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THESIS

**AN ANALYSIS OF THE BRAIN DRAIN
PHENOMENON IN THE FIELD OF DEVELOPMENT
OF CHEMICAL AND BIOLOGICAL WEAPONS IN
RUSSIA DURING THE 1990s**

by

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June 2002

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DEVELOPMENT OF CHEMICAL AND BIOLOGICAL WEAPONS IN RUSSIA
DURING THE 1990s**

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ABSTRACT

Proliferation of chemical and biological weapons (CBW) is one of the most dangerous challenges in the modern world. Among the countries that developed CBW, the most advanced programs were in the former Soviet Union. At the beginning of the 1990s, Russia inherited most of the main centers of CBW production and development from the former Soviet Union. The Russian government terminated most CBW programs during the 1990s, leaving scientific personnel almost completely on their own. Many Russian CBW scientists in this situation looked for employment abroad. At the same time countries of proliferation concern, especially Iran and Syria, sought foreign experts to assist their CBW programs. This thesis examined the emigration of highly qualified CBW scientists from Russia during the 1990s. The methodology is an analytical assessment of the literature and critical synthesis of information in the CBW field available from newspapers, journals and the WWW. The thesis concluded that the CBW brain drain from Russia during the 1990s did occur to a very limited degree. Iran and Syria were successful in finding and employing some Russian CBW expertise. The Russian government implemented different programs to combat brain drain during the 1990s, but all of them failed because of the lack of funding. The US-funded programs to stop brain drain from Russia and convert former military researchers to civilian projects appeared to be effective during the 1990s.

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LIST OF ABBREVIATIONS

1. BW – Biological weapons.
2. BTWC - Biological and Toxin Weapons Convention.
3. CBW – Chemical and biological weapons.
4. CIS – Commonwealth of Independent States.
5. CRDF - the Civilian Research and Development Foundation.
6. CW - Chemical weapons.
7. CWC - Chemical Weapons Convention.
8. DOE – Department of Energy.
9. IPP - the Initiatives for Proliferation Prevention.
10. ISTC - the International Science and Technology Center in Moscow.
11. KGB – Committee of State Security of the former Soviet Union.
12. MoD – Ministry of Defense.
13. MCC – Military-chemical Complex.
14. NCI - the Nuclear Cities Initiative.
15. OPCW - Organization for the Prohibition of Chemical Weapons
16. OTC - Organophosphorus toxic chemicals.
17. RCB Forces - the Radiation, Chemical and Biological Protection Forces of the Ministry of Defense of Russia.
18. R&D – Research and development.
19. STCU - the Science and Technology Center of Ukraine.
20. TC - Toxic chemicals.
21. WMD - Weapons of mass destruction.
22. UNMOVIC - the United Nations Monitoring, Verification and Inspection Commission.
23. UNSCOM - the United Nations Special Commission.

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I. INTRODUCTION

A. BACKGROUND

The problem of the proliferation of weapons of mass destruction, and chemical and biological weapons (CBW) in particular, became very significant after the disintegration of the former Soviet Union, which possessed the largest and most sophisticated CBW programs in the world at the end of the 1980s. Russia, which had inherited almost all of the main centers of CBW production and development from the former Soviet Union, started drastically cutting these programs once it obtained independence in 1991. In the former Soviet Union, chemical weapons (CW) programs involved about 30,000 people and the biological weapons (BW) programs 60,000, thus indicating the importance of this issue [Tucker, 2000].

Facilities and laboratories of weapons of mass destruction suffered not only insufficient funding, but a lack of control and support by the Russian government. The CBW scientists faced a new reality in which the new post-Soviet government did not claim them and their unique knowledge. These scientists had three options: stay in the laboratories in Russia until the situation improved, find new activities or professions in Russia, or work abroad using their knowledge.

For countries seeking the possibility of obtaining weapons of mass destruction, the former Soviet CBW scientists are especially valuable. These scientists could save them years of experiments and help them to go straight from basic research to the production and development of these types of weapons.

At the same time, the focus of the Organization for Prohibition of Chemical and Biological Weapons (OPCW) was primarily on halting production and transfers of CBW materials, while human resources factors were the responsibility of national governments.

B. OBJECTIVES

This thesis will examine the problem of the emigration of highly qualified CBW scientists from Russia in the 1990s. Thus, an assessment of CBW programs in Russia, an

analysis of the main factors contributing to the brain drain phenomenon in this country, and a study of the main consequences of this process for Russia itself and for the international community will be conducted.

This thesis will also consider the characteristics of the demand for CBW scientists and technicians and the development of Chemical and Biological Weapons programs by the countries of proliferation concern. International programs and projects will also be touched upon, most of which are U.S.-funded, to combat the brain drain from Russia through the redirection of Russian scientists into peaceful areas of research.

C. RESEARCH QUESTIONS

The primary research question is:

What are the main consequences of the brain drain in the field of CBW from Russia in the 1990s for global security and for Russia itself?

Secondary research questions are:

What are the main factors in this process?

Did the Russian government manage to stop the brain drain in the field of the development of CBW at the end of the 1990s?

Which actions and methods did the Russian government use for these purposes?

Were countries that support international terrorism searching for Russian CBW scientists during the 1990s? If yes, were they successful in their search? If yes, were Russian scientists helpful in the development of CBW programs in these countries during the 1990s?

What was the impetus of the international cooperation on preventing the brain drain from Russia abroad?

What was the position of the United States on this issue as the only superpower in the modern world? Which programs were worked out by the United States in response to the development of the brain drain from Russia?

D. ORGANIZATION OF STUDY

The thesis will focus on Russian CBW personnel and their activities during the 1990s. Do they continue to do research in these areas in Russia, or do they conduct

research in other, probably civilian, areas in Russia, or do they find themselves in different activities outside Russia? What is the position of the Russian government on this issue? What is the attitude of the international community on this issue? How successful are U.S.-funded programs and projects to combat the brain drain from Russia and enable Russian CBW scientists to remain and work at home?

The focus will also be on the issue of countries that are particularly interested in assistance in the development of their own CBW programs.

The methodology used for this thesis will be an analytical assessment of the literature and critical synthesis of information in the CBW field that is available from newspapers, journals and the WWW. Data will also be used from the Center for Nonproliferation Studies at the Monterey Institute of International Studies. Due to the focus of this thesis, namely Russia, some Russian governmental and public sources of information concerning this topic will be used.

The benefits of this research can be used to shape policy to curb and to prevent brain drain in the field of CBW. The results of this study can be also used to better understand the role of human resource factors in the nonproliferation of weapons of mass destruction (WMD).

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II. CHEMICAL AND BIOLOGICAL WEAPONS PROGRAMS IN RUSSIA

The programs described below on the development of chemical and biological weapons (CBW) in Russia are mainly derived from information about relevant programs in the former Soviet Union. The correlation between Russia and the former Soviet Union appears to be very strong in this case, and can be explained by several factors. First, the former Soviet Union initially was created on the territory of Russia. Second, basically all centers for the development and production of CBW in the former Soviet Union were concentrated on the territory of modern Russia. Third, Russia declared itself to be the absolute successor to the former Soviet Union, to include issues on military programs developed on the territory of Russia during the Soviet era, and international treaties in arms control, non-proliferation and disarmament [Bunn].

A. CHEMICAL WEAPONS PROGRAMS

The development, testing, and production of chemical weapons (CW) in Russia, as mass-casualty weapons, have been in progress for more than a hundred years. For example, some chemicals subsequently used as toxic agents had already been discovered in Russia in the 19th century [Fedorov]. At that time, all research in the field of CW was concentrated mainly at the universities of Moscow and St. Petersburg. However, despite knowledge in the aforementioned field, the government of Czarist Russia did not mass produce CW either before or during the course of World War I [Krause].

The Socialist Revolution in Russia in 1917 drastically changed the attitude of the authorities concerning CW and the possibility of using it. The fact that the Soviet government committed twice as much funding to the development and production of CW than on all public education, and many times more than on the advancement of culture during the entire time the former Soviet Union existed is an indication of how seriously they took this issue. [Fedorov].

Beginning in the 1920s, development, production, stockpiling and use of CW was the occupation of an entire sector of the economy. A system for organizing the army, industry and medicine had evolved into a stable and tightly closed military-chemical

complex (MCC). The development of technologies for producing toxic chemicals (TC) and corresponding chemical munitions was tied up with the activity of a network of special chemistry organizations and various secret production, design and testing institutes of the MCC. All these organizations worked secretly under the control of the KGB [Krause].

In the pre-World War II years, the Soviet Army took CW as seriously as tanks and aircraft. According to the existing data, the Soviet Army had quite a large arsenal of CW in 1941. However, during World War II, no side wanted to risk resorting to using CW, and the latter was relegated to the backdrop of military operations [Hirsh].

Nevertheless, CW in the former Soviet Union was developed much more extensively in the post-WWII period. The Military-Chemical Administration was initially in charge of all military-chemical issues in the Soviet Army. This organization had its own system of research, academic and testing organizations [Pikalov]. In modern Russia, these issues are under the purview of the Radiation, Chemical and Biological Protection Forces (RCB) of the Ministry of Defense of Russia (MoD).

Throughout the post-WWII years, the Soviet Army and, currently, the Russian Army, had a Scientific-Technical Committee. This is an institute that has been involved in military-chemical planning, including the planning of "likely enemy" targets meriting the attention of "chemical gnomes" [Fedorov].

The Ministry of Chemical Industry of the former Soviet Union developed CW production capacities since 1930s. The ministry was in charge of the work to develop CW facilities at its plants, and it coordinated production of TC and loading them into munitions at the same plants. In 1963, the "Soyuzorgsintez" All-Union Association was created which included almost all CW plants in former Soviet Union. The Association directed the production of CW in the former Soviet Union right up to the late 1980s, and weapons development until 1 January 1993 [Krause].

Key personnel for the TC industry have been trained by several institutes, such as a special department of the D. I. Mendeleyev Institute of Chemical Technology in Moscow [Fedorov], as well as the corresponding departments of the Military Academy of Chemical Protection of the Soviet Army, which was also located in Moscow.

Sanitation and health support of TC production during the Soviet era was under the Institute of Labor Hygiene and Occupational Illnesses of the Academy of Medical Sciences (Moscow), and the Institute of Labor Hygiene and Occupational Illnesses (Nizhniy Novgorod).

Production of new generations of CW was handled by specialized institutes and plants of the Ministry of Defense, Ministry of Chemical Industry, and Ministry of Public Health of the former Soviet Union. The leading institutes of the Ministry of Public Health in the field of CW research and development were the Institute of Biophysics (Moscow) and the Institute of Labor Hygiene and Occupational Pathology (St. Petersburg), and its affiliate in Volgograd. They were all part of a special closed system of classified medicine consisting of the Third Main Administration of the Ministry of Public Health (which today is the Federal Administration of Medical-Biological and Emergency Problems of the Russian Ministry of Health Care). Also incorporated into this system was the "Medstatistika", or Scientific Research Institute. The mission of this specially created institute was to accumulate all available toxicological information, including CW, high-toxicity dioxins, and so forth. [Krause].

Large-scale industrial production of TC was organized in the former Soviet Union mainly in the Volga basin, where the waters of the Volga, Oka and Kama rivers were used for production needs, as well as for dumping [Feshbach].

CW produced in the former Soviet Union, and owned by Russia, are divided into three generations. Each has been marked by an era in military-chemical affairs (technology of use), and, also, in industry (technology of production). The military differences of the three generations of CW boil down essentially to a sequential changes in their combat effectiveness: specifically toxicity and other combat characteristics of the TC [Blagov].

The TC that provided the basis for the first generation of CW were developed in Moscow in 1924 at the State Union Scientific Research Institute of Organic Chemistry and Technology (Moscow), which was the leading institute developing chemical weapons [Krause].

These TC include persistent TC (yperite, nitric and lewisite), non-persistent TC (prussic acid, phosgene and diphosgene) and irritating TC (adamsite, CS gas and chloropicrin) within the scope of combat classification. They were designed for temporarily disabling an enemy and could cause skin-blistering and general toxic action. These, like chloroacetophenone ("tear gas") and CS gas, were not retired from "active duty" in the Soviet Army until the late 1980s [Krause].

The second generation of CW includes Organophosphorus TC (OTC) of paralytic nerve action such as tabun, sarin, soman, and V-gases. The development of OTC began in 1943 at the departments of the Military Academy of Chemical Protection of the Soviet Army (Moscow) and the Military Chemical Scientific Research Institute (Shikhany). They were not stopped even when the advent of nuclear missile weapons seemed to have eliminated the strategic need for CW [Feshbach, Krause].

During this same period, Russian scientists developed psychochemical compounds which are TCs that do not destroy or irritate, but merely temporarily disable the enemy [Hirsh].

Three kinds of OTC were included in the armament of the Soviet Army, produced on an industrial scale, and are still being stored in army stockpiles. They are sarin, soman, and V-gas. At one time, the Soviet Army also had stockpiles of tabun that was captured in Germany in 1945 [Blagov].

The present Russian stockpiles of OTC and munitions charged with them are entirely linked to two plants: the old S. M. Kirov Chemical Plant in Volgograd and a relatively new plant at Novocheboksarsk "Khimprom" Production Association [Blagov].

The advent of the third generation of CW (binary chemical weapons) in the former Soviet Union was a direct result not only of the Cold War, but also of attempts of the MCC to "survive". These weapons represented not only new advanced types of TC, but also more effective means for use in combat (multiple warheads) [Fedorov].

The development of new OTC that became the basis for the third generation of CW dates from 1973-1976. This was followed by technological research, production of experimental lots and many years of combat tests of various munitions that were

completed in 1990-1992. As a whole, these programs yielded five promising OTC of a new type. Nerve agents A-232, V-gas, and "novichok-5" turned out to be very convenient for combat use in binary form [Krause].

It is known that these CW are superior to any foreign counterparts, five to ten times more toxic than the second generation OTC, and resistant to medical treatment. Also, they are relatively simple to manufacture, with raw materials being readily accessible. [Tucker, 2000].

CW have always had mass-casualty features. The civilian population could not be excluded from their range of coverage, and for that reason, they could never be treated as a means of attacking only troops. It had never been officially acknowledged that the Soviet Army had chemical weapons. Their existence was admitted only by the President of the former Soviet Union M. Gorbachev in April 1987 when he had to declare that industrial production was stopped:

I can tell you that the Soviet Union has stopped making chemical weapons. The USSR has no chemical weapons outside its own borders, and with regard to stockpiles, I wish to inform you that we have started to build special enterprises for destroying them [Blagov].

CW have been partly removed from armaments. There is no provision for using them in Russian military doctrine, and production is unconditionally prohibited.

After the collapse of the former Soviet Union, Russia signed an agreement with all other members of the Commonwealth of Independent States (CIS) in which it assumed sole responsibility for destroying the former Soviet CW stockpile of some 40,000 tons of chemical agents. However, only four years later did the Russian Duma pass a law which established a federal program for the destruction of CW [Smith].

Currently, CW are stored at seven depots in Russia, and 24 former CW production facilities. Two of the declared depots belong to the RCB Forces in Kambarka (Udmurtia) and in the settlement of Gornyy (Saratov Oblast). Two depots belong to the Missile and Artillery Administration of the Ministry of Defense of Russia in Shchuchye (Kurgan Oblast) and in the settlement of Kizner (Udmurtia). The other three CW storage

bases belong to the Russian Air Force in the settlements of Leonidovka (Penza Oblast), Maradykovskiy (Kirov Oblast), and Pochep (Bryansk Oblast) [Tucker, 2001].

In November 1997, Russia ratified the Chemical Weapons Convention (CWC), which bans the use, development, production, stockpiling, and transfer of chemical weapons, and requires the destruction of CW stockpiles by April 2007.

However, Russia's efforts to dispose of its large CW stockpile and its former production facilities have faced numerous problems. Bureaucratic fighting among Russian government bodies responsible for the program to destroy CW and the financial crisis in August 1998 were the main obstacles for successfully developing a destruction plan. The Russian government could not afford to destroy the entire stockpile, estimated to cost \$7 billion, without extensive international assistance. However, donor countries were unwilling to contribute significant amounts in the absence of Russia's clear political and financial commitment [Blackwood].

In addition, Russia has been suspected of continuing to work on binary chemical weapons and maintaining the production potential for making munitions with the latest V-gas. These claims have been denied by the Russian authorities. But Russia has not been able to provide sufficient evidence to support its position [Blagov].

So, the process of destroying CW in Russia is slowly moving forward. However, it is likely that it will take at least another decade to complete the federal program. At the same time, even though the CW programs in Russia no longer exist, the ample R&D potential and technological capabilities in this country still make the proliferation of CW possible.

B. BIOLOGICAL WEAPONS PROGRAMS

The Soviet Union's biological weapons (BW) program was established in the late 1920s. One of the key events which prompted the Soviet government to explore BW was the typhus epidemic that raged in Russia from 1918 to 1922. During this period, approximately 12 million people contracted typhus. Estimates of resultant deaths range from 2 to 10 million. The Soviet leadership realized that if they could harness this destructive and disruptive force, they would be able to create a very powerful weapon indeed [Alibek].

Prior to World War II, Soviet scientists conducted research on a wide variety of agents. By the beginning of the war, the Soviet Union was able to manufacture weapons using the agents for epidemic typhus, tularemia (an incapacitating illness that can be fatal if not treated with antibiotics), and Q fever (which is not fatal but incapacitates its victims for an average of 8-16 days). They were also working on techniques for producing weapons using smallpox, the plague, and anthrax agents [Alibek].

World War II brought several advances to the former Soviet Union in the form of German industrial techniques and machinery for manufacturing large-scale biological reactors as well as other industrial equipment and valuable information from the Japanese BW program [Bodanyk].

After the war, the BW program in the former Soviet Union continued to expand and develop. In many cases, it closely shadowed the U.S. biological weapons program. While only a few agents had been weaponized before the war, the number of weaponized agents increased to approximately ten after the war. A number of weapons affecting crops and livestock were also developed. Research during this period also included developing and refining techniques and equipment for more efficient cultivation and concentration of agents; and devising methods for more advanced weaponization for a number of agents [Alibek].

There were numerous government bodies involved in BW development and production in the Soviet Union such as MoD, the KGB, the Academy of Science and the Ministries of Health, Agriculture, and Industry [Bodanyk]. During the post-war period, which lasted until the signing of the 1972 Biological and Toxin Weapons Convention (BTWC), the leadership of the former Soviet Union formulated its position regarding the use of weapons of mass destruction (WMD). Strategic weapons, according to the doctrine, were those to be used on the farthest targets, i.e., the U.S. and other distant countries. Operational weapons were those intended for use on medium-range targets, nearer than strategic targets, but well behind the battlefield; and tactical weapons were those to be used at the battlefield. BW were excluded from use as tactical weapons, and were divided into strategic and operational types. Strategic biological agents were mostly lethal by nature, such as smallpox, anthrax, and the plague. Operational agents were

mostly incapacitating, such as tularemia, glanders, and Venezuelan equine encephalomyelitis. For both types of weapons, employment was envisioned on a massive scale, to cause a large number of casualties and extensive disruption of vital civilian and military activities [Preston].

It is important to note that, according to the doctrine, the best biological agents were those for which there was no preventive cure. In cases where vaccines or treatment existed (such as the plague, which can be treated with antibiotics), antibiotic-resistant or immunosuppressive variants were to be developed [Preston].

Although the former Soviet Union was party to the BTWC, it continued a high-intensity program to develop and produce BW through at least the early 1990s. The size and scope of this program was enormous. In the late 1980s and early 1990s, over 60,000 people were involved in the research, development and production of BW. Hundreds of tons of anthrax were stockpiled, along with dozens of tons of smallpox and the plague. The total production capacity of all of the facilities involved was many hundreds of tons of various agents annually [Tucker, 2000].

During this period, the focus of the Soviet BW program was expanded and included improved manufacturing equipment, testing techniques, improved delivery means for existing weapons, and exploring other possible agents as weapons. This has allowed the former Soviet Union not only to catch up with the U.S. program, terminated in 1969 by President Nixon's Executive Order, but it by far became the most sophisticated biological weapons program in the world [Bodanyk, Cole].

Soviet scientists developed a completely new class of weapons based on genetically modified agents. For example, during 1982-1985, the former Soviet Union developed antibiotic-resistant strains of the plague, anthrax, tularemia and glanders. One of the “best” agents was the 836 strain of anthrax, which was extremely virulent, stable in aerosol form, and remained in the environment [Alibek].

The Soviet leadership understood that offensive biological work had to be conducted under strict secrecy since the Soviet Union had signed the BTWC. In fact, the Soviet BW programs were even more secret than nuclear weapons program. All research,

development and manufacturing of BW, as well as any related work, were classified as "top secret" and of "special importance" [Alibek].

The creation of Biopreparat (Chief Directorate of Biological Preparations) in 1973 in the Soviet Union was linked to the need to hide any BW activities prohibited by the BTWC. According to the plans of the Soviet government, Biopreparat would not have any "footprints" from previous BW activities in the Soviet Union. The new entity was funded from MoD and consisted of about 40 facilities - including research institutes, experimental plants and laboratories. The leading Biopreparat institutes were the Center for Applied Microbiology in Obolensk near Moscow, the State Center for Virology and Biotechnology "Vector" in Novosibirsk, and the Institute for Ultra-Pure Biological Preparations in St. Petersburg. Biopreparat did some legitimate secondary work on pharmaceuticals, biotechnology, and vaccines [Tucker, 2000].

Biopreparat was not responsible for manufacturing BW in peacetime. Instead, it had mobilization capacities, or in other words, facilities that could rapidly begin weapons production if war was imminent [Bodanyk].

The MoD of the former Soviet Union was supposed to assign tasks to Biopreparat, monitor its programs, conduct testing, and accept the new agents and munitions. However, MoD not only controlled Biopreparat, but continued developing its own BW. MoD worked on some of the same agents and weapons as Biopreparat and sometimes on different ones [Bodanyk].

MoD had three facilities that manufactured and stockpiled BW in peacetime. The smallpox virus was produced at a military plant in Zagorsk located near Moscow. The MoD facility in Kirov stockpiled the plague BW, and a plant in Sverdlovsk stockpiled anthrax BW [Alibek].

As the former Soviet Union weakened during the late 1980s and early 1990s, and as more and more details were revealed regarding its BW program, the Western countries put increasing pressure on the Soviet government to stop these activities. In 1991, a series of trilateral inspections was conducted by the United States, Great Britain, and the former Soviet Union. The inspectors did not find any direct evidence of BW programs in the

former Soviet Union, but they were only allowed to inspect Biopreparat's institutes while MoD microbiological facilities were not included in these inspections [Cole].

After the collapse of the former Soviet Union, Russian President Boris Yeltsin signed a decree banning all biological weapons-related activity in early 1992. Considerable downsizing in this area occurred, and included the destruction of the existing BW stockpiles. Some Biopreparat facilities were shut down, and at others, personnel was cut up to 80 percent [Alibek].

However, a number of events in this field in Russia during the 1990s made it doubtful that Russia had completely dismantled the old Soviet program:

Russia's only repository for the smallpox virus was officially transferred in 1994 from the Ivanovsky Institute for Viral Preparations (Moscow), which was not involved in any biological weapons research, to the State Center for Virology and Biotechnology "Vektor" in Novosibirsk. In the late 1980s, "Vektor" was doing biological weapons research on the smallpox virus, and thus far the Russian government has not verified the activities or conducted transparency measures at this facility.

Extensive genetic engineering research has been conducted using the vaccine virus, ostensibly, for vaccine development. The research has entailed the insertion of genes from the Venezuelan equine encephalomyelitis virus and from the Ebola virus into the vaccine genome. The genome of the smallpox virus has been fully analyzed and compared to the genome of the vaccine.

MoD keeps its facilities in Zagorsk, Kirov and Sverdlovsk running and closed to any foreign inspections [Alibek].

This suggests that Russian scientists are continuing to conduct research and following concealment plans that were in place during the Soviet era. Of course, it is impossible to say with certainty whether this research is part of a continuing BW program, because it generally has legitimate uses as well. However, it is important to remember that the Soviet Union managed to hide its enormous biological weapons program from the West for decades, even after signing the BTWC.

In addition, it is obvious that Russia is interested in maintaining its offensive BW programs because these weapons have unique capabilities and are very effective for certain types of low-intensity or high-intensity conflicts. These weapons are now especially valuable for Russia since its conventional military potential becomes weaker every year.

Thus, it is critical that the international community continue to pressure Russia to establish adequate verification measures under the BTWC, as well as measures that will increase the transparency of research programs in Russia and elsewhere.

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III. APPEARANCE AND DEVELOPMENT OF BRAIN DRAIN IN THE FIELD OF CBW FROM RUSSIA DURING THE 1990S

A. APPEARANCE OF BRAIN DRAIN IN RUSSIA DURING 1990S

The so-called "CBW brain drain," an exodus of scientists, technicians, and engineers with CBW knowledge from Russian scientific communities, began in 1991, when Russia was in the throes of dynamic social and economic change. A reorientation and downsizing of the bloated Russian economy, which could no longer sustain the pace of the arms race, touched on military as well as civilian enterprises. With the collapse of the former Soviet Union in December 1991, there was also a loss of central political control, a downward spiraling of the economy, a relaxation of Soviet-era emigration/immigration restrictions, and an escalation of crime and black market activity [Shkolnikov, 1995].

Scientists who worked under CBW programs were considered privileged in the former Soviet Union due to a number of factors. First, the profession was very prestigious in the eyes of society. Second, the state paid generously for the work, and third, the scientists had great prospects for their careers as well as for scientific research [Shkolnikov, 1994].

Russia, which inherited from the former Soviet Union almost all its CBW potential, including 30,000 CW scientists and 60,000 Biopreparat scientists, was unable to maintain all those programs [Tucker, 2000]. The only exception, as noted earlier, has been the Russian MoD BW programs that are still on-going and obtaining sufficient funding.

Since early 1992, severe cutbacks in scientific and defense spending (50-70 percent according to some estimates), high rates of inflation (up to 30 percent per month), defense conversion, and privatization policies have placed scientific institutes and research and development (R&D) facilities under great strain [Sharon]. The average official salary for scientists dropped dramatically to about 65 percent of the national average in 1996. In the years preceding the economic reforms in Russia, the average salary for scientists was 10 to 20 percent higher than the national average [Schweitzer].

Since these meager salaries did not meet the minimal needs of scientists, they had to look for additional sources to earn a living, mostly outside the R&D sector. Scientific organizations were forced to focus on meeting immediate financial requirements rather than making commitments to research activities with deferred payrolls. There was no funding available for libraries, buildings, maintenance or essential utilities [Schweitzer]. The civilian scientists from the former Soviet Academy of Sciences who worked on military-related problems on a contract basis for Soviet military-industrial ministries found themselves in the same situation [Schweitzer].

Thus, all those R&D organizations were thrown into totally new conditions when they were almost completely on their own without sufficient state support. They had to convert their activities and research from military to civilian needs and had to compete to obtain private orders. Such organizations did not possess any business experience because they were accustomed to guaranteed state orders [Shkolnikov, 1995].

In fact, the situation for most research groups was even worse, because the impact of the budgetary cuts was compounded by two other negative factors. One was the cessation of orders from industries that also suffered without state support. The second factor was an enormous escalation in the costs of electricity, heating, water, and other utilities, which had previously been negligible, following the liberalization of prices in 1992.

In April 1992, Russian President Boris Yeltsin officially acknowledged the existence of an offensive BW program and issued a decree ordering the termination of research on offensive biological weapons, the dismantlement of experimental technological lines for the production of biological agents, and the closure of biological weapons testing facilities. Personnel involved in military biological programs were cut by 50 percent, the operating and research budgets of many biological research centers were slashed, and thousands of scientists and technicians stopped receiving pay [Moody].

At the same time, some R&D organizations in Russia during that time actually increased their activities and some organizational consolidation occurred as well. However, comparatively few facilities have folded under the economic pressure, choosing instead to shorten workweeks, grant extended administrative leave to

employees, and compensate for the decline in government funding by attracting foreign business [Sharon].

Responding to social insecurities and declining economic prospects, many scientists had to leave their jobs:

By 1994 the State Center for Virology and Biotechnology “Vector” in Novosibirsk which specializes in biological warfare agent R&D, had lost about 3,500 personnel since the 1980s;

Between 1992 and 1996 D. I. Mendeleyev Institute of Chemical Technology in Moscow, which trained key experts for former Soviet CW programs, lost about 1,800 personnel;

Between 1990 and 1996 the State Research Center for Applied Microbiology in Obolensk lost 54 percent of its staff, including 28 percent of its Ph.D. scientists. The operating budget of the Center dropped from about \$25 million in 1991 to about \$2.5 million in 1996 [Schweitzer].

By October 1995, employees of the “Khimprom” Production Association at Novocheboksarsk, one of the former centers of CW production, had not been paid for five months [Schweitzer].

Some directors of former BW research centers have sought to keep their senior scientists by dismissing more junior scientists and technicians. These senior scientists are highly trained, many with doctorates or other advanced degrees and represent the intellectual core of the world’s largest and most sophisticated biological weapons program. Yet, because of the Russian economic crisis, which worsened in August 1998 with the collapse of the ruble, even high-level scientists are not being paid their \$100 average monthly salaries [Schweitzer].

Prior to the disintegration of the former Soviet Union, CBW scientists in Russia were strictly controlled. Those with access to state secrets had almost no opportunities to travel abroad, even to Eastern Europe. However, in May 1991 Russia passed a new law on emigration and immigration policies, which significantly liberalized previous Soviet practices in the above field [Moody].

With the virtual disappearance of official restrictions on emigration, under-funded and jobless Russian scientists began to look for opportunities to recoup their crumbling economic prospects abroad. State responses to those tendencies in Russia were

inadequate and poorly designed, because government agencies that had been in place to track such movements were primarily concerned with the ethnic, rather than the professional, character of migration [Shkolnikov, 1995].

At the same time, many internal and external constraints on large-scale emigration of CBW scientists from Russia existed. Among them are:

Russian State Security Service still kept an eye on all activities of Russian CBW scientists, and had the authority to stop any person from traveling abroad [Moody]

Russian scientists with CBW knowledge as a rule were in their 30's and 40's, had families, and the decision to leave the motherland and go abroad was not that easy to make

Russian scientists with CBW knowledge did not have sufficient experience to work with Western lab equipment, computer systems and networks [Schweitzer]

Potential candidates have had to face many general immigration restrictions from the Western recipient countries [Moody]

Western countries, where the situation is stable and competition is high, have a relatively low demand for additional scientists in chemical and biological fields [Moody]

Taking into account the above factors, it is obvious that not all CBW scientists had an opportunity to go abroad to work. Thus, the most serious drain of expertise has occurred internally, or in other words, a flow of CBW scientists from their institutes and labs into business or whatever sort of work that will allow them to make money. It has been estimated that for each scientist who emigrated abroad, another ten left science for another sector of the economy inside the country [Shkolnikov, 1994].

It should be mentioned that the lack of opportunities for CBW scientists to use their military-related knowledge, combined with constraints on movement, pushed some of them to use whatever means available to “market” their expertise. Some scientists, for example, managed to find orders and were working directly or indirectly for foreigners without not even having to leave Russia and even staying in their old institutes simply by using a modem and an Internet connection [Govorun]. Detecting or preventing illicit electronic transfers would be a challenge in any region of the globe. However, in Russia, where social dysfunction and difficulties in implementing and enforcing legislative initiatives are the norm, the ethical standard that distinguishes legitimate scientific dialogue from the illegitimate diversion of weapons expertise is becoming increasingly

difficult to recognize. The Internet, which has mushroomed in Russia, has opened a formerly closed society to virtually unlimited global discourse with all the implications this development suggests [Graham].

At the same time, it is important to mention that beginning in 1991, an estimated 20,000 scientists between the ages of 30 and 45 emigrate from Russia every year. The combined number of scientists that work under CBW programs in Russia as of 1990 was 90,000 [Tucker, 2000]. Among them were 10,000 core specialists who had many years of direct hands-on experience in the laboratories and on the test ranges where components and materials for thousands of real weapons were developed. Thus, it can be concluded that at least a few hundred of these CBW scientists have emigrated.

B. DEVELOPMENT OF BRAIN DRAIN FROM RUSSIA DURING 1990S

The process of the external brain drain from Russia has changed during the last ten years. According to current data, there were four waves of Russian brain drain that occurred during 1991-2001 [Dezhina].

The first wave was in 1991 consisting largely of elite scientists who were well known in the international scientific community. About 70 percent of the scientists who left Russia in this year continued their scientific careers at universities and R&D organizations abroad. Another significant outflow was ethnic emigration to Germany and Israel; in many cases, those newcomers later moved to the United States, seeking more favorable research conditions and immigration laws [Dezhina].

The second wave of emigration came in 1992-1993, the time of the most intensive outflow. However, only 20-40 percent of the total number who emigrated abroad during this time remained in science after arriving in foreign countries [Dezhina].

The typical scientist-emigrant abroad between 1992 and 1993 was 31 to 45 years, male, with a doctorate, engaged in theoretical research and had often been widely published. According to different surveys, in terms of scientific disciplines, physicists and mathematicians composed 55 percent of the total number of emigrants, followed by biologists, about 30 percent, and chemists, about 10 percent. The largest share of emigrants came from Moscow, St. Petersburg, and Novosibirsk, the major Russian

scientific centers. Many of those researchers apparently took with them decades of collective work that often had yet to be patented [Dezhina].

The third wave took place from 1994 to 1998. The typical representatives of this wave were biologists, especially in fields such as genetics, molecular biology, and virology, and computer science specialists. There were fewer chemists in this wave, mostly because of the diminishing demand for these specialists in foreign countries, especially in the United States. In 1997 – 1998, external outflow was stable at about 10,000 scientists per year leaving permanently with an additional 7,000 researchers per year working abroad on a contract basis. Graduate students and young researchers were prominent among those leaving during these years, resulting in a scarcity of young researchers in Russia between the ages of 30 and 40 [Dezhina].

In 1999, the current wave of scientific emigration started. The volume of this wave is the smallest compared to the previous three, at approximately 8,000 per year [Dezhina]. However, an overall slowing of the scientific personnel drain in recent years was primarily because those who could leave Russia, have already done so [US Central Intelligence Agency]. According to a 2000 survey conducted among scientists from different fields, the major reasons for emigrating from Russia at the present time are as follows:

- Low levels of salaries for both research and teaching
- Ever-worsening shortages of equipment and instruments for conducting fundamental research
- Absence of prospects for career growth in Russia
- Low prestige of scientific careers in Russia
- An unstable political situation [Dezhina]

Characteristic features of this last wave are leaving Russia after first defending a thesis there, and a “pendulum migration,” in which a growing number of researchers move back and forth rather than leaving Russia permanently [Govorun]. From the perspective of CBW proliferation, the most “dangerous” waves were the first three, because the last one consists of relatively young scientists who do not possess enough practical experience in offensive programs [Dezhina].

The difficult economic situation in Russia, coupled with the continued presence of a significant number of experts in the field of R&D and production of CBW, raised concerns in Western countries that some CBW experts might be recruited by outlaw states or terrorist groups. According to U.S. government official Andrew Weber, a special advisor for threat reduction policy at the Pentagon in 1995, about 3,000 former Biopreparat scientists have emigrated from Russia to the United States, Europe, and elsewhere during 1992-1995, but no one knows how many have moved to countries of CBW proliferation concern [Schweitzer].

It is worth mentioning that the majority of Russian scientists who emigrated to the U.S. and Western Europe during the last 10 years, as a rule, did not find positions in science. Those who are the most successful use their language and entrepreneurial skills to find jobs in commerce. Even among Russian scientists and engineers who came to the United States under the program of exchange visitors, only 50 percent worked in their previous areas of expertise [Dezhina].

C. ATTEMPTS OF THE RUSSIAN GOVERNMENT TO ADDRESS THE BRAIN DRAIN PROBLEM

It would be incorrect to say that the Russian government during the 1990s did not pay appropriate attention to the issue of brain drain and CBW scientists in particular. There were numerous meetings, conferences, reports, Presidential orders and federal laws, special awards for scientists, which were aimed at supporting scientific organizations in order to create good conditions for scientists to stay in the country and not go abroad [Dezhina].

In 1996 a program entitled “The State Support of the Integration of Higher Education and Fundamental Science for 1997-2000” was initiated by the Ministry of Education and Russian Academy of Science. It was given the highest status for a governmental program and was officially designated as “presidential and goal-oriented.” Its purpose was to support fundamental research conducted jointly by researchers of the Academy of Science and by those in higher educational institutions. However, the factor that hampered the full realization of this program was its poor financing. The program has received only 44 percent of the funding it was promised [Dezhina].

President Vladimir Putin also announced in May 2000 that support of defense-related research and development is one of the major priorities of his policy toward science and technology. A realization of this policy can be seen in the growing expenditures by the government on defense-related research and development. A noticeable redistribution of resources from the civilian sector of the economy to the defense sector is occurring, which is understandable considering that the crisis in Russian science affected the defense sector to a greater degree than civilian areas [Moshkov].

The government also started a new program on special assistance to higher educational institutions preparing defense scientists. Starting in 2001, students studying in specialties related to defense receive scholarships that are four times larger than those for students studying in other fields, and teachers in appropriate defense-related departments will receive salaries that are 30-40 percent higher than those of their “civilian colleagues”. The government also established a special support program for young scientists working in defense-related fields. As a rule, the support can be given in the form of various types of prizes, grants, and scholarships awarded on a competitive basis [Dezhina].

The most notable development was that in 1999 and 2000, for the first time since the dissolution of the former Soviet Union, the Russian government actually delivered the amounts promised in the budget to science. Another event was that the number of scientists in Russia in the government research sector in 2000 began to increase after years of decline. The government also increased its financing for education. In the budget for 2001 the allocations for education increased by 51 percent over the previous year. Thus, it can be concluded that the situation has been gradually improving in Russian science during the last two years [Dezhina].

However, the brain drain problem is still real in Russia [Govorun]. In August 2001, at a meeting with top science officials, President Vladimir Putin identified brain drain as one of the key problems of Russian science, influencing all science and technology areas. Scientists, including those with CBW knowledge, continue to leave science and the country, and only in isolated cases do they return from abroad [Govorun]. Although the Russian government has realized that attempts to lessen the severity of

brain drain depend critically upon improvements in the economic situation of scientists in Russia, so far it has not found effective ways to address this problem.

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IV. ANALYSIS OF ATTEMPTS OF THE COUNTRIES SUPPORTING INTERNATIONAL TERRORISM TO BENEFIT FROM THE CHEMICAL AND BIOLOGICAL WEAPONS BRAIN DRAIN FROM RUSSIA

A. CHEMICAL AND BIOLOGICAL WEAPONS PROGRAMS IN COUNTRIES OF PROLIFERATION CONCERN

Up until this chapter, the issues were mainly focused on the situation in Russia concerning CBW programs and the personnel involved with them. The significance of these issues on international security is quite important because of the size of these programs and the present problems of dismantling them, as well as how to employ the CBW personnel who worked on these programs.

At the same time, these problems are closely connected with another issue that is not so obvious, but could have much greater consequences for international security. This is the possibility that Russian CBW experts might be recruited by states with proliferation concerns or by terrorist groups needing assistance in developing these types of weapons.

Among the states that are of international concern and that might be interested in foreign assistance in establishing or developing CBW programs are Iraq, Iran, Libya, North Korea, Sudan and Syria [Tenet]. The CBW potential of these countries, as of 1999, is stated in Table 1 [Report of Foreign Intelligence Service of Russia].

Table 1. CBW Programs in Countries of Proliferation Concern.

State	Offensive R&D		Testing		Production		Stockpiling	
	CW	BW	CW	BW	CW	BW	CW	BW
Iraq	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Iran	Yes	Yes	Yes	No	Yes	Small	Yes	Small
Syria	Yes	Yes	Yes	No	Yes	No	Yes	No
Libya	Yes	Yes	Yes	No	Yes	No	Yes	No
North Korea	Yes	Yes	Yes	Yes	Yes	No	Yes	No
Sudan	Yes	No	Yes	No	No	No	No	No

In accordance with the statement by John Lauder, Special Assistant to the Director of the U.S. Central Intelligence, all these countries were put in the category of proliferation concern or rogue countries for two reasons. They supported international terrorism such as, for example, the Iranian-sponsored terrorist organizations of Hamas, Hezbollah, and the Islamic Jihad, and their hostile policy towards democratic countries, and first and foremost, towards the United States [Lauder].

The precise status of Iraq's CBW programs is unknown because of the country's efforts since 1991 to conceal the full extent of its prohibited activities. Iraq's expulsion of inspectors from the United Nations Special Commission (UNSCOM) in December 1998, and its continuing refusal to admit inspectors from the successor agency, the United Nations Monitoring, Verification and Inspection Commission (UNMOVIC), has further impeded international efforts to assess the status of Iraq's prohibited weapons programs. It appears likely, however, that Iraq has rebuilt key elements of its chemical and pharmaceutical production infrastructure that were destroyed during the Gulf War and by UNSCOM. These dual-use facilities could easily be converted to the production of CBW agents, and probably already have been. Various reports indicate that Iraq may retain a sizable stockpile of chemical munitions, including 25 or more special chemical/biological warheads for the al-Hussein ballistic missile and 2,000 aerial bombs. Iraq is also believed to possess sufficient precursor chemicals to produce hundreds of tons of mustard gas, VX and other nerve agents. In short, Iraq retains the materials and technical expertise to revive its chemical warfare program within months, if it has not already done so [Bowman]. Iraq has not signed the Chemical Weapons Convention.

Iraq is also believed to retain a substantial offensive BW capability. According to some estimates, Iraq may possess undeclared stocks of the smallpox virus and has retained a mobile production facility capable of producing dried biological agents, which are particularly lethal. Iraq currently maintains the technical expertise and equipment to reconstitute its BW capabilities within months, including the production of anthrax bacteria and different toxins [Bowman].

Although Iran has signed and ratified the Chemical Weapons Convention, it continues to pursue the acquisition of technologies and materials needed for the

production of chemical and biological agents. Iran began its CBW programs in the mid-1980s in response to Iraqi chemical attacks during the Iran-Iraq War. After 1985, Iran began manufacturing and stockpiling blister, blood and choking agents. Reportedly, Iran began nerve agent production in 1994. Iran continues to augment its CBW production capability by seeking to acquire relevant production technology, technical expertise and precursor chemicals from other states, including Russia [Carus, Giles].

During the 1980s, Libya produced more than 100 metric tons of nerve and blister agents at the Rabta facility, which Libya claimed was a pharmaceutical plant. A project to build a large underground chemical and biological weapons production facility using Russian technology at a second site called Tarhunah has been underway since 1995, although international pressure has slowed the pace of construction. Libya has not signed the Chemical Weapons Convention and is heavily dependent on foreign suppliers for precursor chemicals and production equipment [Sinai].

Libya's BW program has not advanced beyond the R&D stage. It is possible, however, that Libya can produce small quantities of BW agents. Libya's offensive BW program is also heavily dependent on dual-use materials and foreign assistance [Sinai].

Evidence in the public domain suggests that North Korea has operated an extensive CW program for many years and has the ability to produce a variety of agents, including adamsite, mustard, sarin and VX. North Korea has not signed the Chemical Weapons Convention. This state has pursued its BW capabilities since the 1960s and reportedly conducts research on the biological agents that cause anthrax, the plague and smallpox [Zilinskas].

A party to the Chemical Weapons Convention, Sudan has pursued the capability to produce chemical warfare agents since the 1980s. Sudan has sought foreign assistance from a number of countries that have CW programs, including Iraq. During the 1990s, Sudanese officials allegedly produced chemical weapons in collaboration with Osama bin Laden's al-Qaeda terrorist network, although evidence in the public domain for this allegation remains equivocal. There are no confirmed reports that Sudan is pursuing a BW program [Barletta].

Syria has one of the largest and most advanced chemical warfare capabilities in the Middle East. With an estimated CW stockpile in the hundreds of tons, Syria is believed to be capable of producing and delivering sarin and the VX nerve agent, as well as a mustard agent. Syria's chemical warfare program remains dependent on foreign precursor chemicals and equipment, and it has continued to seek CW-related materials from various countries. Syria has not signed the Chemical Weapons Convention. Although it is likely that Syria is developing an offensive BW capability, evidence suggests that it is currently restricted to a research program [Diab].

B. ROGUE COUNTRIES' ATTEMPTS TO BENEFIT FROM CBW BRAIN DRAIN FROM RUSSIA

In speaking of the attempts of the aforementioned countries to find experts and knowledge in Russia to assist in the field of CBW, it is important to note that the most well-known facts about recruiting Russian CBW scientists are associated with Iran, which was particularly active in this field during the 1990s. The London Sunday Times, in its August 27, 1995 edition, stated that by hiring Russian BW experts, Iran had made a “quantum leap forward” in its development of BW by proceeding directly from basic research to production and acquiring an effective weapons system [Khairullin].

An article published in the December 8, 1998 edition of the New York Times supported this statement and alleged that the government of Iran offered Russian BW scientists jobs paying as much as \$5,000 a month, which is far more than these people can make in a year in Russia. Although most of the Iranian offers were rebuffed, Russian scientists who were interviewed said that at least five of their colleagues had gone to work in Iran in recent years. One scientist described these arrangements as a “marriage of convenience, and often of necessity. These five scientists were among the best people in the Russian BW program” [Miller].

According to the New York Times, many of the initial contacts with the former “Biopreparat” institutes were made by Mehdi Rezayat, an English-speaking pharmacologist who claims to be a “scientific advisor” to Iranian President Mohammed Khatami. Iranian delegations, which visited the Russian institutes usually expressed interest in scientific exchanges or commercial contacts. In such a manner, the two leading CBW experts from the State Research Center for Virology and Biotechnology “Vector”

were invited to Iran for “educational and scientific purposes”. Of particular interest to the Iranians were genetic engineering techniques and microbes that could be used to destroy crops. In 1997, for example, V. Lipkin, Deputy Director of the Russian Academy of Sciences Institute of Bioorganic Chemistry, was approached by an Iranian delegation that expressed interest in genetic engineering techniques and made tempting proposals for him and his colleagues to come and work for a while in Tehran. According to V. Lipkin, his institute officially turned down the Iranian proposals, but he could not say that any of his employees had not accepted those proposals, since only in 1997 did the Institute lose 15 percent of its researchers [Giles, Miller].

Evidence collected by opposition groups within Iran and released publicly in January 1999 by the National Council of Resistance indicates that Brigadier General Mohammed Fa’ezi, the Iranian government official responsible for overseas recruitment, has signed up several Russian scientists. Some of them were employed under one-year contracts. According to this report, Russian BW experts are working for the Iranian Ministry of Defense Special Industries Organization, the Defense Ministry Industries and the Pasteur Institute. Moreover, in 1998, Anatoliy Makarov, Director of the All-Russian Scientific Research Institute of Physiopathology, led a scientific delegation to Tehran and gave the Iranians information related to the use of plant pathogens to destroy crops [Giles].

In many cases, the movement of CBW specialists from Russia occurs within the confines of state-sanctioned projects or long- or short-term temporary work to countries of concern such as Iraq, Cuba, Syria and Iran. The potential for diversionary activity beyond the scope of such projects is very high [Tucker 2000].

In 1992, for example, the governments of Russia and Syria signed an agreement to create a Syrian Center of Ecological Protection that would not only address ecological problems, but conduct research on CW defense. Reportedly, three Russian scientists participating in the Syrian center had worked on the “novichok” program. In November 1996, the Israeli Defense Minister, General Y. Mordechai, claimed that Russian scientists were helping Syria manufacture the nerve gas VX. In 1999, the London-based Arabic

newspaper Al-Quads al-Arabi reported that Syrian missile warheads had been loaded with the nerve agent VX and a novel agent “novichok” [Zanders, 2000].

The threat of proliferation of CBW-related materials from Russia to the countries of proliferation concern also exists. In 1995, the Russian Federal Security Service charged A. Kuntsevich, a former general of the Russian RCB Forces, with having shipped 800 kilograms of CW precursors to Syrian buyers and attempting to smuggle an additional 5.5 tons. Although Kuntsevich was fired, the charges against him were later dropped [Zanders, 1999].

Sources in the U.S. intelligence community assert that samples of the smallpox virus were smuggled from Russia to Iraq and North Korea in the early 1990s. Recent press reports indicate that even under the United Nation embargo on CBW-related equipment, Iraq has been able to acquire equipment in a clandestine purchase from Russia that could be used to produce BW [US Government White Paper].

The 1995 sarin attack in a Tokyo subway by the cult Aum Shinrikyo also is connected to Russia. During an investigation, a substantial number of Aum members have been found in Russia with ties to the Russian RCB forces, the Russian Academy of Science and Russian Intelligence. It has been documented that the cult was able to procure various Russian weapons systems. Although the cult manufactured its own sarin, a Russian military recipe was allegedly used [Zanders, 1999].

A new form of brain drain is the training of foreign specialists in Russian institutions that deal with CBW. In July 1998, the Russian government closed down a training program for Iranian students at the Baltic State Technical University in St. Petersburg on the grounds of national security. A number of other cases suggest that the threat of “brain drain through training” remains high [Tucker, 2000].

In 1996, the Istanbul Security Directorate seized vials of Russian-made mustard gas and sarin, which detectives had agreed to buy for \$1 million. The seller appeared to be a former KGB officer from Russia. The Turkish authorities transferred the smuggler to the Russian Security Service [Ersemiz].

During the 1999 trial in Egypt of members of al-Jihad, a group associated with Osama bin Laden, it was discovered that the group had purchased ingredients for CBW agents from Russia with the intent to produce and employ such agents for terrorist attacks against the US and Israeli targets [Khairullin].

At the same time, some Russian CBW scientists made their own attempts to offer their skills and knowledge to foreign countries. For example, the former Director of the State Research Center for Applied Microbiology in Obolensk, I. Domaradskyi, in March 1992, desperate for work, offered to sell his services to the Chinese and North Korean Embassies in Moscow, but reportedly received no response to either inquiry. Russian law enforcement authorities only became aware of these events in 1996 [Khairullin].

It can be concluded from the information presented above that countries of proliferation concern were able to benefit from the CBW brain drain from Russia. At the same time, the existing data indicate with certainty that only the governments of Iran and Syria seriously considered the possibility of using CBW expertise from Russia during the 1990s. However, it does not mean that Russian CBW scientists could not have worked for other rogue countries in the field of their expertise during the 1990s. These issues are so sensitive that any country pursuing CBW development will hide these activities behind civilian programs. In other words, Russian CBW experts could officially work on civilian programs, for example, at pharmaceutical plants in these countries [Zanders, 2000]. In addition, even if rogue countries did not specifically search for foreign assistance, some Russian scientists actively market their skills and could work on foreign programs by remaining in Russia and using a modem [Cooperman].

According to the existing data, besides Iran and Syria, none of the rogue countries made significant developments or discoveries in the field of CBW during the 1990s. It suggests that even if Russian CBW scientists assisted these countries in any manner, resources were very limited, and not much progress was made in this field [Report of Canadian Security Intelligence Service].

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V. INTERNATIONAL ACTIVITIES IN THE FIELD OF THE BRAIN DRAIN PREVENTION

A. US-FUNDED PROGRAMS

Among the states and international organizations that took seriously the threat of CBW proliferation from Russia through brain drain, the leading role belongs to the United States. Almost all measures to combat it during the 1990s were conducted with the active participation, particularly financial, of the United States [Tucker, 2000].

Since 1991, the United States has designed and implemented a variety of programs to reduce the risk of CBW proliferation from Russia and other CIS countries [Smith]. The US programs aimed at halting brain drain offer Russian and CIS scientists alternative employment in peaceful research and cooperative activities. A number of these programs were initiated by the Department of Defense, with funding from the Nunn-Lugar Cooperative Threat Reduction program. They were later placed under the administration of other US agencies, sometimes at the insistence of Congress [Tucker, 2000]. Programs to combat the CBW brain drain from Russia and to assist in the conversion of the national defense industry were a key part of the programs initiated by the Department of Defense. The main efforts are concentrated on projects designed to provide grants for civilian research to scientists and institutions formerly involved in the development of weapons of mass destruction (WMD). The Department of State and the Department of Energy (DOE) were the main US agencies managing these particular efforts during the 1990s [Schweitzer].

The State Department managed the US participation in two international organizations established specifically to combat the threat of brain drain from the former Soviet Union: the International Science and Technology Center in Moscow (ISTC), formally established in 1993, and the Science and Technology Center of Ukraine (STCU), created in 1995. These centers, chartered by international agreements and funded by the US, Japan, Canada, and several other countries, provide financial support to former weapons scientists who submit proposals to research grant competitions (Table 2). Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan and Russia are CIS

members of the ISTC, while Georgia, Ukraine, and Uzbekistan are members of the STCU. Scientists from all these countries have received grants from the centers. Proposals are evaluated by the Governing Board of each center, which represents all its members, and are approved based on a combination of scientific, political, and nonproliferation considerations [Schweitzer]. As of 1999, the ISTC had funded 835 projects worth \$231.3 million and provided employment to some 24,000 CIS scientists and engineers. Eighty percent of these projects were from Russia. For the STCU, the numbers are 240 projects, \$32.1 million and 5,000 scientists, respectively [Tucker, 2000]. From 1994 through 1998, about three percent of the center's grants went to chemistry projects, and just over 13 percent to biology projects. In 1999, the US government increased ISTC and STCU funding for biological projects by \$10 million, including expanded support for civilian research at the "Vector" and Obolensk Centers, and other Biopreparat institutes. The total funding for projects in the field of biotechnology and life sciences was increased to approximately \$40 million [Wolfsthal].

Table 2. International Support for Science Centers during 1993-1999, by Donor and Amount.

Science center	Funding parties	Total contribution (\$US millions)	Comments
ISTC (Moscow)	United States	\$92.8	Russia supports ISTC by providing a headquarters facility and related expenses
	European Union	\$86.9	
	Japan	\$31.5	
	Norway	\$1.8	
	Republic of Korea	\$0.8	
	Other sources	\$17.5	
	Subtotal	\$231.3	
STCU (Kiev)	United States	\$21.4	Ukraine supports STCU by providing a headquarters facility and related expenses
	European Union	\$2.1	
	Canada	\$1.8	
	Sweden	\$1.7	
	Japan	\$0.7	
	Subtotal	\$32.1	
	Total	\$263.4	

The science centers initially focused more on supporting basic and applied research and technology development, but are increasingly oriented toward finding commercial applications for former weapons technology. The US portion of funding for

these centers comes from Nonproliferation, Anti-terrorism, Demining and Related Programs within the budget for the State Department. However, in the past few years, the Department of Defense, Agriculture, Health and Human Services, and the Environmental Protection Agency have begun funding scientific grant programs for former Soviet CBW scientists through the ISTC and STCU as well [Schweitzer].

Since 1997, both centers have actively sought to engage Western firms in selected projects through their Partner Programs. The goal of these projects is to reduce dependence on government funding, increase project sustainability, and promote integration of CIS research into the international R&D community. Joint collaboration with Western partners provides former Soviet personnel with much needed project management and entrepreneurial skills, which are retained as they learn to use their expertise for peaceful purposes. For example, the ISTC has approved 71 partner projects worth a total of \$16.6 million as of December 1999, [Tucker, 2000].

In 1996, the State Department also began funding the Civilian Research and Development Foundation (CRDF), which was created in 1995 by the National Science Foundation. Unlike the multilateral science centers, the CRDF is a US program that provides grants for US-CIS cooperative activities. Its annual budget is much smaller than that of the science centers. The FY 1998 funding, for example, was only \$1.8 million. \$1.6 million came from the State Department and \$200,000 from the National Institute of Health. The CRDF has provided funding for collaborative work between US scientists and scientists mainly in Russia and Ukraine. To date, the CRDF has committed resources to support about 1,400 scientists on 257 projects. The CRDF grants are often made to individual scientists, rather than to project teams (ISTC and STCU approach). In 1996, the CRDF provided \$250,000 for projects involving former BW scientists and \$550,000 for those involving CW scientists [Tucker, 2000].

The DOE has two programs aimed at stemming brain drain: the Initiatives for Proliferation Prevention (IPP) and the Nuclear Cities Initiative (NCI). The primary goal of the IPP is nearly identical to that of the ISTC and STCU. It offers CIS weapons scientists and engineers the opportunity to work with US counterparts on the development of commercially viable, non-military projects [Wolfsthal]. Due to the

heavily developed weapons infrastructure in the CIS, funding has gone towards projects in Belarus, Kazakhstan, Russia and Ukraine. Eighty five percent of the projects are in Russia. According to the charter of this program, the projects funded by the IPP must have the potential for commercialization. The IPP is exclusively a US-CIS program and does not involve additional international partners [Tucker, 2000].

Each IPP project proceeds through three stages, culminating in the location of a US commercial partner and the eventual withdrawal of US government funding. In the first stage, all selected projects are fully funded by the DOE. They involve laboratory-to-laboratory contacts between US national laboratories and CIS institutes and are intended to identify commercially feasible technologies. In the second stage, a US industrial partner agrees to share the cost of developing potential technologies. In the final stage, projects are expected to become self-sustaining business ventures [Tucker, 2000].

At the end of FY 1999, the IPP had approved 511 projects. Overall, IPP projects have engaged about 6,200 CIS scientists at over 170 institutes. Seventy percent of the projects have been in the nuclear sector, and 30 percent in the chemical and biological sectors. Since 1994, the IPP has received about \$182 million in funding. In the CW area, IPP funding has supported civilian research at former Soviet CW production facilities. In the BW area, the IPP program has commissioned research projects at 18 former BW institutes [Wolfsthal].

A report by the US General Accounting Office, released in February 1999, criticized IPP programs in the CBW area on the grounds that they had not been adequately reviewed by U.S. officials prior to approval and could have dual-use characteristics. To address these concerns, DOE officials have intensified their review and oversight of IPP proposals [Wolfsthal].

In the fall of 1998, the DOE started the NCI, a program targeted at Russia's formerly closed nuclear cities. The goal of the program was to create 30,000 to 50,000 jobs in the 10 closed cities of the Russian nuclear complex within seven years, at a cost of \$550 million. Current program operations are limited to three nuclear cities in Russia [Smith, Tucker, 2000].

B. OTHER INTERNATIONAL EFFORTS IN THE FIELD OF THE BRAIN DRAIN PREVENTION

There were no other international programs in the field of CBW brain drain prevention in Russia during the 1990s. All available funds from foreign countries were directed to the science centers [Wolfsthal]. International organizations, primarily the Organization for the Prohibition of Chemical Weapons (OPCW), were mainly concerned with the destruction of CBW in Russia and the prevention of illicit trafficking of CBW from Russia. Most importantly, they did not have the financial resources to establish or participate in brain drain prevention programs in Russia. The only effort that is being made in the sphere of brain drain prevention by OPCW has been proficiency testing leading to certification of designated laboratories in the State Parties to the CWC, including Russia [Rybalchenko].

The above testing aimed at selecting the best-prepared national laboratories to perform independent analysis of the samples taken during OPCW inspections. As of today, the Laboratory of RCB Forces of the Russian MoD has become a designated OPCW laboratory and has been conducting relevant testing since 1998. In this way, scientists at this laboratory got opportunities to apply their knowledge and skills for peaceful purposes [Rybalchenko].

C. ASSESSMENT

The international and national programs to combat CBW brain drain from Russia (which were funded mainly by the US) appeared to be quite effective during the 1990s. Their main goal was achieved. The lack of confirmed large-scale brain drain to countries of proliferation concern can be attributed at least in part to the science centers, IPP, CRDF and NCI. Of course, these programs did not eliminate completely the possibility of the CBW brain drain. However, participation in these programs has enabled many former Soviet CBW scientists to remain at home, support their families, and live in dignity without having to sell their weapons-related knowledge to states of proliferation concern or terrorists. Collaborative research programs at former Soviet CBW facilities have also increased the level of transparency at these inherently dual-use sites.

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VI. ANALYSIS OF THE CONSEQUENCES OF THE CBW BRAIN DRAIN PHENOMENON IN RUSSIA DURING THE 1990S

A. THE CONSEQUENCES OF THE CBW BRAIN DRAIN FOR RUSSIA

There were a number of consequences resulting from the CBW brain drain from Russia during the 1990s for the country itself and for the international community.

These consequences had the greatest impact on Russia. The most obvious result for Russia is negative, i.e., the loss of scientific potential represented by the many scientists who left the country. The loss of even 10 percent of the national scientific potential would have negative implications for the development of the whole country. Human resources are particularly valuable for a state that spent significant material and financial resources on their education and training. In addition, those who emigrated abroad often took with them know-how developed by whole institutions and laboratories during years of R&D. These emigrants also took their financial capital abroad [Shkolnikov, 1995].

At the same time, there is strong evidence that Russia's transitional economy cannot absorb all the educated people it produced. This suggests that although the resources spent on the education of migrants may be lost to Russia, the loss is a consequence of inappropriate manpower policies [Shkolnikov, 1995].

The inability of the Russian government to support CBW scientists during the 1990s forced more than 60 percent to leave their institutes and laboratories. There was, however, a silver lining; all these scientists stopped their offensive weapons research. As concluded earlier, it is highly possible that Russia is continuing with the CBW programs. However, the scope of these programs is very much reduced compared to such programs during the Soviet era [Schweitzer].

At the same time Russia started programs on destruction of CBW arsenals and conversion of relevant R&D and production facilities that required not only significant financial resources but appropriate scientific potential as well. Taking into account that many qualified Russian CBW experts left their institutes and laboratories during the

1990s, it is possible that Russia soon would have to rely more and more on foreign expertise in this field [Tucker, 2001].

More than 90 percent of the CBW scientists that left their research work during the 1990s remained in Russia [Shkolnikov, 1995]. Some of them started their own businesses, some joined civilian enterprises, and some had to study new professions. In these ways, they obviously helped the state continue conversion reforms in Russia. The huge scientific potential that many of the former CBW scientists possessed and could have used for civilian research was lost at the same time.

The most traumatic aspect for Russian science with respect to brain drain is that 80 percent of those who left scientific work in Russia during the 1990s ranged in age from 25 to 50, which is the most productive period for scientists. In 1992, for example, the share of researchers in the fields of chemistry and biology who were under twenty-nine years of age was 11.2 percent, and the share of those who were aged thirty to thirty-nine was 24 percent; by 1998 those numbers decreased to 5.7 and 14.1 percent, respectively. The average age of scientific personnel in Russia was 51 years old in 1999. This situation in Russia slowly improved in 2000-2001, when the Russian government started to address the issues of scientific funding, but still is far from ideal [Dezhina].

The largest number of Russian CBW scientists who left the country during the 1990s went to the United States, Israel and Western Europe. Among them, only 20 percent continued research in chemical and biological fields. At the same time, these researchers continued their contacts and exchanged information with their former colleagues in Russia - indirectly supporting development of science in Russia. These researchers also, as a rule, regularly send money back home, supporting their relatives and friends [Shkolnikov, 1995].

B. THE CONSEQUENCES OF THE CBW BRAIN DRAIN FOR THE INTERNATIONAL COMMUNITY

The most significant result of the CBW brain drain from Russia for Western countries is that it gave important evidence of the size of CBW programs in the former Soviet Union. Information that was released in 1991 by V. Pasechnik, the former director

of the Institute for Ultra-Pure Biological Preparations in St. Petersburg, who defected to Great Britain, was used by Western governments to raise questions before Soviet and later Russian governments about CBW programs. The inspections of Biopreparat facilities by the US and UK experts were directly linked to Pasechnik's information [Zilinskas]. So, in some way, the brain drain helped start transparency initiatives for CBW programs in Russia, the US and Great Britain.

The CBW brain drain from Russia abroad was not large during the 1990s. But, as discussed earlier, the governments of Iran and Syria were successful in finding and employing for Russian CBW expertise. CBW programs in Iran and Syria during the 1990s produced some significant results that could be linked, with a certain degree of certainty, to the participation of Russian CBW scientists.

So, we can conclude that CBW brain drain from Russia during the 1990s did occur to a very limited degree. Fortunately, as of today the brain drain phenomenon has not brought the world to such dramatic events as large-scale use of CBW. However, potential threats in this field for the international security system remain high.

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VII. CONCLUSIONS

A. MAJOR FINDINGS

Analysis of facts, trends and expert opinions in the field of the CBW brain drain from Russia during the 1990s suggests the following conclusions.

The CBW brain drain from Russia during the 1990s was the result of the termination of most of the CBW programs and drastic decreasing of funding of the majority of scientific organizations in Russia at that time. An unstable political situation and worsening economic conditions in Russia during this period of time contributed to the development of the brain drain phenomena.

The majority of CBW scientists who left the R&D institutes and labs remained in Russia during the 1990s working in civilian sectors of the Russian economy. The possibility to leave the country in search of new jobs attracted only a limited number of CBW scientists due to various internal and external constraints.

There is strong evidence that those who moved abroad settle down mainly in Western countries. A small number of the former Russian CBW scientists who left for the West keep on working in the field of chemical and biological R&D. The rest of the scientists have changed their expertise.

Among the countries of proliferation concern, only Iran and Syria used CBW personnel from Russia for R&D in their WMD programs. It is very difficult to predict the future of the situation in the Middle East. Thus the participation of the Russian experts in offensive R&D programs in Iran and Syria is a serious concern. As of today there is no available information about any attempts of other rogue countries to hire CBW specialists from Russia. At the same time such a possibility cannot be excluded, since unclaimed scientific potential in the above sphere in Russia remains significant.

The Russian government realized the magnitude and possible consequences of this problem. First of all, well-known and gifted scientists were leaving Russia, thus damaging Russian scientific potential. Despite this the Russian government during the 1990s did not find a solution to address the aforementioned problem. The situation of the

emigration of scientific personnel from Russia started to change for the better in 2000-2001, but it still is not optimistic. Even comprehensive funding of scientific projects is not the ultimate solution of the brain drain problem. There are a number of other aspects of everyday life of scientists in Russia that need to be improved to reach this goal.

The U.S. programs to combat the possible brain drain of weapons scientists, including CBW experts, appear to have been relatively effective. The lack of a confirmed large-scale brain drain to countries of proliferation concern can be attributed at least in part to the science centers, IPP, CRDF and NCI. Officials at the ISTC admit that it is difficult to prove that the lack of obvious weapons brain drain is attributable to the assistance provided by the science centers and other similar programs. At the same time, the existence of these programs has changed the atmosphere among former Soviet weapons scientists and given them a realistic way to convert their skills to civilian uses.

The brain drain problem in Russia is still pending resolution. Further efforts depend on policy and actions of the Russian government.

B. TOPICS FOR FURTHER RESEARCH

There are two more topics closely related to the CBW brain drain problem in Russia that could have negative consequences for regional and international security. First, the process of destroying chemical and biological weapons in Russia is moving ahead extremely slowly. The common reason is lack of funding. Meanwhile, the present stock of CBW in Russia could be the source of illegal trafficking of relevant weapons and materials around the world.

Another topic is the present status of CBW programs in Russia. There is some evidence that Russia continues offensive R&D in this field. In this case, it is difficult to understand how Russia, having so little funding for most scientific projects and asking the international community to assist in sustaining Russian science, is able to spend available funds on very expensive R&D in the field of CBW.

So, despite the efforts of Russia and the international community to address certain issues related to the CBW programs in Russia and scientific brain drain, related problems remain.

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