • EPA drinking water limit: 0.005 ppm
Phosgene, $COCl_2$ (Synonyms: carbonyl chloride, chloroformyl chloride) *Traces reportedly found at Pančevo*	Used as a chemical warfare agent during World War I. Used industrially to make polyurethanes, resins, isocyanates, synthetic foams, polymers, insecticides, herbicides, pharmaceuticals, and dyes	• Corrosive, nonflammable, colorless to yellow gas or compressed liquified gas with an odor similar to musty hay • When heated above 300°C, produces hydrogen chloride, carbon monoxide, and chlorine gases • Reacts with water, producing corrosive, pungent and toxic gases	• Corrosive to eyes, skin, and respiratory system • Short-term exposure via inhalation may cause lung edema. Exposure over a long term may cause fibrosis of the lungs. • High level exposure may result in death	• OSHA PEL: TWA 0.1 ppm • NIOSH REL: TWA 0.1 ppm; ST 0.2 ppm • NIOSH IDLH: 2 ppm

* A number of other chemicals are formed when the chemicals above are burned. They include chlorine gas, carbon monoxide, hydrogen chloride (hydrochloric acid), and dioxins and furans. We have not listed the effects of such byproducts of combustion in this table. As regards phosgene, it is not known if this was stored at the Pancevo plant as one of the feedstock chemicals or whether residues have been reported because it is a by product of combustion of vinyl chloride monomer.

† Although the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) were created by the same Act of Congress (the Occupational Safety and Health Act of 1970), they are two distinct agencies with separate responsibilities. OSHA is part of the U.S. Department of Labor and is responsible for creating and enforcing workplace safety and health regulations. NIOSH is in the U.S. Department of Health and Human Services and is responsible for conducting research and making recommendations for the prevention of work-related illnesses and injuries. (SOURCE: NIOSH website, http://www.cdc.gov/niosh/about.html, observed June 28, 1999)

Polychlorinated Biphenyls, or PCBs (Some PCB mixtures are known by their industrial trade name, Aroclor) *Amount released from bombing of Yugoslav transformers: unknown*	PCBs are a family of man-made chemicals comprising 209 individual compounds with varying toxicity. Used widely as coolants and lubricants in transformers and other electrical equipment due to their insulating properties. Their manufacture stopped in the U.S. in 1977 because of evidence that PCBs accumulate in the environment and could cause human health hazards.	• Clear to yellow, oily liquid or solid • PCBs may burn, but do not ignite readily • Some PCBs produce poisonous gases in fire, including dioxin and chlorinated dibenzofurans	• The U.S. Department of Health and Human Services has determined that PCBs may reasonably be anticipated to be carcinogens • Exposure may cause reproductive and developmental effects • PCBs may be passed to a child through mother's milk • Some PCB mixtures may in the short-term burn the eyes, nose and throat, and in the long-term cause acne-like lesions and damage the skin and nervous system • Shown to cause liver cancer and thyroid and stomach injury in animals	• OSHA PEL: TWA 0.5 or 1 milligram per cubic meter (mg/m^3) air, depending on the amount of chlorine present in the particular PCB compound; TWA 0.5 mg/m^3 skin • NIOSH REL: TWA 0.001 mg/m^3 air • NIOSH IDLH: Potential occupational carcinogen 5 mg/m^3 • FDA limit in infant foods, eggs, milk, poultry fat, fish, and shellfish: 0.2 to 3 ppm, by weight • EPA drinking water limit: 0.0005 milligrams PCBs per liter water
Vinyl Chloride, C_2H_3Cl (Synonyms: chloroethene, chlorethene, chlorethylene, chloroethylene, ethylene monochloride, VC, vinyl chloride monomer [VCM_6]) *Amount reportedly released from Pančevo: 1,500 tons*	Vinyl chloride is used in the manufacture of polyvinyl chloride (PVC), a resin used in many plastic and vinyl products including pipes, packaging, wire coating, upholstery, and housewares. The use of vinyl chloride as an aerosol propellant and in drug and cosmetic products was banned in the U.S. in 1974.	• Highly flammable, explosive, reactive, colorless, man-made liquid or gas with mildly sweet odor • Slightly water soluble • Produces poisonous gases in fire, including phosgene, carbon monoxide and hydrogen chloride gas	• The U.S. Department of Health and Human Services has determined that vinyl chloride is a known human carcinogen and that exposure results in liver cancer in people. • Breathing high levels can cause dizziness, unconsciousness, and death • People who work with VC have developed damage to the liver, nervous system and immune system • Animal studies show that long-term exposure can damage the sperm and testes, harm unborn offspring, and cause miscarriages	• OSHA PEL: TWA 1 ppm; ST 5 ppm • NIOSH REL: "Lowest reliably detectable level" • NIOSH IDLH: No data provided • EPA requires that VC in drinking water not exceed 2 ppb

ACRONYMS

ATSDR Agency for Toxic Substances and Disease Registry, an agency of the U.S. Department of Health and Human Services directed by congressional mandate to perform specific functions concerning the effect on public health of hazardous substances in the environment, including information development and dissemination concerning hazardous substances.

C Ceiling value, or maximum concentration recommended at any moment. It is recommended this value should not be exceeded even once during a work shift (or other specified period of time).

EPA U.S. Environmental Protection Agency

FDA U.S. Food and Drug Administration

mg/m^3 milligrams per cubic meter

NIOSH IDLH Immediately Dangerous to Life and Health, as defined by the National Institute for Occupational Safety and Health (U.S.)

NIOSH REL National Institute for Occupational Safety and Health Recommended Exposure Limit (U.S. recommended limit), based on a 10-hour workday, assuming a 40-hour work week.

OSHA PEL Occupational Safety and Health Administration Permissible Exposure Limit (U.S. legal airborne limit), based on an 8-hour workday, assuming a 40-hour work week.

PCB Poly-Chlorinated Biphenyl

ppb parts per billion

ppm parts per million

ST Short-term (15 minute) exposure limit. In other words, the time-weighted average concentration exposure limit in inhaled air over a period of 15 minutes.

TWA Time-weighted average. Exposure limit in inhaled air averaged over a specified period of time, usually an 8 or 10 hour work shift. Exposure limits can also be expressed over a specified period: 10 minutes, 15 minutes, 1 hour, etc.

SOURCES: Stan Roach, *Health Risks from Hazardous Substances at Work: Assessment, Evaluation and Control*, Pergamon Press: Oxford (1992), pp.127-145; International Programme on Chemical Safety and the Commission of the European Communities, *International Chemical Safety Cards* [for Ammonia (anhydrous), 1,2-Dichloroethane, Polychlorinated Biphenyl (Aroclor 1254), Phosgene, and Vinyl Chloride], http://www.cdc.gov/niosh/ipcsneng/nengsyn.html (observed June 22, 1999); New Jersey Department of Health and Senior Services, *Hazardous Substance Fact Sheets* (for Ammonia, 1,2-Dichloroethane, Polychlorinated Biphenyls, and Vinyl Chloride), http://www.state.nj.us/health/eoh/rtkweb/rtkhsfs.htm (observed June 22, 1999); *ATSDR ToxFAQ for 1,2-Dichloroethane* (September 1995), *Poly-Chlorinated Biphenyls* (September 1997), and *Vinyl Chloride* (September 1997), http://www.atsdr.cdc.gov/toxfaq.html (observed June 28, 1999); website of C.F.C. Reclamation & Recycling Service, Inc., http://www.c-f-c.com/specgas_products/phosgene.htm (observed June 28, 1999); *ATSDR Public Health Statement: Ammonia*, December 1990; *Toxicological Profile for Vinyl Chloride (Update)*, ATSDR, September 1997, p. 150.

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> standards, such as those of the IAEA … As a result, some of the VVER 440-230s have been shut down (in Russia and Armenia and also in eastern Germany). [NAS, *Management and Disposal of Excess Weapons Plutonium: Reactor-related Options* (National Academy Press: Washington D.C., 1995, p. 136)]

In addition to the inherent design flaws of the reactors, over $100 million dollars has been spent on Kozloduy units 1–4 since the early 1990s to try to remedy serious deficiencies in the physical condition and operation of the reactors. International assistance paid for upgraded safety and other physical systems and improvements in operations and management. Despite this, the European Union has been pushing for the early shutdown of the reactors. This would mean closing the first two units by 2002 or earlier and units three and four a few years ahead of their scheduled 2010 and 2012 closures.

TABLE SOURCES: National Public Radio, All Things Considered, May 24, 1999; Federation of American Scientists Public Interest Report, May/June 1999, p. 12; Chris Hedges, "Serbian Town Bombed by NATO Fears Effects of Toxic Chemicals," *The New York Times*, July 14, 1999.

TABLE 3. ELECTRICITY PRODUCTION IN BULGARIA

Electricity Production (1996 est.)	41.6 billion kWh
Electricity Consumption per capita (1996 est.)	5,000 kWh
Total Installed Generating Capacity (1996)	12,000 MW
Thermal-Fired Plants	7,400 MW (62%)
Nuclear Plants	3,760 MW (31%)[a]
Hydroelectric Plants	840 MW (7%)
Nuclear Plant Operator	National Electric Company
Nuclear Regulatory Authority	Committee on the Use of Atomic Energy for Peaceful Purposes

[a] According to International Nuclear Safety Program at Pacific Northwest National Laboratory, "[I]n 1997, nuclear power supplied 45 percent of the country's electricity. However, at times that share has often risen to nearly 50 percent because fossil fuel power plants and hydropower plants have not achieved expected outputs." (http://insp.pnl.gov:2080/?profiles/ceec/bulgaria_intro)

NOTE: In order to operate reliably without blackouts and brownouts, an electric power system needs roughly 20 percent capacity above its peak load.

TABLE 4. BULGARIA'S NUCLEAR REACTORS AT KOZLODUY

Unit	Reactor Model	Net Output	Initial Criticality	Commercial Start
Unit 1	VVER-440/230	400 MWe	6/1974	12/1974
Unit 2	VVER-440/230	400 MWe	8/1975	12/1975
Unit 3	VVER-440/230	400 MWe	12/1980	1/1981
Unit 4	VVER-440/230	400 MWe	4/1982	8/1982
Unit 5	VVER-1000	910 MWe	11/1987	9/1988
Unit 6	VVER-1000	910 MWe	6/1991	12/1993

Reactor Supplier: Atomenergoexport (USSR)
Type of Reactors: Pressurized Water
Moderator: Light Water
Fuel: Low Enriched Uranium
Fuel Supplier: Russia

Spent Fuel Management: Storage. In the past spent fuel has been sent to Russia for reprocessing. A new agreement on reprocessing is being held up by disputes over pricing and shipment routes as well as due to opposition.

SOURCE: International Nuclear Safety Program, Pacific Northwest National Laboratory (http://atom.pnl.gov:2080/); Oleg Bukharin, personal conversation, June 15, 1999; Michael Marriotte, personal conversation, June 17, 1999.

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composition, as well as in their form of storage—merits special attention. Liquid wastes are classified primarily according to their origin, the primary form of their contamination, their radioactivity (low-level, medium-level, and high-level), and by their saturation with salts. Some are stored in metallic and cement tanks, others in surface pools and reservoirs, and a large volume is injected into underground layer-collectors (see box on below). Some are even stored on ships and barges.

A number of management techniques have been tried for liquid radioactive wastes. Methods that have been developed include purifying and concentrating with subsequent solidification and then bituminization or cementification. For medium-level wastes (containing transuranic elements) and high-level wastes, technologies of encasing wastes in mineral-like matrices and of mixing radionuclides with molten glass and pouring the mixture into metal canisters are used. These technologies have been developed at nuclear power stations and at the Mayak plant, borrowing broadly on international expertise.[3] Technologies from non-nuclear applications are being implemented on wastes (including liquid wastes) at the Moscow and Leningrad "Radon" low-level waste facilities. The volumes involved are relatively large—the Moscow facility receives 2000 cubic meters (m^3) of liquid wastes per year.

Managing liquid waste continues to be a pressing problem at nuclear power plants. The amount of waste produced depends on the type of reactor: graphite-moderated RBMK type reactors produce 100,000 m^3 of

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CONCENTRATIONS AND RADIOACTIVE CONTENT OF LIQUID WASTES IN RUSSIA

Mayak, Chelyabinsk region[a]

- High-level wastes: 11,120 cubic meters (m^3) of solutions with an activity of 258 million curies (Ci), and 18,650 m^3 of pulps with an activity of 131 million Ci are stored in:
  - 20 containers with volumes up to 300 m^3 each
  - 20 concrete tanks each with a capacity of 1100 m^3
  - 61 tanks with nitric acid materials
- About 1700 m^3 of high-level liquid wastes with an activity of 200 million Ci have been vitrified.
- Medium-level liquid wastes are located in reservoirs Nos. 2,3,4,10, and 11, with a combined area of 84 km^2, and an activity of 394 million Ci.
- Lake Karachai (Reservoir No. 9) contains 120 million Ci.
- Staroe Boloto (an artificial lake) contains 35,000 m^3 of liquid wastes, with an activity of 2 million Ci.

Siberian Chemical Plant, Tomsk Oblast[b]

- Pools 1 and 2 have an area of 75,000 m^2, and contain 180,000 m^3 of liquid wastes with 126 million Ci. There is indication of high levels of plutonium in the wastes. Remediation of the pools has consisted of filling them in with soil.
- Underground storage (deep-well injection): 33–36 million m^3. Low-level wastes are at a depth of 240–290 meters, medium- and high-level wastes 310-340 meters. The original activity of the wastes is estimated to have been 1.1 billion Ci.

Mining and Chemical Plant, Krasnoyarsk region[b]

- Steel tanks (300 m^3 and larger) contain 6500 m^3 of liquid wastes, 110 million Ci.
- Four reservoirs. Activity of 5000 Ci.
- Four open pools with 50,000 m^3 of wastes, 20,000 Ci.
- Underground storage facility "Severny." Since 1963, 4.5 million m^3 of liquid wastes have been injected at a depth of 190–475 meters, 700 million Ci.[c]

National Research Institute of Nuclear Reactors, Dmitrovgrad[b]

- Injection of 2 million m^3 of liquid wastes with activity of 90,000 Ci.

SOURCES: *Bellona Working Paper*, 1995 No. 4; V. I. Bulatov, *Radioactive Russia* (Novosibirsk: TsERIS, 1996); Don J. Bradley, *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union*, (Battelle Press: Columbus, Ohio) 1997, p. 490; and Anatoli Diakov, "International Reprocessing Report: Russia," *Energy & Security*, No. 2, 1997.

a Figures are decay-corrected (adjusted for reduction of radioactivity with time as the radionuclide decays) and include the daughter products of strontium-90 and cesium-137.

b Figures not decay-corrected

c An alternate estimate gives an original activity of about 1 billion Ci, with a current activity of about 450 Ci (Bradley, p. 490).

TABLE 1. RADIOACTIVE WASTES STORED AT SITES OF VARIOUS MINISTRIES IN RUSSIA[a]

Source of wastes	Type of waste	Volume, cubic meters (m^3)	Activity, curies (Ci)	Place of storage
Minatom sites				
Extraction and mining	Mine and mill tailings (low-level)	1.0×10^8	1.8×10^5	Tailings storage and piles
Uranium enrichment and fuel fabrication	Liquid and solid (low-level)	1.6×10^6	4.0×10^3	Tailings storage, warehouses and sites
Energy production at nuclear reactors	Liquid concentrates (medium-level)	1.5×10^5	4.2×10^4	Tanks, storage facilities at power plants
	Solid (low- and medium-level)	1.2×10^5	1.0×10^3	Storage facilities at power plants
	Hardened/solidified (medium-level)	1.6×10^4	1.0×10^3	Storage facilities at power plants
Fuel reprocessing and production of weapons materials[b]	Liquid (high-level)	2.5×10^4	5.7×10^8	Tanks at Tomsk-7, Krasnoyarsk-26, Mayak (Chelyabinsk-65)
	Vitrified (high-level)	9.5×10^3	2.0×10^8	Storage facility at Mayak
	Liquid (low- and medium-level), including pulp	4.0×10^8	7.0×10^8	Tanks, reservoirs, pools
	Solid (low- and medium-level)	1.0×10^8	1.2×10^7	Above-ground storage at sites
Ministry of Defense				
Operation of nuclear submarines	Liquid (low-level)	1.4×10^4	1.8×10^2	On- and offshore bases
	Solid (low-level)	1.3×10^4	8.0×10^2	Onshore storage facilities
Ministry of Transportation				
Operation of nuclear icebreakers and container ships	Liquid (low-level)	3.9×10^2	0.6	Onshore storage facilities
	Solid (low-level)	1.36×10^3	2.1×10^2	Onshore storage facilities
	Solid (high-level)	1.04×10^2	2.0×10^4	Onshore storage facilities
State Committee on Defense Industries				
Construction and use of nuclear submarines	Liquid (low-level)	2.5×10^3	5.0×10^2	On- and offSshore bases
	Solid (low-level)	1.5×10^3	1.0×10^2	Storage facilities at sites
Ministry of Building/Construction				
Use of radioactive sources	Liquid, solid, and solidified wastes, encapsulated sources of ionizing radiation	2.0×10^5	2.0×10^6	"Radon" facilities

SOURCE: *Bulletin of the Center for Public Information on Atomic Energy*, No. 6, 1996, p. 14.

[a] We have omitted totals, given in the original source as $\sim 2.4 \times 10^5$ m^3 volume and $\sim 2.1 \times 10^9$ Ci activity, because they do not represent the sum of the figures given in this table and we were unable to determine on what they are based.

[b] Figures for liquid wastes do not include large quantities that were injected underground or otherwise discharged into the environment (see box, p. 15).

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liquid wastes per year; light-water VVER type reactors, 40,000 to 135,000 m^3. In total 1.7 million m^3 of liquid wastes are produced annually. The overwhelming portion of these wastes, supposedly harmless, are poured into open reservoirs. Tanks of liquid wastes at nuclear power plants contain ion exchange resins, contaminated filter materials, waste treatment sludges, and decontamination solutions.

As of January 1, 1995, more than 150,000 m^3 of liquid radioactive waste were stored at nuclear power plants in Russia (see Table 2 on page 17).[4] It is officially acknowledged that no nuclear power plant in Russia has adequate facilities for the treatment of liquid wastes. Treatment centers are only in the planning stages, and liquid waste storage facilities are filled almost to the brim. Injection of low- and medium-level wastes into underground collection layers is also being considered at some nuclear power plants.

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TABLE 2. LIQUID WASTES STORED AT NUCLEAR POWER PLANTS IN RUSSIA

Nuclear power plant	Amount (in thousands of m^3)	Activity (in thousands of curies)
Kursk	48.0	13.5
Smolensk	14.0	4.1
Novovorenezh	7.7	2.2
Kalinin	2.6	0.8
Kola	65.0	19.0
Balakovo	2.7	0.8
Beloyarsk	4.9	1.4
Bilibin	0.7	0.2
Leningrad	11.5	data not available
Total	**157.1**	**>42**

TABLE 3. STATUS OF RADIOACTIVE WASTES FROM SPENT FUEL REPROCESSING AT RT-1, MAYAK

Waste category	For entire period of plant operation (1978–1993)	1994–1995	1996–2000	After 2000	Comments
High-level	11,050 m^3 in tanks (~3 million Ci) 1700 m^3 in vitrified blocks (200 million Ci)	520 m^3 in vitrified blocks	300 m^3 in vitrified blocks	72 m^3 in vitrified blocks	Storage in special above-ground facilities with final disposal in geologic formations
Mid-level	19,000 m^3 pulp (in tanks; 140 million Ci)	16,000 m^3 in liquid (released into Reservoir No. 9, Karachai)	2000 metric tons bituminized blocks	1000 metric tons bituminized and cement blocks	Above-ground storage facilities for barrels(200 liters) with bituminized compounds
Low-level	Dumped in reservoirs with partial purification	500,000 m^3 (dumped in non-flowing reservoir after purification)	Treatment with recycling of purified water		Treatment with ion-exchange filters
Solid (mostly low-level)	50,000 metric tons (without processing)	3,000 metric tons (without processing)	Compacting of wastes (incineration, pressing) with reduction of volume by 5–10 times		Surface on-site concrete storage facilities

SOURCE: *Bulletin of the Center for Public Information on Atomic Energy*, 1996, No. 10–11, p. 30.

Spent fuel and liquid waste: "Siamese twins"

Minatom's commitment to a closed fuel cycle involves a policy to reprocess irradiated fuel, which results in the production of large volumes of liquid waste. The volume of these stored liquid wastes at radiochemical facilities is currently calculated to be 25,000 m^3 of highly-radioactive wastes (in steel tanks) and 400 million m^3 medium- and low-level wastes (in tanks, reservoirs and pools). Medium- and high-level liquid wastes are concentrated by evaporation and stored in the form of concentrates, pulp, ion-exchange resins and filter-materials in stainless steel and re-inforced concrete tanks. Some of the medium-level pulps are cemented and bituminized. The volumes of low-level liquid wastes are so great that treatment of all of them is simply impossible. "Remediation" of pools and reservoirs containing these wastes is accomplished by filling them in with cement blocks, rocks, soil, crushed rock, or mud.

> It is officially acknowledged that no nuclear power plant in Russia has adequate facilities for the treatment of liquid wastes.

As of January 1, 1995 the amount of spent fuel in Russia was estimated to be 9,335 tons with an activity of 4.65 billion curies. Subtracting the 6,100 tons of RBMK fuel rods (which are not reprocessed) leaves 3,500 tons, including the 270 tons that have been generated between January 1995 and August 1998, slated for reprocessing at "Mayak" (Chelyabinsk-65) where the RT-1 plant is located. Reprocessing one ton of spent fuel generates 45 m^3 high-level, 150 m^3 medium-level and 2,000 m^3 low-level liquid wastes.

High-level reprocessing wastes have been treated in

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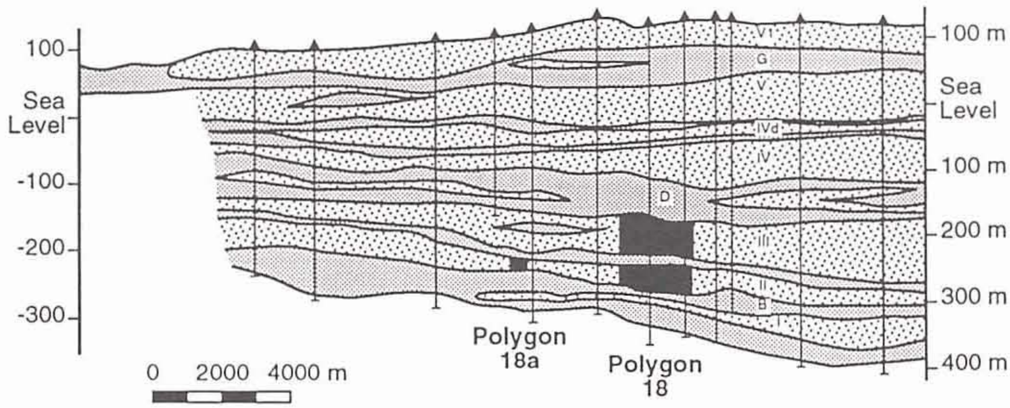
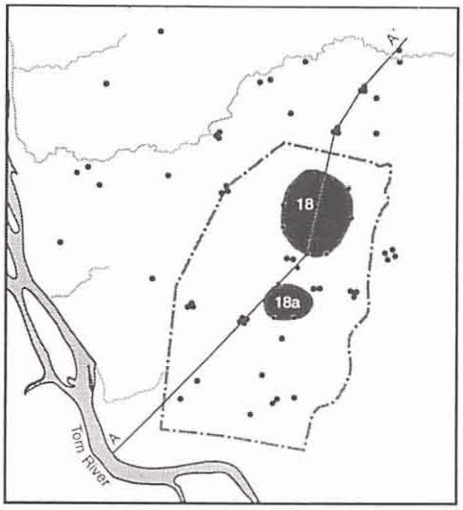
INJECTION AREA (POLYGON) AT TOMSK-7





The injection polygon at Tomsk-7 showing the two injection regions and a cross-section of the layered injection scheme for low-, medium-, and high-level radioactive liquid waste.

REPRINTED WITH PERMISSION FROM: Don J. Bradley, *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union* (Columbus, Ohio: Battelle Press, 1997), p. 211.

KEY

- Region of Injection
- Boundary of Polygon
- Observation Wells
- Stratigraphic Index

SOURCES: Don J. Bradley, *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union* (Columbus, Ohio: Battelle Press, 1997); *Atlas of the World*, Sixth Edition (Oxford University Press, Inc.: New York), 1998.

RUSSIA

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many different ways over the last several decades. From March 1949 to November 1951, high-level reprocessing wastes at Mayak (then a military facility which produced plutonium for nuclear weapons) were dumped into the Techa River. Within this period, 2.8 million curies of radioactivity were released into the river, as a result of which 124,000 people in 41 settlements received radiation doses of various levels. Dumping of low- and medium-level liquid wastes in the Techa continued into the mid-1950s.

After 1951, high-level liquid wastes were stored in tanks. In 1957, one of these tanks exploded, with disastrous environmental consequences. After the explosion, research began on injection of wastes into underground "collection beds." The geology near the Mayak site was not considered suitable for this method of waste disposal, but large-scale use of deep-well injection began in the late 1960s at three facilities in Russia: Tomsk, Krasnoyarsk and Dimitrovgrad (see figure on page 18). A total of 46 million cubic meters of waste containing more than 2 billion curies of fission products have been injected into collection layers at liquid waste storage sites with an area of 24 square kilometers. The activity of the waste has decreased from its original level as a result of radioactive decay, and is now estimated at 800 million curies. Other hazardous wastes have been injected along with radioactive wastes.

Proponents of this method assure that the issue of deep underground storage of liquid wastes has been studied carefully and thoroughly, and is well monitored.[5] References are made to the Inter-Ministerial Commission on Geological Means of Securing Safety of Radioactive Waste Storage (chaired by the vice-president of the Russian Academy of Sciences, N. P. Laverov). It has declared that deep underground storage of liquid waste is acceptable and sufficiently safe.[6] Many geologists dispute this, and even N. P. Laverov has said that "direct disposal of liquid wastes is obviously more dangerous than that of solid wastes. Therefore solidification of liquid wastes is at the present time a general means of increasing safety of their storage."[7]

The scientific community does not have access to information about injection of radioactive wastes, and no independent expert analyses of this technology exist. Inquiries usually receive the response that "research is being conducted into injection of waste in deep underground earth layers, including some relating to 'conservation technologies.'"[8, 9] It is said that discussion of this

The scientific community does not have access to information about injection of radioactive wastes, and no independent expert analyses of this technology exist.

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RUSSIA

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would "exert a negative influence on the choices for the optimal development of atomic energy" and even "ensuring military preparedness."[10] Another reason for concealing the scale of this activity is the following, unfortunately very real, fact: the transition from underground injection of liquid wastes to an alternative method of waste management requires significant financial resources and capital investments.[8] Injection of liquid radioactive wastes of varying activity levels continues, in violation of environmental protection laws.

Injection of liquid radioactive wastes of varying activity levels continues, in violation of environmental protection laws.

More recently at Mayak, high-level liquid wastes have been evaporated, fractionated, and then vitrified. So far, almost 13,000 m^3 have been treated, producing 2,188 tons of vitrified material. Since the melter at the vitrification facility was shut down in 1997, having operated twice as long as its design lifetime, the most dangerous high-level liquid wastes have again been stored in tanks. Start-up of a new vitrification facility has been held up for financial and environmental reasons.

Medium-level wastes at Mayak are concentrated by evaporation and disposed of in above-ground reservoirs. The infamous Lake Karachai is one such reservoir—120 million curies were dumped into it during the reprocessing of only 150-250 tons of spent fuel. It is not clear what will be done with future medium-level reprocessing wastes, since the situation at Karachai is already disastrous. Additional hundreds of millions of curies of medium-level wastes are contained in other reservoirs (see Table 3, page 17).

In the cascading reservoirs at Mayak, 400 million m^3 of low-level wastes with an activity of long-lived beta-emitting radionuclides of 300,000 curies have accumulated. Already, filtration from the reservoirs into the groundwater (10 million m^3 per year) has contaminated a volume of 3.5 million to 5 million m^3 of water with an activity of 0.9 million curies. The contamination has spread to a depth of 100 meters with an area of 10 km^2, in the direction of the Mishelyak River. Strontium-90 contamination is spreading at a rate of 84 meters/year; cobalt-60, 51 meters/year.[8,10]

Filtration from the reservoirs and the potential for their overflow due to catastrophic floods, similar to those which occurred in some regions in spring-summer 1998, could cause a breach in the last dam of the reservoir cascade and the release of more than 200 million m^3 of contaminated water into the hydrologic system of the Techa River. According to some estimates, 215 million curies would end up in the Ob River (a major Siberian river into which the Techa River flows. The Ob, in turn, flows into the Arctic Ocean).

The ability of Mayak to reprocess additional spent fuel, considering the waste already accumulated, is reduced. The first task should be to treat existing waste, using the experience gained to date and existing technologies.

Naval operations and underground explosions

Two other areas of nuclear operations have produced significant quantities of liquid wastes: nuclear submarines and underground nuclear explosions. Operation of nuclear submarines in the military and civilian nuclear fleets presents a number of pressing problems in the northern and far eastern regions of Russia, where there is an insufficient capacity for nuclear waste management.[9] Since ocean dumping was halted, wastes have been steadily accumulating in these regions.[11] The last dumping of liquid wastes into the Sea of Japan (400 m^3, with an activity of 0.38 curies) occurred in September 1993.

A total of 10,000 to 12,000 m^3 of liquid radioactive wastes is produced every year at naval facilities. Of this, 40 percent is from the Pacific Fleet. The specific activity of the wastes is from 10^{-7} to 10^{-2} curies/liter. Ten percent of these wastes have an activity at the higher end of this range, from 10^{-3} to 10^{-2} (0.001 to 0.01) curies/liter.

Operation of nuclear submarines presents a number of pressing problems in the northern and far eastern regions of Russia.

A portion of the liquid wastes generated by the military fleet (1,000-1,500 m^3) are treated at the "Atomflot" liquid waste treatment plant in Murmansk. More than 2,500 m^3 of liquid wastes have collected at the submarine construction center at Severodvinsk, where all of the storage tanks are full. Five underground tanks for liquid wastes are located at Andreeva Bay.[12]

The "Onega" and "Amur" tankers were to be designated for the transport of liquid wastes to onshore purification plants (coagulation and evaporation), and the resulting concentrates were to be stored in special tanks. However, the program for processing naval liquid wastes has been stopped: the shoreline facilities have not been built and processing facilities on the tankers are not operating. "Atomflot" could meet the needs of the civilian and the Northern fleets if a new purification plant were put into operation. Treatment of an additional 6,000 m^3 year would help address the

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problems of liquid wastes for all nuclear ships of the Northern region—financing is all that is needed.

The Murmansk shipping company has five nuclear-technical servicing ships. These are the "Imandra" (12 liquid wastes tanks), "Lotta," "Lepse" (one liquid waste tank) and "Volodarskii" floating storage facilities, and the "Serebryanka" tanker for liquid waste storage and floating radiation measuring and control points. Nuclear submarines are serviced by several dozen barges.

A volume of 8000 m^3 of liquid wastes of varying activity and levels of salination have been collected from the Pacific Fleet. Three of five tankers are filled, and one is not operational. There are also four overflowing floating facilities for storage of spent fuel and liquid radioactive wastes, as well as small tankers. Onshore storage facilities, primarily three aging tanks at the Shkotovo-22 site at Sysoev Bay, are filled. There is interim liquid waste storage in Primore and Kamchatka.[13]

The most serious problem with liquid radioactive wastes from the naval fleets are being addressed with international help, including financing from Finland, Norway, and Japan.

Russia has no unified government policy for liquid waste management.

The question of liquid wastes formed in the cavities from underground nuclear explosions remains practically unnoticed. Studying this question would show that the cavities and surrounding areas, concentrated with significant volumes of contaminated masses, classify as long-term nuclear waste sites.[14] Leakage from these areas has impacted Prikame, Sakha (Yakutia), Astrakhan and Tyumen regions.

Conclusion

The federal program on "Management of radioactive waste and spent nuclear materials, their use and storage 1996–2005" has established that existing waste management capacities are not sufficient for treatment and reliable isolation of existing and newly generated spent fuel and liquid wastes. The amount of liquid waste is increasing not only through reprocessing of spent fuel, but also as a result of the decommissioning and dismantlement of nuclear power plants. The number of power plants that will be decommissioned will soon sharply increase, but this point is not currently taken into consideration by the Russian government.

Without having the means of guaranteeing environmental security and safe storage of existing spent fuel, Minatom publicly advocates reprocessing of spent fuel. But as this review shows, there is no unified government policy for liquid waste management.

1 Valery I. Bulatov is a well-known independent expert on Russian radioactive waste problems. He is a member of the International Union of Radioecologists, the Russian Geographical Society, and the Siberian Ecological Fund.

2 *Bulletin of the Center of Public Information on Atomic Energy*, No. 7–8, 1997, p. 15.

3 V. I. Bulatov, ed., *Radioactive Wastes: Environmental Problems and Management, Bibliographic Review*, Parts 1–3 (Novosibirsk: Russian Academy of Sciences, 1998).

4 *Bulletin of the Center of Public Information on Atomic Energy*, No. 7, 1996, p. 21.

5 *Deep underground storage of liquid radioactive wastes*, (Moscow: IzdAT) 1994, p. 256.

6 *Bulletin of the Center for Public Information on Atomic Energy*, 1996, No. 6, p. 17.

7 *Citizens' Initiatives*, No. 1, 1998, p. 2.

8 V. Larin. *Bulletin of the Center of Public Information on Atomic Energy*, No. 2, 1998, pp. 37-50.

9 V. F. Menshikov, *Nuclear Control*, No. 32–33, 1997, pp. 31–38.

10 *Bellona Working Paper*, 1995 No. 4, p. 35

11 *Facts and Problems Connected to Disposal of Radioactive Wastes in the Seas Bordering the Territory of the Russian Federation*, Moscow, 1993, p. 108.

12 V. F. Menschikov, *Nuclear Control*, No. 32–33 (1997), pp. 31–38; Yadernaya Bezopasnost, No. 2 (1997), p. 4.

13 J. Handler, *The Pacific Fleet: Radioactive Wastes, Operation of Nuclear Submarines, Submarine Accidents, and Nuclear Fuel Safety*, Greenpeace Report, 1995, p. 51.

14 B. A. Bachurin. *Underground Nuclear Explosions in Oil Production Areas of Perm Prikamya: Radiological Aspects: Safety Issues for Development of Fossil Fuel Deposits in Urban and Industrialized Areas.* Ekaterinburg: UroRAN, 1997, pp. 420–427.

It pays to increase your jargon power with Dr. Egghead

ANDRA

a. The feminine form of the Norwegian name Anders.

b. An Egyptian word meaning "and Ra" to avoid going through the list of all the deities.

c. The female android with whom R2D2 falls in love in the movie *The Phantom Menace*.

d. Agence nationale pour la gestion des déchets radioactifs, the national waste management agency of France.

Bituminization

a. The process of reducing the volume of bite-size objects.

b. The fusing together of two small tumors.

c. New treatment for dog bites, created especially for postal workers.

d. In the context of nuclear waste management, the incorporation of liquid radioactive waste into asphalt-like material.

PCBs

a. Abbreviation for Peas, Carrots and Broccoli.

b. In entymology, acronym for Pretty Cool Bumblebees.

c. Personal Computers of category B.

d. Poly-Chlorinated Biphenyls, a family of man-made chemicals known for their lubricating and insulating properties and used in transformers and other electrical equipment. The manufacture of PCBs stopped in the U.S. in 1977 because of evidence that they accumulate in the environment and could cause human health hazards, including possibly skin lesions, damage to the skin and nervous system, and liver cancer.

Teratogenic

a. Originally "Terre à Togenik," an expanse of land discovered by the Viking explorer Togenik.

b. Genetically modified dirt.

c. A term used to describe a person who is always "biting the dust."

d. Describes substance that causes birth defects by damaging the fetus.

VVER

a. What IEER used to be called.

b. The Russian version of the television show ER.

c. Very Very Excellent Return, term used by financial analysts.

d. The Russian acronym for pressurized water reactors. There are several models that have been built. Older VVERs, called VVER 440/230s, have no secondary containment.

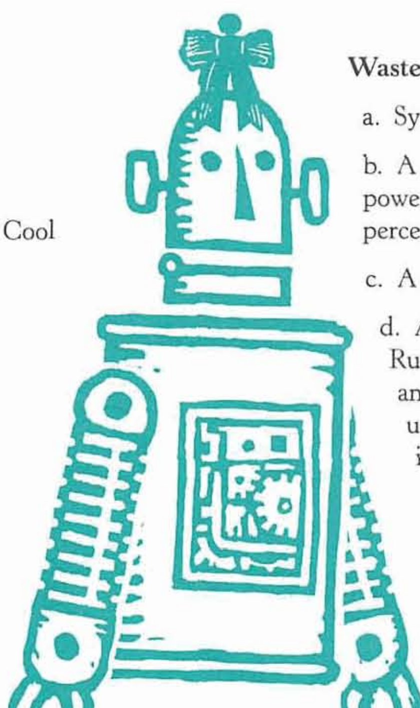
Waste injection

a. Synonym for toilet flushing.

b. A household appliance which increases the power of the home garbage disposal 250 percent.

c. A self-destructive drug habit.

d. A nuclear waste management practice in Russia involving the insertion of radioactive and other hazardous liquid waste deep underground. Large-scale use of waste injection began in the late 1960s at three facilities in Russia—Tomsk, Krasnoyarsk and Dimitrovgrad. The practice continues today. In the past, waste injection was also used in the U.S., notably at the Department of Energy's Oak Ridge facility in Tennessee.



Andra the Android

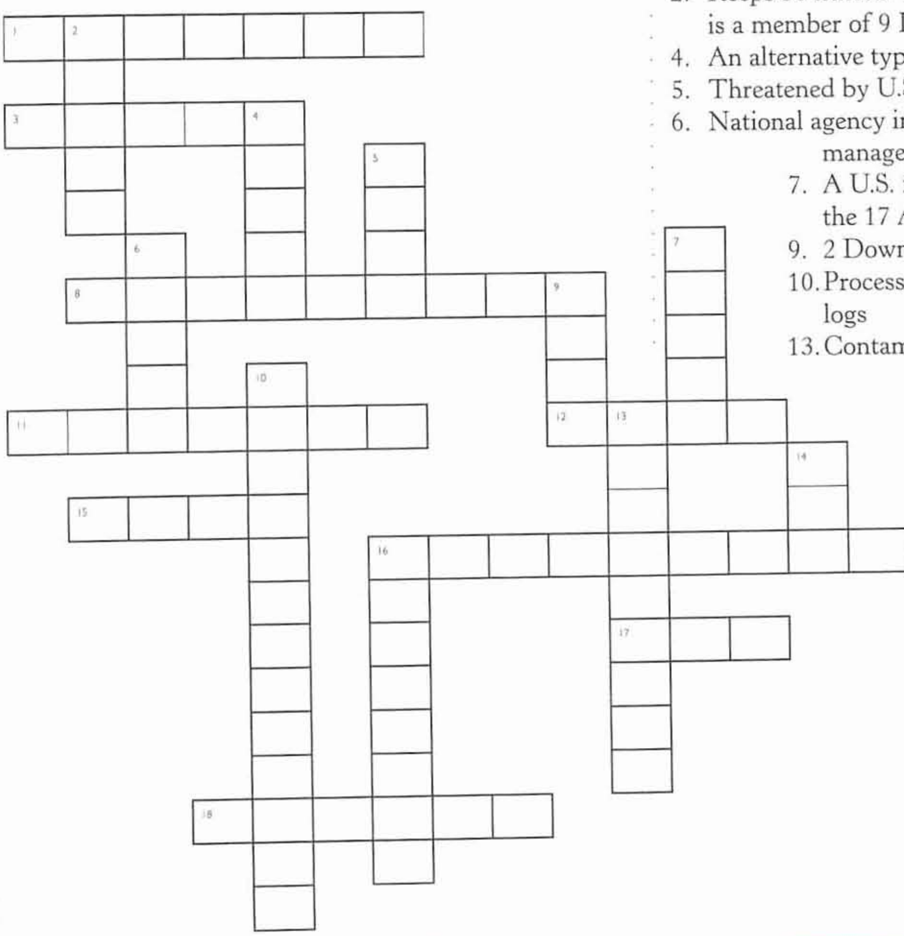
ANSWERS: d, d, d, d, d

Sharpen your technical skills with Dr. Egghead's Atomic Puzzler

Gamma is back! Dr. Egghead's trusty dog Gamma has returned from a stint as Citizen Inspector at the opening of the Waste Isolation Pilot Plant near Carlsbad, New Mexico. Because Gamma is cross that WIPP has opened despite evidence that it may accept hazardous waste without the required permit (see *SDA* vol. 7 no. 2, January 1999), he has created a special cross-word puzzler for SDA readers.

Across

1. A substance used to solidify liquid radioactive waste
3. These are used to store liquid radioactive waste
8. Russian liquid radioactive waste management method
11. Hard rock proposed as suitable for a geologic repository for radioactive waste
12. A U.S. federal body which enforces the 17 Across for chemicals like 16 Down
15. Type of Russian nuclear reactor
16. Mayak was the site for production of this element for the Russian nuclear weapons program
17. Concentration limit based on the level of exposure averaged over a period of time
18. Where to find 11 Across in France



Down

2. Keeps 30 nuclear weapons on its territory because it is a member of 9 Down
4. An alternative type of material to 11 Across
5. Threatened by U.S. and French laser fusion programs
6. National agency in charge of radioactive waste management in France
7. A U.S. federal body which recommends the 17 Across for chemicals like 16 Down
9. 2 Down is a member
10. Process to solidify liquid waste into glass logs
13. Contamination from this fission product is spreading from Mayak and threatens the Mishelyak river
14. Nuclear weapons usable material present at the Yugoslavian nuclear research institute
16. The 17 Across for this World War I chemical warfare agent is 0.1 ppm

See page 24 for answers to recent Puzzlers.

Send us your completed crossword puzzle via fax (301-270-3029), e-mail (ieer@ieer.org), or regular mail (IEER 6935 Laurel Ave., Suite 204, Takoma Park, MD 20912 USA), postmarked by **August 31, 1999.** IEER will award 25 prizes of $10 each to people who send in a completed puzzle (by the deadline), right or wrong. There is one $25 prize for a correct entry, to be drawn at random if more than one correct answer is submitted. International readers submitting answers will receive a copy of the 1999 revision of IEER's report *The Nuclear Power Deception* in lieu of a cash prize, due to conversion rates.

FRANCE

FROM PAGE 5

France. Opponents of deep underground storage of waste argue that the waste should be retrievable in case of possible future technological advances allowing a better solution. The Green party has argued that the government's decision was a political one, made under heavy pressure from the nuclear industry. They fear that political pressure will cause a permanent repository to be sited at one of the two laboratories. Furthermore, there are fears that the Meuse site, because of its location close to France's borders, could become a dumping ground for waste from other European countries, particularly Germany.

1 Mary Byrd Davis is the director of the Yggdrasil Institute and the vice-president of the French Centre de documentation et de recherche sur la pax et les conflits (CDRPC). She is the author of numerous books and articles on commercial and military nuclear issues.

2 Stockage en profondeur des déchets radioactifs. Présentation et contexte des travaux de reconnaissance géologique préliminaires (Conseil Supérieur de la Sûreté et de l'Information Nucléaire) Mai 1987, *La Gazette Nucléaire*, no. 75–76, mai 1987, pp. 19–20.

3 Karin Leigh, *Nuclear Fuel*, November 28, 1988, p. 7.

4 *Silence*, February 1990, p. 25.

5 Ann MacLachlan and Karin Leigh, *Nuclear Fuel*, October 17, 1988, pp. 6–7.

6 Christian Bataille, Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques, *Rapport sur la gestion des déchets nucléaires à haute activité*, Assemblée Nationale, No. 1839 (1990).

7 Ann MacLachlan, *Nuclear Fuel*, February 19, 1990, p. 5.

8 *Journel Officiel*, January 1, 1992.

9 Hélène Crié and Michèle Rivasi, *Ce nucléaire qu'on nous cache* (Paris: Albin Michel, 1998), pp. 219–21.

10 Quatre Départements en quête de laboratoires, *L'Environement Magazine*, January-February 1994.

11 Les Echos, July 5, 1995.

12 Midi Libre, 25 January 1995; *Le Vigneron*, June 13, 1996.

13 Commission Nationale d'Evaluation, *Réflexions sur la réversibilité des stockages* (June 1998), pp. 39–40.

14 Commission Nationale d'Evaluation, *Rapport d'évaluation, no. 2* (June 1996), pp. 61–62.

15 Commission Nationale d'Evaluation, *Rapport d'évaluation, no. 3* (September 1997), p. 88.

16 Christian Bataille and Robert Galley, Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques, *L'aval du cycle nucléaire, Tome I: Etude générale*, Assemblée Nationale, no. 978 (1998), pp. 125–29.

17 Institut de Protection et de Sûreté Nucléaire, *Rapport scientifique et technique 1997*, p. 152.

PAST PUZZLERS

Answers to Atomic Puzzler, *SDA* v6n4/v7n1 double issue, October 1998, "Gamma's New Job":

1. 2.72×10^{-12} J/reaction
2. 27.2 MJ
3. More
4. Yes
5. 12.95lb. TNT
6. More

Answers to Atomic Puzzler, *SDA* v7n2, January 1999, "Gamma at the Lab":

1. 2.56×10^{11} disintegrations/sec
2. 8.07×10^{18} disintegrations/yr
3. 4.52×10^{19} MeV/yr
4. 2.80×10^{20} molecules/yr
5. 36.16 mg/yr
6. 18.08 mg/kg (in one year)
7. Yes

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