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# Scientific and Technical Intelligence Report

## *Soviet Radioactive Waste Management*

Top Secret

OSI-STIR/TCS/75-20

September 1975

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# Soviet Radioactive Waste Management

*Project Officer* [redacted]

## PRÉCIS

An increasing accumulation of radioactive waste from its expanding nuclear power program and other sources will confront the Soviet Union in the relatively near future. Satisfactory methods must be developed for the management of these wastes over the long term to prevent unacceptable releases of radioactivity to the environment.

Soviet radioactive waste management practices, facilities, and research and development programs are described and evaluated in this report. Those low-level waste treatment and disposal facilities which have been visited by Westerners are adequate but not up to Western standards of construction or operation. The Soviets are doing research on all the standard methods of waste management, such as bitumenization and vitrification. They have developed and now advocate deep-well injection as a method for ultimate storage of low- and medium-level wastes and are even suggesting its use for future disposal of high-level wastes from reprocessed power reactor fuel. [redacted] For environmental reasons it is unlikely that the injection method will be acceptable in the West. Soviet high-level waste from plutonium production reactor fuel reprocessing is now stored in tanks as in the US. Low- and medium-level radioactive wastes resulting from naval nuclear operations are stored at several naval bases. A variety of special purpose barges are used in servicing nuclear vessels and handling these wastes.

# SOVIET RADIOACTIVE WASTE MANAGEMENT

*Project Officer*

[ ]

OSI-STIR/TCS/75-20
September 1975

CENTRAL INTELLIGENCE AGENCY
DIRECTORATE OF SCIENCE AND TECHNOLOGY
OFFICE OF SCIENTIFIC INTELLIGENCE

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# PREFACE

As worldwide nuclear power programs expand, the safe and economic management of large volumes of radioactive waste is a problem of special concern. It is estimated that over 99 percent of the radioactivity resulting from nuclear power-plant operation and spent fuel reprocessing will be contained in high-level liquid wastes. This waste will require long-term storage in some type of high-integrity containers or by encasing in a solid or some other safe method of storage until final disposal in a manner safe to the environment.

Plutonium and tritium production programs have been the principal sources of high-level radioactive waste in the past, particularly in the United States and USSR. Treatment and storage of these wastes have provided useful experience but many problems remain, and the question of ultimate disposal has not been resolved. Also, the management of low- and medium-level activity wastes has been under constant study and development in the US, the USSR, and other developed countries with nuclear programs.

In the USSR radioactive wastes are classified as:

(1) low level—below $1 \times 10^{-5}$ curies/liter (Ci/L) specific activity,

(2) medium level—from $1 \times 10^{-5}$ to 1.0 Ci/L, and

(3) high level—all exceeding 1.0 Ci/L.[1]

The purpose of this report is to describe and evaluate Soviet radioactive waste management processes, practices, and facilities, and to determine the status of the Soviet radioactive waste management research and development program. This report was prepared by the Office of Scientific Intelligence and coordinated within the CIA. Information available through January 1975 was used in its preparation. Additional information available through June 1975 was considered but did not alter the conclusions.

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# SOVIET RADIOACTIVE WASTE MANAGEMENT

## PROBLEM

To assess and evaluate the Soviet radioactive waste management program.

## CONCLUSIONS

1. Soviet low- and medium-level radioactive waste management techniques are generally adequate and are similar to those in use in the West. Some facilities observed by Westerners, however, have been found to be of shoddy construction. In some, housekeeping is poor and safety regulations are not always followed.

2. A waste injection technique has been developed and used in the USSR for disposal of low-level radioactive waste in deep, water-bearing geologic formations. The Soviets claim that this technique is now a technically proven, safe, and economical process for ultimate disposal of low- and medium-level wastes. But environmental considerations make it unlikely that this technique would be acceptable in the West in the foreseeable future.

[redacted] Although the Soviets consider this type of storage temporary because of the cost of long-term monitoring and the dangers of leakage due to corrosion or damage to the tanks, little if any spent nuclear-power reactor fuel has been reprocessed in the USSR so far.

4. The Soviets are aware that they will be confronted with the problem of managing large volumes of high-level radioactive waste as a result of their expanding nuclear power program. They are actively engaged in research on radioactive waste treatment and concentration methods that will permit safe ultimate disposal. Bitumenization and vitrification processes are under development. There is no evidence that they have planned to use or used ultimate repositories (such as salt mines).

[redacted]

## SUMMARY

The Soviets have a partly secret, partly open radioactive waste management program. Openly, they discuss, publish, and allow Westerners to visit some of their low-level radioactive waste treatment and disposal facilities. This waste is mainly derived from laboratory, hospital, and industrial use of radioactive isotopes. Also, treatment and disposal of low- and medium-level wastes from experimental and power reactors are discussed openly. And in recent years the Soviets have published research and plans for future management of high-level waste from the reprocessing of power-reactor fuel

Complete secrecy is maintained regarding the treatment, handling, or disposal of nuclear submarine-associated radioactive waste and of waste from plutonium-production reactors that are under the control of the Ministry of Medium Machine Building. The fuel cycle (reprocessing, refabrication, and waste management) is still considered classified by the Soviet Government.

About 20 standarized, low-level waste treatment and burial stations are said to be distributed throughout the USSR. Of these, the Zagorsk Waste Burial Station and the Moscow Central Radiation Safety Station are best known and have been visited frequently by Westerners. [redacted] The techniques used at these facilities are similar to those in the West and appear to be adequate. But building and bunker construction is shoddy, some of the buildings are small and poorly designed, and housekeeping is not up to Western standards. New construction being completed in 1974 at the Moscow station will provide improved research and development facilities there. The Soviets have safety regulations and requirements that appear on paper to be up to Western standards for radioactive waste management, but in actual practice they are careless in following their own regulations.

Well understood concentration methods—filtration, coagulation, centrifugation, evaporation, and ion exchange—are used by the Soviets in treating low-level wastes. Concentrates, ashes from incineration, and solid radioactive wastes are encased in concrete or mixed with cement slurries and buried in ditches or bunkers such as those seen at the Zagorsk site. Decontaminated waters, reported to be well below the maximum permissible concentration (MPC), are discharged to open ponds or the sewer. This effluent is apparently considered to be "nonradioactive" waste by the Soviets. The Moscow station dumps such effluent into the Moscow River. A pilot plant for bitumenization of low-level wastes has been in operation at Zagorsk since about 1970. The resulting bitumen blocks are stored in bunkers above ground water level and the surrounding area is monitored. The Soviets could encounter future leaching and soil contamination from runoff if they continue to use this technique.

Since 1963 the Soviets have been pumping low- and medium-level radioactive wastes into deep, water-bearing geologic formations at the Dmitrovgrad (formerly Melekess) Scientific Research Institute of Atomic Reactors (NIIAR) site on the Volga River. They claim to be the first in the world to develop this technique to commercial scale. Work began in 1963 and a pilot project was run between 1966 and 1970. During that period 320,500 cubic meters of radioactive waste were pumped into the earth. Injection has continued at this site up to the present. The Soviets claim that such wastes cannot harm the environment, because they are "safely insulated." Although the Soviets conceivably could dilute their high-level waste obtained from nuclear power reactor fuel reprocessing and inject it into deep geologic strata, there is no indication that they intend to do so.

[redacted] Viktor Spitsyn, director of the Institute of Physical Chemistry of the USSR Academy of Sciences, Moscow, is the principal Soviet spokesman advocating deep-well radioactive waste injection. His institute and others have cooperated with NIIAR in supporting research on deep-well injection. Good cooperation exists between the Academy of Sciences and the State Committee for Utilization of Atomic Energy on research and development in the field of radioactive waste management.

The Soviets express confidence that injected radioactive waste will not leach or seep into any domestic water supply. In 1972 they began discussing the possibility of injecting high-level radioactive waste into geological formations. Nevertheless, they probably have actually injected little if any high-level waste into the earth, in spite of a few statements made by research workers to that effect.

Leading Soviet scientists and administrators are concerned about the expected volume of high-level radioactive waste that will result from their expanding nuclear power program. Since little if any spent power reactor fuel has been reprocessed so far, the Soviets are not yet confronted with the problem of management and ultimate disposal of high-level waste in large volumes. [redacted]

[redacted]

Except for the suggested deep-well injection, which may prove impractical, the Soviets have said little about ultimate disposal of high-level wastes. Although they are aware of such techniques, they appear to have but slight interest in using salt mines, caverns, or cavities formed by underground nuclear explosions as waste repositories. They could be waiting for US decisions in this area before committing themselves.

[redacted]

Research underway in the USSR on radioactive waste treatment includes vitrification, bitumenization, and cementation methods of solidifying waste for long-term storage. A two-stage, fluidized-bed vitrification process has been tested to pilot-plant scale. Some studies on bitumenization of high-level wastes indicated a lack of understanding of the explosion dangers.

Various separation techniques are also being studied to remove fission products from waste solutions. These include ion exchange, electrophoresis, electrodialysis, reverse osmosis, and adsorption. A pulsed-column ion exchange facility at the Moscow Central Radiation Safety Station gave promise of increased throughput and efficiency in treating low-level wastes in 1974.

The propaganda value of radioactive waste disposal has not been missed by the Soviets. For home consumption they claim to be ahead of Western countries in treatment and disposal methods. They are more realistic in statements beamed to the West but take every opportunity to criticize the United States and United Kingdom, pointing to their own opposition to dumping radioactive waste at sea. They apparently justify dumping treated waste into rivers by classifying it as non-radioactive. The Soviets have also attempted to use international meetings on radioactive waste management for political purposes.

# DISCUSSION

## SOURCES OF RADIOACTIVE WASTE

Low- and medium-level wastes are being generated in the USSR as a result of the routine operation of nuclear power reactors or of research, test, and propulsion reactors (submarines and icebreakers). Also solid and liquid wastes are produced as a result of using radioactive sources at medical, research, university, and industrial facilities.[1]

In addition to low- and medium-level wastes, high-level radioactive waste is now being generated in the USSR primarily as a byproduct of plutonium/tritium production reactors and their associated fuel reprocessing plants

[redacted]

[redacted]

As is the case in the United States, the nuclear power program in the USSR will become its greatest source of high-level, long-lived radioactive waste in the future. In September 1974 at the Ninth World Energy Conference in Detroit, the Soviet Minister of Power and Electrification, Pyotr Neporozhyny, stated that the USSR now has 12 nuclear power reactors in operation and is planning and building 30 more. The growing role of nuclear power in the production of electrical energy in the USSR was most recently emphasized in speeches by both M. V. Keldysh, the president of the Academy of Sciences, and by V. A. Kirillin, Chairman, State Committee for Science & Technology, at the November 27 General Session of the USSR Academy of Sciences.[3] The Soviets are reported to have about 7,000 MWe of nuclear power planned for 1975 and 27,000 MWe by 1980.[4]

At present, little if any spent reactor fuel from the power reactors in operation at Beloyarsk, Novovoronezh, Shevchenko, Bilibino, Kola, Leningrad, and Dmitrovgrad (formerly Melekess) is being reprocessed.

Although the reprocessing of spent fuel elements from water-cooled, water-moderated power reactors has been discussed in Soviet research publications,[5-7] it is likely that only small amounts have been handled, possibly [redacted] where plutonium production reactor fuel is reprocessed. In 1972 A. N. Kondratiev, of the Radium Institute Imeni Khlopin, Leningrad, in summarizing the outlook for waste management in the USSR, discussed a future 5-ton/day, light-water reactor fuel reprocessing plant. He indicated that scale-up of a pilot plant process is expected by 1978-80.[8] In 1973 a Soviet delegate to the International Atomic Energy Agency (IAEA) indicated by questions and comments that the USSR was considering construction of a power reactor fuel reprocessing plant.[9]

The spent fuel elements probably are encased in noncorrosive sheaths and stored in sealed containers designed to dissipate the heat created by radioactive decay. As the Soviet nuclear power program expands and spent fuel reprocessing is undertaken to recover the uranium and plutonium, increasing amounts of high-level waste will require proper management. Therefore (as in the United States), the Soviets are not now confronted with the problem of treatment and ultimate disposal of large volumes of high-level radioactive waste, but they are acutely aware that this problem must be dealt with in the relatively near future.[5]

An additional radioactive waste load will result if the Soviets perform spent-fuel reprocessing services for foreign countries. They have indicated a willingness to negotiate contracts for such service with Western customers. The Soviets are already committed to reprocess fuel which they provide for reactors in East European countries and for reactors which they sell in the West.[10]

## LOW- AND MEDIUM-LEVEL RADIOACTIVE WASTE TREATMENT FACILITIES

The Soviets reportedly operate about 20 standardized low-level radioactive waste treatment and burial stations located at suitably remote sites [redacted] These were set up to handle liquid and solid wastes from medical, research, university, and industrial facilities within prescribed zones. The best known and reportedly largest facility of this type is the Zagorsk Waste Burial Station [redacted] about 145 km north of Moscow.[12 15 16] It is openly discussed in the Soviet press and technical literature and is used as a showplace for touring foreign delegations. The Zagorsk facility serves institutions in the Moscow area either directly or via the Moscow Central Radiation Safety Station, which functions primarily as a collection, treatment, and waste concentration point.[1 11] The Khar'kov Radioactive Waste Disposal Facility has also been visited.[15] [redacted]

[redacted]

[redacted]

## LOW- AND MEDIUM-LEVEL WASTE MANAGEMENT TECHNIQUES IN USE

The Moscow Central Radiation Safety Station is reported to be typical of regional radioactive waste collection stations in the USSR. It is located near the Institute of Atomic Energy imeni Kurchatov and may have been established originally to service that institute. At least since 1968 the station appears to be a part of the All Union Institute of Inorganic Materials that was set up to study design of fuel elements for nuclear reactors. The station, built in 1958, was visited by foreign delegations in 1964,[15] 1969,[16] and recently in 1974.[12] It is equipped to treat wastes of a specific activity below $1 \times 10^{-3}$ curies/liter, which are received from hospitals and research establishments. Capacity in 1974 was 500 cubic meters per day.[1]

Liquid wastes are delivered to the station, chemically analyzed, and then blended in a mixing tank. This is done to obtain a more or less average chemical composition and to dilute organic substances (such as detergents) which interfere with subsequent treatment by coagulation and ion-exchange resins.[1]

Flocculation is induced in the raw blended waste by additions of ferrous sulfate ($FeSO_4$) and alkali ($NaOH$), and the resulting precipitate is allowed to settle in clarifier drums. The liquid is decanted and the precipitate is mechanically compacted and filtered. Clarified effluent is passed through strongly acid cationite (Soviet type KU-2) and weakly alkaline anionite (Soviet type AN-2F) ion-exchange resins after filtration through sand and anthracite coal filtration beds.[1] The effluent is then sufficiently decontaminated (reportedly less than $10^{-7}$ curies of beta activity/liter) to allow disposal into the Moscow River or open reservoirs.[17] The Soviets claim that strontium-90 (Sr-90) concentration in the final effluent is substantially below the maximum permissible concentration (MPC). In some cases they report it is not possible to reach the MPC for sulfur-35 (S-35).[1]

Suspensions obtained during the flocculation process are reduced in volume by a factor of 12 to 14 by centrifuging. The Soviets use a modern flocculating agent—polyacrylamide ($CH_2CHCONH_2$)—as a centrifuge aid. The temperature is raised to 45-50° C, and the resulting radioactive sludge is removed by vacuum. Radioactive waste suspensions can be centrifuged at a rate of 150-200 liters/hr at this station.[1]

In an attempt to improve performance and increase throughput, the Moscow station tested a self-discharging plate separator for concentrating radioactive suspensions. This equipment was reported to have a greater capacity than a centrifuge, produced a clearer effluent and a denser precipitate, and provided automatic discharge of the solid phase. But the Soviets found that frequent dissembly of the equipment was necessary—a major disadvantage because of the radioactivity.[19]

Ion-exchange resins that have become saturated at the Moscow station are reactivated by backwashing and are reused until they become mechanically and/or chemically degraded. Contaminated backwash effluent contains radioactive isotopes in the form of sulfates, chlorides, carbonates, and nitrates. This slurry is concentrated by evaporation to obtain a hydrate-carbonate precipitate. It is claimed that up to 90 percent of the Sr-90 and some of the organic impurities are removed. The evaporator concentrates are cooled in a crystallizer to 20-30° C and are transferred to a waste tank. The collected radioactive precipitates, slurries, and bottoms from the treatment processes are finally transferred to special trucks and transported to the Zagorsk Waste Burial Station for disposal.[1, 19]

Information on the Moscow Central Radiation Safety Station, obtained from visitors and published technical reports, indicates that the radioactive waste treatment techniques presently in use are essentially the same, with some improvements, as those described in 1960.

The Zagorsk Waste Burial Station has been visited in the past and as recently as 1974 by a [redacted] delegation. It was visited in 1972 by US scientists during a meeting of the IAEA Panel on Choice of Burial Conditions for Radioactive Waste, held in Moscow. A group of [redacted] scientists also visited the Zagorsk station in 1971.[12, 18, 20]

Radioactive waste from the Moscow area is transported to the Zagorsk station under police escort by special rail cars and special trucks. The station is reported to receive about 2 cubic meters of waste water per day on the average, plus other solid and liquid wastes. Solid combustible wastes are incinerated. The ashes and noncombustible radioactive solids are encased in concrete blocks which are placed in ditches and then covered with concrete that also contains radioactive slurry and concentrate.[1, 7, 16]

Raw radioactive waste waters brought in from other locations as well as that generated at the Zagorsk station itself are treated by precipitation and ion exchange using procedures like those used at the Moscow Central Radiation Safety Station, described previously.[1]

The Zagorsk Station had a pilot plant in operation in 1971 for the study of bitumenization of radioactive waste. The US delegation in 1972 observed asphalt blocks of encased low-level waste as well as concrete blocks stacked on the ground above the water level. Monitoring did not appear as strict as that practiced in the US. Monitoring wells were said to be located around the waste pile, but the Soviets did not give well depths nor on what horizons they were sampling the ground water.[20]

## HIGH-LEVEL RADIOACTIVE WASTE MANAGEMENT

Because all their high-level waste (HLW) treatment and storage facilities up to the present have been associated with plutonium production under the Ministry of Medium Machine Building, the Soviets have been highly secretive about this subject. As recently as October 1974, US members of the US-USSR Fast Breeder Reactor Joint Coordinating Committee were dismayed to find that the fuel cycle (reprocessing, refabrication, and waste management) was closed to discussion by the Soviets. When questioned about this at the first committee meeting in Moscow, A. M. Petrosyants, chairman of the USSR State Committee on Utilization of Atomic Energy, stated that the fuel cycle is part of the Soviet classified program.[21]

Reflecting this secrecy, Soviet papers presented at international meetings on radioactive waste management have dealt primarily with low-level waste treatment and disposal. Also, Soviet attendees are often theoreticians who display a lack of understanding of practical problems associated with radioactive waste management.[22]

Nevertheless, by the late 1960s a trend began toward increased [redacted] publication of Soviet research on the treatment and storage of high-level wastes expected from the reprocessing of nuclear-power-reactor fuel. In a 1973 report Viktor I. Spitsyn, director of the USSR Academy of Science's Institute of Physical Chemistry and a leader of Soviet research on radioactive waste management, discussed plans for the management of highly active wastes from Soviet pressurized-water power reactors fueled with sintered uranium dioxide enriched to 3.3 percent U-235. The Soviets plan to hold spent power-reactor fuel for 1 ½ to 3 years or longer to allow it to "cool." The length of the cooling period will depend on the need to return the uranium to the fuel cycle. A solvent-extraction process will be used in the reprocessing of the fuel to recover uranium, plutonium, and neptunium, according to Spitsyn. The high-level wastes will remain in aqueous solution and be concentrated to recover nitric acid. Spitsyn reported that the USSR is operating "experimental-industrial plants" (probably pilot plants) to test high-level waste solidification methods—vitrification and bituminization. He claimed that the injection of high-level wastes into deep geological formations was also being tested, a process the Soviets pioneered for disposal of low and intermediate wastes.[6]

The US Power Delegation, while visiting the Novovoronezh nuclear power plant in 1973, were told that solidification of high-level waste is in the planning stage at this plant and will be incorporated into the fifth nuclear unit to begin operating in 1976. Shipping containers of 10 cubic meters each will be used to carry the high-level waste to a reprocessing plant. Low-level waste resulting from washing down equipment and from other sources is purified at the reactor site. Contaminated liquids are stored in concrete tanks with a steel and concrete container inside and placed in special concrete trenches located at the reactor site. Monitoring for tank leaks and ground water seepage has been provided for.[4]

The most forthright statements concerning current Soviet high-level waste management practices were made by Y. P. Martynov at the March 1974 IAEA International Working Group on High-Level and Alpha-Bearing Wastes, held in Vienna, Austria. He reported that the only method now in use on an industrial scale in the USSR is controlled storage of evaporated liquid wastes in stainless steel tanks. These tanks are placed on special protective plates and equipped with cooling and blower systems, instrumentation, communication systems, and equipment for pumping wastes from one tank to another. He reported that this method of storage is considered provisional because of undesirable characteristics such as the high cost, the requirement of continual maintenance and control for decades, and the possibility of widespread contamination due to corrosion, accidents, or damage to the tanks in war time.[23]

[redacted]

## DEEP-WELL INJECTION

The Soviets claim to be the first in the world to develop to commercial scale deep-well injection of low- and medium-level wastes into geologic formations. They began this work in 1963 at the Dmitrovgrad (formerly Melekess) Scientific Research Institute of Atomic Reactors (NIIAR) site[24, 25] [redacted] While the Soviets use a different technique, they do not predate US radioactive waste injection activities. (At Oak Ridge, medium-level waste has been injected into deep shale formations by high-pressure fracturing techniques since the 1950s. A cement-waste slurry is forced into the fracture and solidifies, ensuring permanent, dry storage of the waste. At Idaho Falls, since 1952 low-level, aqueous waste has been discharged into the Snake River aquifer beneath about 400-500 feet of sand.)

The Soviet technique involves pumping wastes into water-bearing permeable strata. They do not consider this to be "releasing" the waste to the environment. Pressure in the disposal aquifer or basin is controlled by pumping water out as the waste is pumped in at pressures up to 20-22 atmospheres. A [redacted] delegation in 1971 noted pressures of 50-55 atmospheres. Overpressure was said to equalize in a few days, which could indicate either very large water-tight strata or the possibility that the stata being used are not water-tight at some place. The [redacted] questioned the safety of the process.[18] A pumphouse is located over each wellhead. In earlier testing the Soviets injected wastes to depths of 1,380-1,540 meters.[26] By 1971 they reported pumping wastes on an industrial scale containing $10^{-4}$ to $10^{-2}$ curies/liter into pockets of water-bearing, permeable strata located between strata of relatively impermeable clay at depths of 325 to 450 meters.[27]

After initial testing, the NIIAR in 1966 began a 4-year pilot project to study the feasibility of injecting low-level wastes on a commercial scale. This project was described by Viktor Spitsyn and others in a paper presented at the Symposium on Treatment of Medium- and Low-level Radioactive Wastes held at Aix-en-Provence, France, in September 1970.[28]

[redacted]

Spitsyn reported that over a 4-year period beginning in April 1966, 320,000 cubic meters of waste containing 3,500 curies of alpha activity were pumped into water-bearing strata at a depth of 1,432 to 1,508 meters. Four injection wells had been drilled by 1970. Also, 10 control wells were drilled at similar depths, and three 60-meter-deep holes were drilled for monitoring. Planned maximum capacity is 550 cubic meters per day at the Dmitrovgrad site.[25]

The results of this experiment form the basis of the Soviet claim that they have a technically proven, economical, and safe process for radioactive waste injection into a deep, water-bearing horizon containing highly mineralized waters. They claimed that the construction cost of the pilot plant would be made up in savings in 1 year of operation.[25]

At the 1971 Geneva Conference on the Peaceful Uses of Nuclear Energy, Spitsyn presented a paper stating that 1.2 million cubic meters of waste had been pumped underground and that a total of 50 million curies of radioactive waste had been injected over an 8-year period (1963-71) at Dmitrovgrad.[27] According to these figures, the average radioactivity of the waste was slightly over $4.0 \times 10^{-2}$ curies per liter, i.e., medium-level activity.[28]

Based on their expressed confidence in the safety and technical feasibility of the injection method, the Soviets might conceivably decide to dilute high-level waste and inject it underground rather than attempt to concentrate and solidify it for permanent storage. They have never suggested that they are considering such a procedure. But considering that by the year

[redacted]

2000 they will have an estimated 150,000 MWe of nuclear power, they could have an accumulation of about 46 million liters of high-level waste averaging about 1,000 curies per liter. Diluted 1,000 fold, about 46 billion liters of waste containing 1 curie per liter would result. This would mean a requirement to inject (on the average) about 2 billion liters per year, or about 35,000 barrels per day, not an unmanageable amount.

The Soviets are confident that the injected waste *will not* leach or seep into any domestic water supply. Monitor drill holes and pressure-relief holes surround the wellhead at appropriate intervals in a concentric circle. In 1971, V. D. Balukova showed diagrams and photographs of the Dmitrovgrad site to members of a US AEC delegation headed by chairman Glen Seaborg. There were five control holes at a radius of 50 meters, nine holes at 125 meters, and three at 400 meters.

[redacted]

[redacted] there are indications that the Soviets are pumping radioactive wastes into the ground at sites other than Dmitrovgrad. In 1973 Viktor Spitsyn was evasive when pointedly asked where the Soviet deep-well injection waste facility was located in the USSR. Surprisingly, he said the location had not been published and that it is not in a densely populated area, not in the southern USSR where earthquakes are prevalent, and not in Siberia.[9] In view of the fact that the Dmitrovgrad site has been described and visited, Spitsyn may have been refering to a secret site. His Geneva Conference paper in 1971 did not give a specific location but referred to "a pilot installation." While most of the details in that paper closely matched those given in earlier published reports on the work by the NIIAR in Dmitrovgrad, there are some unexplained anomalies. He could have been referring in part to experiences at other waste injection sites.[17]

Spitsyn's description of the number of wells drilled, distances of control wells from the injection center, the geologic zones into which wastes were pumped are slightly different from the data given in his report on Dmitrovgrad in 1970 at Aix-en-Provence.[25] [redacted]

[redacted] Possibly they are presenting the project as planned on paper along with some real data from more than one of their drilling sites. Spitsyn stated in the Geneva paper that some of the waste consisted of that obtained from the removal of aluminum "coatings." These may have come from plutonium production reactors which commonly use aluminum-clad fuel elements but could have been spent fuel from any of the Soviet research reactors that use aluminum cladding. In addition, some of the injected waste was said to consist of "aqueous solutions of sodium nitrate and carbonate, caustic soda, some nitric acid and compounds from technological operations." [redacted]

Another anomaly was reported by A. N. Kondratiev of the Radium Institute in a paper presented in 1972 at the Paris Symposium on Management of Radioactive Wastes from Fuel Reprocessing. He stated that wastes up to 10 curies per liter had been injected into porous underground formations.[2] [redacted] Kondratiev and the other Soviet delegate, N. V. Krylova of the State Committee for Utilization of Atomic Energy, gave the impression that they were theoreticians not associated with a real radioactive waste program. They were describing material contributed by others and were unable to answer meaningful questions about the Soviet program.[22]

Spitsyn and coworkers reported in 1972 that the USSR is investigating the injection of high-level wastes into geological formations similar to their "already developed" burial of intermediate-level wastes.[6] They did not state that any high-level waste had actually been injected nor did they identify the location of the investigations. They did imply that injection would be done with wastes stored for about 10 years to allow some decay of cesium-137, and that Sr-90 and promethium-142 should be extracted before storage. It appears from this and other Soviet reporting that no significant quantity, if any, of high-level wastes have been injected into the earth.[6,30]

## RESEARCH IN PROGRESS

Soviet research and development on radioactive waste management cover practically all the standard techniques being investigated elsewhere. Recent published research reflects growing Soviet concern with the problem of ultimate treatment and storage of high-level wastes from reprocessing of fuel from nuclear power reactors. Bitumenization, vitrification, and cementation of wastes as well as work in support of their deep-well injection program are underway.

While it is the most advanced country in the field of peaceful nuclear explosions, there is no evidence that the Soviet Union is working on or planning to use cavities produced by underground nuclear detonations for ultimate waste disposal. With regard to the use of salt mines or natural caverns for waste storage, the Soviets appear to have no working projects. They may be waiting to see what decisions the United States makes in this area. The Soviets were not interested in visiting the West German Asse salt mine waste storage project in 1972.[31]

The Soviets are studying the chemical effects of aqueous radioactive waste solutions on soils and rock formations in support of their evaluations of high-level waste injection. They advocate pretreatment of such wastes, including neutralization of acids and the addition of complexons (chelate compounds) to tie up metallic ions. The object is to prevent chemical reactions underground that could have deleterious effects such as loss of strata permeability, loss of mechanical strength of the rock layers, and formation of gases. They also consider it desirable to pretreat the strata into which the waste is to be injected. Acid treatment is said to decrease the chemical reactivity of the stratum. Further treatment with surface-active agents also was said to prevent the accumulation of solid radioactive isotopes in the rock formation. As an example, the Soviets have cited the absorptive capacities of sandstone treated in this manner. Nevertheless, the impression gained was that the Soviets were extrapolating data obtained from their low/medium-level waste injection work.[30]

The effect of underground heating due to the energy of radioactive decay has also come under study. It was claimed that underground temperatures at Dmitrovgrad increased from about 10° C to over 50° C during a 3-year period, after which no further increase was observed. In their studies of high-level waste the Soviets calculated the amount of waste that could safely be injected without raising the temperature above the boiling point. For a cubic foot of permeable rock with absorptive capacity of 3.5 curies per cubic inch they concluded that the temperature will rise to 200° C, safely below the 255° C boiling point at the stratum pressure of 42 atmospheres. The waste was assumed to average 0.1 to 10 curies per liter, with 67 percent of the activity from short-lived isotope cerium-144, 8 percent from long-lived Sr-90 and the rest consisting of isotopes with short and medium half lives. There is no indication that this experiment was done except on paper. Also, the Soviets did not take into account what effects decay heat or radiolysis may have on the organic complexing agents they propose to use as stabilizing agents.[28]

### Bitumenization

Workers at the Institute of Physical Chemistry and at the Central Station of Radiation Shielding, Moscow, reported in 1970 on experiments in bitumenization of low-level radioactive wastes containing sodium nitrate. They studied various grades of bitumen (asphalt) to determine gas formation, the dangers of explosion, water absorption, and lamination of the bitumenous mass depending on the amount of nitrate present. A pilot plant based on these studies was set up in 1970 and was said to be ready for startup.[32] This pilot plant probably is the one at Zagorsk that was operating in 1971 and is apparently copied from the type developed at Mol, Belgium.[12]

The Soviets also are considering the bitumenization of high-level wastes. K. P. Zakharova V. V. Kulichenko, Yu. P. Martynov, and others in 1972 described a 5 year study they conducted to determine the radiation/chemical stability of bitumen blocks composed of 60 percent asphalt and 40 percent sodium nitrate, with specific activities ranging from 0.15 to 15.4 curies of Sr-90 per liter. Data were collected on: the formation and liberation of hydrogen, methane, ethane, acetylene, and carbon dioxide gases; the oxidation of the bitumen; softening and penetration temperatures; and radiation heating. Further tests were said to be underway on bitumenous specimens with activities of over 50 curies per kilogram. The Soviets concluded that bitumenized waste with specific activity up to 10 curies per liter with a specific heat liberation of 30 watts per cubic meter may be stored in uncooled burial pits. Also, they said that storage of wastes with activities up to 100 curies/liter is possible with air cooling in the burial pits. It is necessary to prevent the accumulation of radiolysis products because of the possibility of hydrogen accumulation.[33] Western radioactive waste research has indicated a considerable danger of explosion of large accumulations of bitumen containing nitrate, nitrites, and voids. It would be difficult to accommodate the swelling and gas formation at concentrations greater than 10 curies/liter. Mrs. N. V. Krylova, who presented the Soviet report (although she was not a coauthor) on high-level waste bitumenization at the December 1972 IAEA Symposium on Management of Radioactive Wastes from Fuel Reprocessing in Paris, appeared unaware of the problems.[22]

## Vitrification

The Soviets have long-term plans for the vitrification of high-level wastes from reprocessed nuclear-power-reactor fuel. At the 1974 meeting in Vienna of the International Working Group on High-Level and Alpha-Bearing Wastes, Yu. P. Martynov described a two-stage process now under development.[23] The waste is first calcined to a powder in a fluidized-bed process. The powder then is transferred to a crucible and melted. The single-use crucible is then sent to a burial site. Martynov reported that the process is being tested in a pilot plant (no location given) with a capacity of 100 liters per hour. In contrast to some Soviets who have attended radioactive waste management meetings, Martynov, who is affliated with the Sverdlovsk Institute of Chemical Technology, was knowledgeable of practical engineering problems.[34]

A detailed description of the vitrification process was published in 1972 and presented at Paris by A. N. Kondratiev, one of the coauthors.[5, 27] The work has been underway at least since 1967, with some glass and ceramic melt studies being done at the Institute of Physical Chemistry. Progress is indicated by the expansion of the pilot plant from the the 15-20 liters per hour reported in 1972 to the 100 liter-per-hour level mentioned by Martynov in 1974.[23] The planned capacity of the pilot plant for the two-stage vitrification process is 200 liters per hour or about 5 cubic meters per day of highly active waste from power reactor fuel reprocessing.

Total capital expenditures of 15.51 million rubles were estimated for construction of a vitrification plant that could handle 5 tons per day of spent nuclear fuel from Soviet water-cooled, water-moderated power reactors (VVER). The plant itself would cost 10.5 million rubles. Twenty year storage will cost 4.6 million rubles and annual operating expenses 2.01 million rubles. The Soviets calculated that commercial vitrification of high-level waste would be 12 percent cheaper than the cost of tank storage and that capital costs would be lower by a factor of 2.2. Nevertheless, they admitted that they had not been able to determine real costs based on production-scale operations. They appeared convinced that vitrified high-level waste can be buried safely for prolonged periods.[5]

A single-stage process was also studied in which the waste was melted down in a reactor vessel heated by induction to 900-1000° C. The Soviets consider this process less viable and apparently have abandoned it.[5]

Problems encountered by the Soviets in testing their vitrification pilot plant were mentioned by Martynov at the 1974 Vienna meeting. These included problems of gas regulation in the calciner, control of calcined powder batches in filling the crucible, selection of crucible material, and control of the melting process.[23]

Chemical stability of the vitrified mass, heat removal, and leaching were also discussed at the Vienna meeting. The Soviets recognize that for high-level wastes even a low rate of radioisotope leaching into the soil cannot be tolerated. It was stated that in the case of a highly stable glass with a leach rate of $10^{-8}$ grams/cm$^2$/day the danger of water pollution exists if the Sr-90 activity is greater than 10 curies per liter and cesium-137 is greater than 100 curies per liter.[23] These wastes could not be buried without natural or artificial hydroinsulation. Studies on radioactive waste vitrification by Martynov, B. S. Kolychev, V. V. Kulichenko, and others have appeared in the Soviet open technical literature at least since the early 1960s.[5, 23, 35] For solidified wastes of several thousand curies per liter the Soviets suggest two-stage storage—storage with water-cooling or intensive air-cooling for several years followed by permanent burial.[23]

### Cementation

Another waste solidification process was developed to small pilot plant scale in the Radiochemical Laboratory of the Institute of Physical Chemistry. The laboratory was built about 1967 and occupies a six-story building on the outskirts of Moscow, well removed from the main institute. Liquid wastes from laboratory experiments are evaporated to a slurry which is mixed with cement and fired in a furnace. Small (1 cm) cubes of solidified waste are formed.[18] Visitors in 1972 were given dummy cubes supposedly produced in this equipment, but the area gave the appearance of inactivity. Gases from the process apparently were emitted through a 6.-foot stack.[12 30]

### Other Research

Treatment of low-level radioactive wastes by electrodialysis has been studied at the Moscow Central Radiation Safety Station under F. V. Rauzen, director of the station. The work began in 1965, and a 100 cubic meter/day pilot plant was reported to be set up at the station in 1970.[1] The objective was to use electrodialysis to concentrate acid or alkali from clarified waste solutions and then remove the radioactive isotopes by ion-exchange resins. The recovered acid/alkali was to be reused in the regeneration of spent ion-exchange resins. The experiments were still underway when the station was visited in 1971.[18] In 1974 the Soviets showed the setup and explained that it will be moved to new buildings under construction.[12]

Reverse-osmosis and continuous-ion-exchange techniques were also being studied at the Moscow Station. Rauzen and coworkers published in 1973 on an experimental pulsed-column, ion-exchange installation with a capacity of 100-150 liters per hour. The columns were 76 mm in diameter and were only 4.8 meters in height because, as Rauzen complained, the room was not high enough.[37] The [redacted] delegation in 1974 described the station's laboratories as dark, small, and cheerless. New buildings under construction will presumably provide much improvement. Based on the experiments, the Soviets expect to build a continuous, pulsed-column, ion-exchange installation with a capacity of one cubic meter per hour at the Moscow station, using columns 10 meters high. They claim a considerable increase in waste decontamination efficiency by the pulsed-column method.[37]

The Institute of Physical Chemistry also does research on the removal of fission products from waste solutions. Various separation techniques have been used, including ion-exchange, electrophoresis, and adsorption. Work was also seen here in 1974 on phosphate-glass melts in support of their waste vitrification work.[12] Other work on the behavior of radioisotopes in saline water and the effect of wastes on deep geological formations supported the deep-well injection work at Dimitrovgrad. The treatment of radioactive wastes generated by the institute itself, primarily by flocculation and ion exchange, was apparently done with more care than that at the All Union Research Institute of Inorganic Materials.[12 18 19]

## SAFETY AND HOUSEKEEPING PROCEDURES

There is evidence that the Soviets are less rigorous than their publications and statements indicate in the degree of caution exercised in the handling, treatment, and transport of radioactive waste. Their regulations require the use of special trucks and rail cars designed for transporting radioactive waste, and the restriction of the movement of wastes through populated areas only during late-night hours. Nevertheless, [redacted] observed[1] at least one incident where radioactive-waste-bearing tank trucks were convoyed through a section of Moscow in heavy, noon-hour traffic in 1971.[3] Some of the special trucks seen at the Zagorsk Waste Burial Station in 1974 appeared old, but were radio equipped, had alarm lights and sirens, had a 15 millimeter thick lead shield behind the driver's seat, and were cleaned in a washdown facility.[12]

At the Novovoronezh Nuclear Power Plant, Soviet officials told the US Power Delegation in 1973 that the radiation level at the plant perimeter was no higher than when original readings were taken in 1964. Air is monitored up to 50 kilometers away. Strontium-90 levels were reported to be essentially zero, or the same as the air in general. The Soviets were amused at what they considered excessive US safety requirements for nuclear power reactors.[4 38]

A [redacted] delegation in 1974 noted that an extruder had recently been installed at the Zagorsk bitumenization plant. The Soviets were embedding slurries, incinerator ash, and compressed solid waste into bitumen blocks. The delegation was highly critical of Soviet practices at Zargorsk. For example, the bitumen blocks are permanently stored in partly underground, partly aboveground concrete bunkers of very shoddy construction. The bunkers consist of several rooms which when filled are covered with concrete slabs and finally covered with sand. The soil in the area is an impermeable clay leading to the possibility of surface contamination from leaching because of the humid climate.[12]

Some highly active waste is stored at Zagorsk in 30-centimeter diameter steel pipes which are put into a 6-meter deep cellar and the overall operation covered by a shed. The entire setup was described as primitive; e.g., poorly finished pipes, insecure plugs in the pipes, a rough concrete floor, and the shed to cover the installation was described as "leaky as a sieve" by the Benelux delegation.[12]

## MANAGEMENT OF NAVAL ASSOCIATED RADIOACTIVE WASTE

[redacted] In addition to waste storage and treatment areas ashore, it was found that the Soviets make extensive use of special support vessels to provide service afloat in connection with the operation, repair, and refueling of nuclear submarines. Based on techniques described in open literature and other information known about Soviet radioactive waste management, it was possible to assess the probable functions of these special support vessels. Services such as decontamination, replacement, and purification of reactor coolant, personnel monitoring and control, waste incineration, and transport of spent fuel appear to be handled by floating facilities.[44,45]

The following sections of this report describe specific facilities, shore-based and afloat, and the probable techniques employed in the management of naval associated radioactive materials and wastes. The table lists shore-based facilities and support vessels.

### Disposal and Treatment Facilities Ashore

[redacted]

### Facilities Afloat for Radioactive Waste Handling, Treatment, and Decontamination

In the management of contaminated submarine reactor coolant, provision must be made for the thermal expansion and contraction of primary coolant water when a submarine reactor is shut down or restarted. The Soviet 80-foot Special Purpose Barge, essentially a floating compensation tank, is used to perform this service. [redacted]

After assisting one or more reactor shutdown/start-up cycles, the compensation barge probably is towed alongside a Zeya or Vala class support vessel to discharge its cargo of radioactively contaminated water and take on a fresh load of deionized water. (Functions of the Zeya and Vala class vessels are discussed in the next section of this report.) In some cases the barges may be towed out to sea to dump contaminated water. Dumping at sea could be justified because this water is only slightly radioactive and the Soviets may not classify it as radioactive waste. [redacted] The US Navy dumps submarine reactor coolant water at sea routinely.[44,45]

WATER PURIFICATION AFLOAT- [redacted]

[redacted]

[redacted] Considering published Soviet water-purification techniques, the Zeya and Vala vessels are probably equipped with mechanical filters and ion-exchange columns to provide deionized water for the first filling of nuclear submarine coolant systems, as well for as servicing the expansion/compensation barges (described previously) and other support vessels. Solutions from laundry, personnel decontamination showers, and equipment washdown may also be taken aboard Zeya and Vala class vessels for treatment.

[redacted]

[redacted]

Since the Vala is self-propelled, it may be used to transport liquid and solid wastes to one of the on-shore waste treatment and storage facilities in addition to its water-purification role.

SUBMARINE REFUELING AT FORWARD REPAIR YARDS—Nearly all operations are performed by floating facilities in the fueling of Soviet nuclear submarines at [redacted] forward repair yards. The special support vessel PM-124 class YRSN is equipped to perform most of these duties. [redacted]

[redacted]

The PM-124 support vessel may also have an onboard incinerator for burning contaminated coveralls, wipes, and other combustible solids. [redacted]

Two recently overhauled PM-124 YNRSs may be fitted to handle second generation nuclear submarines. [redacted]

[redacted]

[redacted]

Another support vessel used in forward repair yards, where shore-based facilities such as cranes and steam and electric power are not readily available, is the Rosta-A class TRSN. [redacted] Functions such as radiological control, monitoring, and decontamination are probably performed aboard the vessel. [redacted] The Rosta-A class YNRS can support two nuclear submarines being refueled at the same time.[44,45]

### Management of Radioactive Waste During Submarine Construction and Major Overhaul Operations

[redacted]

The icebreaker *Arktika*, the first nuclear powered surface ship in the Soviet Navy, built in Leningrad shipyards and designated Auxiliary Icebreaker Nuclear by NATO, was making trial runs in late 1974. It will be serviced in the same manner as the *Lenin*.[45]

## PROPAGANDA AND POLITICS

The Soviets have cleverly taken advantage of the favorable aspects of their radioactive waste management program while hiding its weaknesses. Press releases and broadcasts for home as well as Western world consumption emphasize the Soviet official opposition to dumping radioactive waste at sea. They also state that no waste with an activity above the MPC should be put into the ground at disposal sites.[20]

Especially for home consumption, famous Academicians such as A. P. Aleksandrov have boasted that the USSR is far ahead of the West, particularly the United States and United Kingdom, in radioactive waste disposal. Most such statements are tied in with assurances that Soviet nuclear power reactors are safe for the operators, do not contaminate the environment, and are not dangerous to nearby populated areas.[41]

I. D. Morokhov, deputy director of the Soviet State Committee for Utilization of Atomic Energy, was more forthright in a broadcast beamed to North America in 1974. He said that the main principle being used by the USSR in radioactive waste disposal is to concentrate the waste into small volumes and isolate it to prevent contamination of the environment. Liquid waste is evaporated and buried in steel containers, "a practice believed safe and used by all countries that process nuclear fuel." He then proceeded to blame capitalism for the overall bad ecological situation in the United States, pointing out that in the USSR all lands, minerals, and industries are owned publicly. "Curbing pollution is part of our development program," he said.[42]

In a Soviet Life article of November 1974, Pyotor Neporozhny, Minister of Power and Electrification, said that a separate industry has been set up to recover radioactive wastes in the USSR and that reliable equipment has been developed for storing these wastes. He pointed out that thermal power stations discharge more radiation to the environment than do nuclear power plants.

When Western delegations visit Soviet nuclear power plants and/or radioactive waste management facilities, their Soviet hosts always take great pains to insist that any effluent has been thoroughly decontaminated to below the MPC before being discharged to the environment. On the other hand, spokesmen such as Viktor Spitsyn claim there is no danger in their deep-well injection system for pumping radioactive waste into deep geological formations.[6] The Soviets boast that they are the first to develop such a system to commercial scale. They even advocate pumping high-level wastes underground and seem oblivious of this apparent contradiction of their own stated policy regarding radioactive waste management.[1 3 17]

At international waste management meetings the Soviets seldom make significant contributions to the technology. Some attendees are not able to discuss intelligently the papers they present because the work was done by others. Theoretical work is sometimes presented as if it represented experimental data, with resulting confusion.[20 22 34]

The Soviets apparently attempted to use a meeting held in Moscow in 1972 to embarrass the US and other Western countries. The IAEA Panel on Choice of Burial Conditions for Radioactive Waste was convened in September of that year to prepare a guidebook on the subject. In addition to representatives from the USSR, the US, and West Europe, representatives from Egypt, India, Pakistan, and Japan also were present. The Soviets attempted to force through the meeting a set of guidelines totally unacceptable to the United States and the United Kingdom. The Soviets insisted that they, by governmental decree, are putting no waste into the ground—but they apparently were referring only to laboratory, hospital, and other low-level waste. In addition, attendees were forced to rely on spoken translations of the Soviet papers, although the Soviets had a 6-month lead time before the conference to prepare printed translations. As a result, the conference ended with nothing accomplished.[20 43]

## REFERENCES

The source references supporting this paper are identified in a list published separately. Copies of the list are available to authorized personnel and may be obtained from the originating office through regular channels. Requests for the list of references should include the publication number and date of this report.

Top Secret

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