and Martijn Bakker (eds.), *Technological Development and Science in the Industrial Age* (Dordrecht: Kluwer, 1992), 133–153.

[46] See Carlo G. Lacaita, *Istruzione e Sviluppo Industriale in Italia, 1859–1914* (Firenze: Giunti, 1973), 32. See also Carlo M. Cipolla, *Literacy and Development in the West*, (Harmondsworth: Penguin Books, 1969), ch. 5.

[47] For an assessment of popular scientific culture in Italy *c.* 1900, see Paola Govoni, *Un Pubblico per la Scienza: La Divulgazione Scientifica nell'Italia in Formazione* (Rome: Carocci, 2002), ch. 3.

NATHAN M. BROOKS

MUNITIONS, THE MILITARY, AND CHEMISTRY IN RUSSIA

INTRODUCTION

The Great War imposed immense strains on all countries in the conflict. In many respects, however, Russia was the least prepared of all of the Great Powers to cope with these pressures. The failure of the state to wage war led directly to the overthrow of Tsar Nicholas II in early 1917. Until recently, however, little work has been done by western historians on the conduct of Russian science and technology during the war, and the Russian experience has not been adequately integrated into more general histories.[1] The most complete study in English of Russia's war is Norman Stone's study of the eastern front.[2] Stone covers a vast range of topics, but does not discuss the activities and organisations of Russian science. Nor do other historians of science. For example, L. F. Haber's study of gas warfare contains almost no information about the Russian experience.[3]

Similarly, Russian historians have focused more on the February and October Revolutions of 1917 than on the war itself. As one scholar has noted, most have seen the war as a 'disintegration leading to a disgraceful end.'[4] In a similar vein, studies of Russian science have largely ignored the war.[5] Only recently have scholars begun seeing the war as a critical moment in the establishment of the new Soviet State.[6]

Perhaps a principal reason for this general neglect lies in the fact that, until recently, archival information about wartime events in Russia remained classified by government security. This has been a particular problem for historians of science and technology. One finds in the literature, for example, only scattered references to the production of munitions and other chemical products.[7] This may be explained partly by the fact that General V. N. Ipat'ev, the central figure in the production of wartime explosives and other chemicals, continued to play a leading role in Soviet chemistry until forced to flee to escape a purge of economic officials in 1930. Only with the collapse of the Soviet Union in 1991 have historians had an opportunity to consult archives, and better understand Ipat'ev's contribution.[8]

Like the other allies, Russia entered the war with shortages of munitions, explosives, and other chemical products. Large orders were placed abroad, but these took time to arrive. Meanwhile, Russia's domestic output was called upon to supply a growing share of the military's needs. The domestic effort in chemical products was led by Ipat'ev, who headed the Commission for the Preparation of Explosives (CPE) [in Russian, *Komissiia po zagotovke vzryvchatykh veshchestv*], created

in early 1915. This was one of a myriad of committees and councils that were intended to bring order to the chaotic system of military procurement. Other agencies included the Commission for the Preparation of Asphyxiating Gases (CPAG) [*Komissiia po izgotovleniiu udushaiushchikh sredstv*], the War-Chemical Committee (WCC) [*Voenno-khimicheskii* komitet] of the Russian Physical-Chemical Society (RFCS) [*Russkoe fiziko-khimicheskoe obshchestvo*], the Chemical Section of the Supreme Chief of the Army Sanitary and Evacuation Service (SCASES) [*Verkhovnii nachal'nik po Sanitarnoi i Evakuatsionnoi chasti*], the Chemical Section of the Central War-Industry Committee (WIC) [*Voenno-Promyshlennyi Komitet*], the Chemical Sections of the regional War-Industry Committees, the Chemical Section of Zemgor,[9] and many others. This paper will examine a number of Russian chemists and their organizations, in their attempt to deal with wartime crises, and will show how their partial success helped pave the way for the eventual establishment of the Soviet chemical industry. This paper does not aim to provide a definitive analysis of Russian chemistry and the Russian chemical industry during World War I, but rather is intended as a preliminary sketch to probe the complex contours and interactions of the military and science during the war years.

PRE-WAR PLANNING FOR MUNITIONS AND MILITARY SUPPLIES

Before 1914, Russian military and naval armaments were produced under contract from the Ministry of War by domestic factories using prototypes and designs licensed or purchased from foreign firms. The military conducted little research and development, being content to follow the lead of other countries, principally France and Germany. In the 1890s, for example, the Russian Army converted to smokeless powder, using a French process, while the Russian Navy developed a similar type of powder for their large-caliber guns.[10] In 1914, most Russian factories producing goods for military consumption were state-owned. The problem was that, when pushed, state factories could not produce enough, nor fast enough. In 1914, there were only three State-run arsenals producing cartridges and shells – at Tula, Lugansk, and St. Petersburg – and five other factories that produced explosives and gunpowder. All suffered from a lack of investment, and failed to keep up with technological advances. For example, about 70% of all industrial machinery purchased in Russia in 1913, for example, was of foreign origin, and most came from Germany.[11]

The argument for restricting the production of military goods to state-owned plants was strategic. The Russian military was concerned that privately-owned factories in Russia, largely owned by foreigners (principally German) would be unreliable in times of war, and would eventually report to foreign governments. In addition, the Russian government feared that private companies would demand excessive payment for urgently needed supplies.

Despite these concerns, given the limited capacity of the state factories, the Ministry of War did turn to foreign suppliers in times of great demand. This happened often, despite a law mandating domestic production. During the 1890s,

the introduction of a new type of rifle impelled the military to place massive orders with Belgian and French firms. Once sufficient quantities were obtained to equip most of the standing army, the foreign orders ceased and yearly replacements were met by the state-owned factories.[12] However, Russian technological backwardness and delay sometimes forced the Ministry to give contracts to privately-owned factories even when they evaded domestic production regulations. For example, the Ministry contracted with a private factory for the manufacture of TNT using domestic toluene. However, the factory obtained its toluene from a German-owned plant in the Russian city of Revel, which fractionated the toluene from crude benzene imported from Germany. The Ministry apparently knew this was the case, but decided to turn a blind eye in order to get the product, instead of devoting time and effort to ensuring that the domestic production regulations were followed.[13]

During the Russo-Japanese War (1904–6), domestic producers were unable to meet the demand for military goods, and the Russian government placed extensive orders with foreign suppliers. For example, the War Ministry placed abroad orders worth 2.6 million rubles in 1903, 16.9 million in 1904, and 73.1 million in 1905. Foreign orders for the Naval Ministry increased from 10 million rubles in 1903 to 68 million in 1905.[14] The fact that, during the war with Japan, neither foreign nor domestic orders were delivered in time, does not seem to have deterred the Russian military, as it revised its planning for a future war in Europe. Apparently, the military continued to believe that supplies could be obtained from abroad when needed. This policy had the advantage of keeping down costs, since the state could avoid spending capital on new plant. The financial position of the government was always precarious, and any way to economize was greatly favoured. Although the Russian chemical industry grew rapidly in the two decades before the war, almost all pharmaceuticals were imported, as were large quantities of other chemical essentials, from raw materials and intermediates to finished products.[15]

The agency charged with responsibility for obtaining munitions for the Russian army was the Main Artillery Administration [Glavnoe Artilleriiskoe Upravlenie, or GAU]. The GAU was formally under the War Ministry, but enjoyed considerable autonomy. In 1914, it was led by General D. D. Kuz'min-Karavaev, but Grand Duke Sergei Mikhailovich, Chief Inspector of the Artillery, actually wielded control. The Grand Duke's royal pedigree made him a rival even to the War Minister (V. A. Sukhomlinov). Bureaucratic in-fighting complicated efforts to equip and organize the artillery. At the beginning of the war, the GAU was a dysfunctional organization, with many overlapping organizations. However, it appears that leading military, as well as civilian authorities did not realize the extent of the problem.[16] In the summer of 1914, The Russian military felt fatally overconfident. Indeed, Sukhomlinov stated: 'In a future war, the Russian artillery will never have to complain of a lack of shells. The artillery is supplied with a large amount of equipment and is assured of a properly organized delivery of shells'.[17] Even earlier he also had declared: "If you want peace, be ready for war. Russia...wants peace, but she is ready."[18]

MUNITIONS AND CHEMICALS DURING THE EARLY MONTHS OF THE WAR

Like the other Great Powers, Russia had no inkling of what lay ahead at the outbreak of the war on 1 August 1914.[19] Initial mobilization was astonishingly rapid and successful. However, ominous trends emerged in the first few weeks. When, as early as August, the Chief of Staff, N. N. Ianushkevich, warned the Minister of War about the unexpectedly large expenditures of shell, and requested more. Sukhomlinov responded, "Couldn't measures be taken to economize...?".[20] Russian field commanders were indeed forced to economize, but continued to use shells at a rate that threatened to exhaust stockpiles in less than a few months.

Part of the problem was a classic underestimation of the equipment that mobilisation would require. In a plan adopted in 1910, the General Staff estimated that a full-scale European war would require Russia to field an army of 4.5 million men. This would require 4.5 million rifles, plus 700,000 replacements each year. When war began, the General Staff decided to mobilise far more soldiers than were called for in the 1910 plan. Thus, it turned out that Russia needed not only five million rifles simply to equip the first mobilisation, but also 5.5 million for later mobilizations, and 7.2 million to replace losses. This totaled 17.7 million rifles, or more than eleven million above original estimates.[21] The number of cartridges needed to supply these rifles was correspondingly huge.

In addition, the 1910 plan assumed that a European war would last less than six months. During the first few months, the military would use stockpiles, while domestic production was mobilised and foreign orders were placed.[22] During the Russo-Japanese war, the Russian army used 1,276 artillery pieces and fired 918,000 shells, or just over an average of 700 shells per gun. In planning a future war, the Ministry decided to stockpile a reserve of 1,000 shells per gun. However, this number would give continuous fire at the maximum rate for no more than about 100 minutes. While the Ministry duly met their stockpile targets, their preparations turned out to be ludicrously inadequate.

On 9 September 1914, the Minister of War called a meeting of sixteen large enterprises, both private and state, involved in shell manufacture, and placed orders for 6.65 million shells, to be delivered at a rate of 1.5 million shells per month. However, these enterprises were unable to produce more than 500,000 shells per month with existing capacity, so the Ministry advanced them 10 million rubles to increase production to one million shells per month by October 1915, with continued expansion of production after this date until the full amount was achieved. The shortfall would be met by foreign orders (totaling 9 million shells), rather than by placing orders with other domestic producers (especially small producers) or by further expanding domestic production.[23] Large orders were placed at this time with British, French, American, and Japanese firms.[24]

These foreign orders did not, however, solve the shell shortage. Foreign firms were swamped with orders, and could not expand output fast enough to meet demand. By September 1915, British firms, hard pressed to supply British needs, had shipped only 5,000 of one million shells ordered by the Russian Ministry.

As late as June 1916, only 875,000 of the 9.1 million 3-inch shells ordered from the USA and Canada had arrived. In addition, the closing of Russia's western border reduced import access to the far northern port of Arkhangel'sk [Archangel] and the port of Vladivostok. Even when shells and other military goods were actually delivered, heavy demands on the transportation system often meant that supplies sat on the docks, exposed to the weather, for long periods of time.[25]

As the need for more shells and high explosives became apparent during the first few months of the war, the Russian military authorities began to consider how much of these could be provided by domestic production. In September, 1914, a commission of the GAU, including A. V. Sapozhnikov, a professor of physical chemistry at the Artillery Academy, was sent to the southern Russian coal-mining region of the Donets Basin to investigate the possibility of obtaining toluene from coke by-products.[26] At this time, most of these by-products were burned as fuel in coke furnaces. The commission decided that expanded domestic production was not possible, and Sapozhnikov and others were sent to the USA to oversee the placing of foreign orders.[27] In November, however, the GAU sent a second delegation to make another assessment.[28] V. N. Ipat'ev – a general of artillery and professor of organic chemistry at the Artillery Academy – L. F. Fokin and other engineers came to the opposite conclusion. Ipat'ev reported that, on the contrary, the plants in the region could easily and rapidly be converted to produce toluene. If the private companies did not want to participate, then he urged GAU to build a factory itself, on the grounds that the 'greatly increased output of valuable products would more than pay for the small cost of construction'.[29]

Ipat'ev was a firm believer in a domestic chemical industry, and saw this as an ideal opportunity to make Russia's industry independent of foreign suppliers.[30] However, he had to overcome the skepticism of the War Council. One general asked, 'What kind of a guarantee can you give, General Ipatieff, for the completion of this project in such a short time?' Ipat'ev replied, 'I am not a capitalist, Your Excellency. I cannot bind my guarantee with cash; I can offer only my head as security.'[31] The War Council did not immediately approve his plan, which Ipat'ev saw as evidence that 'the mood in general was one of pessimism with a lack of confidence in our own forces and a feeling of inferiority in the face of German technology.'[32] In Stone's words, 'The Artillery Department could not imagine that Russian industry would be capable of manufacturing war-goods, and therefore had recourse to foreign suppliers, who were supposed to be cheaper and more efficient, and who had also been supplying Russia for many years past."[33]

In January 1915, the GAU set up another Special Commission to assist in the production and delivery of munitions, under the direction of Grand Duke Sergei Mikhailovich. Six months later, this was replaced by a permanent committee (the Special Council for the Coordination of Measures to Guarantee the Supply of Munitions and Other Material to the Army).[34] Meanwhile, on 6 February 1915, the GAU set up a Commission for the Preparation of Explosives (CPE), with Ipat'ev as chairman, charged to coordinate the production of raw materials.[35] The staff of the Commission included engineers L. F. Fokin, V. Iu. Shuman, O. G. Filippov, and

A. A. Solonin; S. P. Vukulov (Director of the Scientific-Technical Laboratory of the Naval Ministry); I. I. Andreev (Director of the Scientific-Technical Laboratory of the War Ministry); and several others.[36]

GAU ordered the CPE to increase production of explosives from the 3,000–5,000 puds (one pud is equal to 36 pounds) [[48–80 tons] per month then being produced in the state plants, to 60,000 puds [964 tons] per month, by calling upon private industry. At this time, in early 1915, there was no survey of available chemical resources and factories, so the CPE surveyed materials and equipment needed to produce explosives. The CPE had limited authority to impose its decisions on industry, particularly those factories owned by foreigners, but Ipat'ev felt comfortable about being able to produce this amount, despite initial resistance. At first, only one private company cooperated with the Commission. Some did not want to expand production because they feared the consequences of overcapacity after the war. Others were reportedly reluctant 'to violate the rights of German concessionaires who might subsequently hold them legally liable'[37] Incredibly, even the Ministry was concerned about the legal ramifications of Ipat'ev's plans. 'Providing materials actually seemed to them of only secondary importance. It took a great deal of persuasion to show them that since we were now at war with Germany, with the future unpredictable, a 200,000-pud [3,214 tons] yearly output of crude benzol [benzene] was much more important than mere legal complications in the future'.[38]

Despite these difficulties, explosives production rapidly increased, fulfilling Ipat'ev's expectations.[39] By September 1915, his initial goal of 60,000 puds per month [964 tons] of explosives was reached.[40] While only 6,000 puds [96 tons] of explosives were produced in February 1915, explosives production jumped to 51,000 puds [820 tons] by July and 85,000 puds [1366 tons] in October. Most of this increase came from the private factories, which increased their output by over fifty times by the end of 1915, while the state factories only doubled their output.[41]

While the CPE had great success with explosives, however, it was unable to alleviate the shortage of shells. State plants increased production from 229,400 shells in January 1915 to 989,000 in June, nearly meeting targets. But the targets were unrealistically low, and by the spring of 1915, actual demand tripled to three million shells per month. The military managed to hide the seriousness of the situation until Russian troops suffered staggering defeats all along the front in Galicia and Poland in May 1915, and were forced to retreat deep inside Russian territory. These losses were blamed on the lack of shells. One observer noted, 'The Russian artillery was practically silent'.[42] After months of enthusiasm for the war effort, the Russian public's view of the war sharply changed to anxiety.[43] The Russian public had continued to support the government up to this time, despite the embarrassing defeats during the initial month of the war at Tannenberg and Masurian Lakes, where the Russians had lost more than 250,000 men and many guns due to the mistakes and cowardice of their generals.

In the wake of the setbacks in the spring of 1915, the CPE was ordered to increase explosives production from 60,000 to 165,000 puds per month [964 tons to 2,651

tons]. To do this, huge amounts of sulfuric acid (as well as other materials) were needed. In 1914, factories in Russia produced about 200,000 tons of sulfuric acid per year [1.25 million puds], as contrasted with 2.5 million tons in the USA and 1.8 million tons in Germany.[44] The main raw material was pyrite, iron disulphide, which is burnt to sulfur dioxide in the manufacture of sulfuric acid. Before the war, Russia imported substantial quantities of pyrite from Scandinavia and Turkey (over five million puds [about 94,000 tons] in 1914), since these could be shipped cheaply by sea.[45] Consequently, many of Russia's sulfuric acid factories were built along the Baltic coast. The main source of Russian pyrite (about nine million puds [about 170,000 tons] in 1914) was the Ural Mountains, and transportation costs to the centers of population were high.[46] With the war, the supply of imported pyrites came to an abrupt halt, even from Sweden. The situation was particularly critical in Petrograd and the Baltic region, which in any case relied upon imports for a wide range of materials. These regions were forced to rely exclusively on domestic sources of pyrites, greatly raising the cost of producing sulfuric acid, as well as adding to the strains on the transportation system.[47]

In February 1915, the CPE began a survey of sulfuric acid stockpiles, and turned to increasing the production of sulfuric acid by requisitioning pyrites at their source. By April 1915, supplies of sulfuric acid had almost vanished in Petrograd. Ipat'ev estimated that 35,000 puds [562 tons] of concentrated sulfuric acid a month were needed to maintain explosives production in the capital and requisitioned 80,000 puds [1,286 tons] of acid from the Urals in a desperate attempt to keep the factories operating.[48] On 14 May 1915, the CPE issued a proposal 'to expand the production of sulfuric acid at state factories and also to encourage the construction of new factories by all means'.[49] However, the retreat of the Russian army during the summer resulted in the loss of factories in Poland, and factories in Riga were evacuated. These two areas produced more than 500,000 puds [8,036 tons] of sulfuric acid per month. The loss of these factories threatened to cripple explosives production. By July 1915, the production of sulfuric acid in Russia dropped to 700,000 puds [11,250 tons] per month.

The CPE had to expand production at significantly fewer factories. Following the losses in Poland and Riga, Ipat'ev convened leading pyrite mine owners and asked them to draw up estimates for increasing production and their lowest prices for two-year contracts. At the same time, he proposed to the Special Committee for Defense that the CPE be given the task of organizing the production of mineral acids using Russian pyrite instead of foreign sources. The Commission requested powers to construct twenty new factories and to renovate old ones, with a goal of doubling sulfuric acid production within a year. Finally, Ipat'ev proposed that the CPE have a central office in Petrograd and six regional offices, with powers to oversee distribution between defense and civilian factories. [50]

The Special Committee for Defense approved, and in June 1915, a congress of owners of pyrite mines and factories gave their support, setting a price of 30 kopeks per pud for pyrites. There followed a rapid increase in pyrites mined and delivered. By January 1916, production of sulfuric acid had risen to 1 million puds [16,072

Ipat'ev recognised the need for toluene, but he also believed that delays in building new ovens and factories would only delay actual production. In addition, such a massive plan would disrupt the chemical industry. In a way that became typical of the CPE (and the later Chemical Committee of the GAU), Ipat'ev and his colleagues approached the problem in a different way. They decided to produce benzene and toluene from petroleum by means of pyrogenetic aromatization – a stop-gap measure until the ovens and factories of the CPE could be finished. By early 1915, even before the full impact of the shell crisis had exploded in public view, N. D. Zelinskii (director of the Central Laboratory of the Ministry of Finance and a former professor of chemistry at Moscow University) and chemists at several laboratories were conducting experiments for the CPE on the pyrogenesis of oil using various catalysts.[64] When the experiments showed success, the chemists moved to scale up the process. Even though yields were low, the cost was in line with the cost of imports, and so could substitute. The first factory-scale experiments were conducted by the CPE at the City Gas Plant in Kazan. Although these were successful, the amount of toluene produced was tiny (about 1,000 puds [16 tons] each month). However, the experience served as a model for other factories that could produce much larger quantities.[65]

To increase production, the Central WIC had several chemists (including A. E. Porai-Koshits, a professor of chemistry at the Petrograd Technological Institute) prepare a proposal for a factory that could produce 4,000 puds [64 tons] a month of benzene and toluene from petroleum. In October 1915, the Baku WIC agreed to construct a factory and signed an agreement with the GAU to begin delivery within seven months. However, once the plant was finished, it was unable to begin production. Ipat'ev visited the plant in early 1916, and sent one of the engineers who had supervised the Kazan plant to offer technical assistance. This engineer brought the plant on line, and by the autumn of 1916, it was in full operation. Ipat'ev believed that further improvements could be made and, in early 1917, sent another engineer to Baku.[66]

The efforts of the CPE and other chemistry organizations to help produce the materials needed for munitions and explosives were very successful. After a slow start during the first months of the war, Russia was able to mobilize its industrial resources during the course of 1915, mainly by increasing production at private firms. By the end of 1915, Russian industry was producing sufficient numbers of shells to supply the needs of its army, with the exception of very large shells (from 203–305 mm). The production of these very large shells remained a problem for Russian industry throughout the war and even as late as 1916 only small numbers of these shells were being manufactured.[67] The increase in production of other artillery shells was very dramatic, however. The numbers of shells provided to the army from domestic sources increased from 150,000 each month in 1914, to 950,000 each month in 1915, to 1,850,000 each month in 1916.[68] According to figures of A. A. Manikovskii, who was the head of the GAU during the war, the Russian army used 72.3 million shells of all kinds. Of these, 56.6 million were produced in Russia, with 15.6 million (about 21%) imported from various countries.[69]

POISON GASES AND GAS MASKS

While the CPE devoted great attention during 1915 to chemical munitions, the spectre of gas weapons soon overshadowed even the horrors of high explosives. At the end of May 1915 and continuing intermittently for several months, the Germans attacked Russian troops near Warsaw with various types of gases.[70] The initial attacks cost more than 1,100 gas fatalities of a total of 9,000 gas casualties.[71] The result was to force the Russians to mobilize their efforts in chemical warfare, both in defensive (gas masks) as well as in offensive (the production and delivery of gases).

Even before the German gas attacks on the Western Front, the Russians had speculated about the possible use of gas for offensive use. At a meeting on 26 January 1915, General A. A. Zabudskii, head of the newly-founded Central Scientific-Technical Laboratory of the War Ministry, considered the use of 'suffocating and intoxicating gases in shells,' although others attending the meeting rejected this, since 'such methods can be regarded as inhumane and have not been previously used by the Russian army'. However, they left open the possibility of using these gases 'in case of the enemy's gross abuse of such methods.' General Zabudskii decided to begin investigations so that gases could be ready 'in case of emergency, to start production'.[72]

The CPE also began to study poison gases at about this time. In early May, Ipat'ev sent a request to the GAU to produce phosgene for shells at a factory near Ivanovo-Voznesensk, an industrial city about 130 miles northwest of Moscow. An engineer at this factory had earlier sent a request to Ipat'ev, proposing the preparation of phosgene. This engineer and the factory owner were brought to Petrograd, and arrangements were being made for the production of 600 puds [9.6 tons] of phosgene for shells when news came of the Germans' first gas attack in Poland at the very end of May.[73]

The War Ministry gave responsibility for both offensive and defensive gas warfare to Prince Oldenburg, the Supreme Chief of the Army Sanitary and Evacuation Service (SCASES). Oldenburg was the husband of Tsar Nicholas II's sister and thus influential in military politics. The War Ministry also sent Ipat'ev, as chairman of the CPE, to Oldenburg to discuss the gas attacks. Oldenburg told Ipat'ev that the Germans had released chlorine from cylinders, and asked whether such cylinders could be produced in Russia.[74] Ipat'ev said it would take two factories four to five months. The War Ministry gave the task to the CPE, which sent A. A. Solonin, professor of artillery at the Artillery Academy, and A. E. Makovetskii, an instructor at the Petrograd Technological Institute, to the two factories to supervise.[75] However, it appears that the War Ministry did not have complete faith in the ability of the Russian chemical industry, and so asked the British for supplies of chlorine.[76]

The relationship between the CPE and the SCASES with regard to gas warfare is not clear from published information.[77] The War Ministry realized that the SCASES was not capable of organizing production, and asked the CPE to assume this task in addition to explosives. Ipat'ev apparently at first agreed, but soon decided the

tons] per month, and by March, stood at 1.3 million puds [20,893 tons] per month.[51] By this time, according to Ipat'ev and Fokin, sulfuric acid was no longer the limiting factor in explosives production.[52]

By early August 1915, the CPE controlled the production and distribution of all sulfuric acid in Russia. Military needs were given priority. However, the diversion of large quantities of acid to explosives precipitated a black market.[53] In September 1915, Ipat'ev informed the CPE that the War Ministry had established, under his direction, a commission to regulate prices. This included representatives of the CPE and the Central War-Industries Committee. At the first meeting of the new Commission, Ipat'ev reported that while the majority of factory owners were satisfied with the agreement, the CPE gave each regional office authority to set prices for supplies that exceeded military needs, which resulted in increased profits for the factories.[54]

By the autumn of 1915, having organized distribution and regulated prices, the Commission began to work with factory owners to increase production. The Commission proposed two methods. First, it advocated increasing the quantities of pyrites mined and the number of factories constructed. It secured support from the War Ministry to improve transportation of pyrites to the factories. Next, the Commission proposed to introduce new methods for preparing sulfuric acid. One such method, widely practiced in the United States and Germany, used sulfur gas collected as a by-product at copper smelting factories.[55]

There were some who objected to the CPE'S measures. For example, A. E. Makovetskii, an instructor of chemistry at the Petrograd Technological Institute, petitioned the Special Council for Defense to increase production targets much more than those of the CPE. Makovetskii believed that 20–22 million puds [32,144–35,358 tons] per year was insufficient to meet military and civilian needs, and proposed 80–90 million puds [128,576–144,648 tons] per year instead. Ipat'ev pleaded with his military superiors to continue plans for a balanced increase. In this case, as in many others, Ipat'ev succeeded in deflecting opposition.[56] He later wrote:

> One does not need to be a prophet to predict the terrible conditions for the Russian chemical industry if the largest proportion of its available materials were directed to the production of such a large amount of sulfuric acid. There is no doubt that Russia needs a large amount of sulfuric acid, not only during war time, but also in peace time. But it is necessary also to fulfill this grandiose program gradually, not hurting the other branches of the chemical industry.[57]

Also, in October 1915, the Chemical Section of the Moscow WIC complained to the Special Council for Defense about the measures being taken by the CPE in regards to the production of sulfuric acid. Ipat'ev defended himself in a long report to the Special Council, apparently to their satisfaction.[58]

The CPE also directed research towards overcoming problems with other raw materials. For example, when imports of Chilean nitrates – used in the production

of nitric acid – were cut off, Ipat'ev directed the search for domestic sources. A leading part in the search for natural resources was taken by the Imperial Academy of Sciences, which in 1915 established a Commission for the Study of Natural Resources [Komissia po izucheniiu Estestvennykh Proizvoditel'nykh Sil Rossii (KEPS)], under the direction of Academician V. I. Vernadskii.[59] When only small reserves of nitrate were located, Ipat'ev and the CPE turned to experiments to determine if ammonia could be produced as a by-product of the coking of coal. During the summer of 1915, small scale experiments in Petrograd were so successful that the War Ministry gave Ipat'ev funding for a large factory. This factory went ahead, but became operational only in early 1917.[60]

The CPE was not the only agency set up to organize the manufacture of chemical products for military and civilian needs. For example, in the wake of the shell crisis in 1915, a group of Moscow industrialists, having been excluded from direct involvement in provisioning the army, decided to set up their own organization, the War-Industries Committee (WIC). Eventually, a number of provincial War-Industries Committees were also established to act as facilitators, distributing orders for military supplies to a wide range of small and medium-sized factories.[61]

Both the Central War-Industries Committee and the provincial War-Industries Committees had numerous sections. The Chemical Sections often worked harmoniously with the CPE, but sometimes conflicts arose. One occurred soon after the shell crisis in the summer of 1915. High explosives required vast quantities of toluene. The CPE had earlier acted by converting coke ovens in the Donets Basin region of South Russia to recover by-products that had been burned off as waste. But this hardly produced enough to reach the targets set. The Chemical Section of the Central WIC decided that the demand could be satisfied only by building a large number of new coke ovens with the recovery process, as well as totally rebuilding old ones. Ipat'ev, chairman of the CPE, opposed the building plan. In a report to the Chemical Section, Ipat'ev argued that the CPE had already done everything that could be done to increase toluene production in the Donets Basin, and that it would be counterproductive to build new ovens due to the huge costs involved. Ipat'ev proposed that the WIC send an engineer to the Basin to report on what could be done within a year. The engineer duly reported that production could not be increased without a huge investment in factories and ovens – the construction of which would require massive investment in manpower and supplies.[62]

However, the Chemical Section ignored the engineer's recommendation, and proposed the construction of 2,000 new ovens and the rebuilding of old ones during the next ten months, at a cost to the state of up to 45 million rubles. The Chemical Section sent a budget to the Special Committee for Defense, where it was opposed by Ipat'ev, on the grounds that it would disrupt construction already underway and drain money from other urgent needs. Ipat'ev later noted that 'It was necessary to have much energy in order to prove the danger of such experiments and to convince the military officials and the people who proposed them that these grandiose proposals could disrupt that which was created on a firm, business-like basis'.[63]

responsibility would be too much for the CPE. Instead, the War Ministry set up a new organization – the Commission for the Production of Asphyxiating Gases [*Komissiia po izgotovleniiu udushaiushchikh sredstv* (CPAG)].[78] CPAG was set up in July 1915, chaired by I. A. Krylov, the assistant director of the Central Scientific-Technical Laboratory of the War Ministry. The new Commission had a wide range of responsibilities, including theoretical studies of poison gases, factory production, the instruction of troops, and the organisation of special army gas units.[79]

At first, the gases were chlorine (produced at the Liubimov-Solvay factory located near Berezniki in the northern Ural Mountains and at a plant in Slaviansk in the Krasnodar region of southern Russia) and phosgene (produced at the Ivanovo-Voznesensk plant). Later, the CPAG also produced chloropicrin (an asphyxiant like chlorine and phosgene), tear gases (chloroacetone and bromine), and blood agents (hydrogen cyanide and cyanogen chloride). However, it appears that Russia never managed to produce mustard gas. At first, gases were delivered by shells and only in 1916 did Russia begin to use gas cylinders. The Russians failed to develop the more effective gas projector or gas projector shell. In addition, very little chlorine was produced during 1915 and only about 200 tons were used in that year.[80] Again, as for so many other products, Russia had only a limited capacity. Thus, new factories were needed to supply the huge amounts of chlorine needed. Ipat'ev later noted that 'the production of liquid chlorine presented a series of new challenges of extreme difficulty to Russian technology.'[81] The CPAG proposed building four new state-owned factories to produce chlorine by electrolysis, as well as three additional factories to produce chlorine by a simpler method.[82] The CPE worked closely with the CPAG to provision the factories with equipment. However, the CPE opposed the building of two of the new chlorine factories (to be located in Finland), 'especially in view of the negative economic results for our future chemical industry which would have an excess of this product...The expansion of the chlorine industry within Russia, in connection with the needs of defense, would lead to overproduction and a crisis immediately after the end of the war.'[83] Despite this opposition, the Special Council for Defense built all the proposed new factories, including the two in Finland opposed by the CPE. In April 1916, CPAG was absorbed into the CPE to form the Chemical Committee, and Ipat'ev again tried to stop the construction of these factories, but to no avail. Instead, the Special Council acted to speed up construction by organizing a special committee of the GAU to overcome bureaucratic problems that were hindering their completion.[84]

For gases to be produced, new methods of manufacture had to be developed and new factories, built. This required resources, both financial and technical, and it could not be accomplished rapidly. For example, bromine was not produced in Russia before 1914 – indeed, only in 1917 did Russia begin to produce bromine in factory-scale quantities, using the brine from the salt industry in the Crimea.[85] Typically, the CPAG asked scientists at the universities and technical institutes to investigate methods for preparing chemical agents. The scientists would first work out the processes in their laboratories, then move on to scale up the processes at a factory, with the assistance of other technical personnel. For example,

Prof. L. A. Chugaev and his students at Petrograd University investigated methods to produce various chlorine compounds.[86] Other chemists worked on the production of hydrocyanic acid and various organic compounds with poisonous or irritating effects. These compounds were intended for artillery shells.[87] Finally, if large-scale production was successful, then one or more large factories to produce the chemical agent would be built, such as the factories for the production of bromine. While this procedure was common in other countries, it was new for Russia. Before the war, Russian chemical industry and Russian academic chemistry did not have much contact.[88] Now, academic chemists began to participate directly in developing new processes and infrastructure to produce new chemicals.

At first, contacts between government organizations such as the CPE and CPAG and academic chemists were made on an ad hoc basis, through personal contacts. However, as the war continued into 1915, the need for a system to distribute scientific tasks became obvious. The CPE and CPAG called on the Russian Physical-Chemical Society (RFCS) to identify members willing to undertake research. Members of the RFCS performed much of the basic work on many of the new products needed by the CPE, CPAG, and other organizations. But by the autumn of 1915, the RFCS felt that these informal arrangements were not satisfactory, and on 11 September 1915, its leaders petitioned the Special Council for Defense to create a new organization to coordinate chemists with the war effort. The Special Council gave permission for a new organization, called the War-Chemical Committee (WCC) of the Russian Physical-Chemical Society.

The statutes of the WCC say that its goal was to unite the strength of Russian chemists 'for joint and planned work on problems connected with the needs of national defense'.[89] The WCC had its headquarters in Petrograd, where the RFCS was located, but separate branches were established in many different cities, including Moscow, Kiev, Kharkov, Odessa, Saratov, Kazan, and Perm. The Moscow branch was especially active, and conducted a survey of chemical industry. The WCC worked on poison gases and explosives, gas masks, pharmaceuticals, X-rays, the preparation of food, and many other tasks.[90] In 1916, the WCC established an Experimental Factory [*Opytnyi zavod*] in Petrograd where chemists could scale up laboratory experiments. After 1919, the Experimental Factory was transformed into the Institute of Applied Chemistry, under the direction of Academician N. S. Kurnakov, as one of the scientific organizations of the Supreme Council of the National Economy. The new Institute continued the same type of activities carried out by the Experimental Factory during the war.[91]

While the CPAG was given the task of developing chemical weapons and instructing troops in their use, the CSASES retained control over the production of gas masks and research on gas masks, perhaps because the Red Cross was under its direction. Even before the first German gas attacks on the Eastern Front in May 1915, the CSASES had prepared large numbers of a wet type of gas mask that used gauze, and sent these to the front. However, these were not given to troops on the front lines, so they had no protection when the Germans first used gas. In any event, the wet mask offered little protection. The CSASES desperately needed

to develop a different, but effective gas mask. However, Prince Oldenburg and the CSASES were not able to organize this work efficiently, and work proceeded very slowly during 1915 and early 1916.

Meanwhile, other organizations, such as the WCC and various non-governmental groups, had begun to conduct research on gas masks. In July 1915, soon after the German gas attack, the Medical Commission of the All-Russian Union of Zemstvos and Towns established an Experimental Commission in Moscow under the direction of S. I. Chirvinskii, a professor at Moscow University. V. M. Gorbenko, an instructor at the Moscow Higher Technical School and a member of the Experimental Commission, set up two chambers to test the effectiveness of different substances. At first, the Experimental Commission focused on a wet mask, finding – rather unsurprisingly – that a mask with 35 layers of gauze was superior to the existing one of 20 layers.[92]

Other organizations concentrated on developing a dry mask. As early as June 1915, in a talk given to the Sanitary-technical section of the Russian Technical Society, N. D. Zelinskii (director of the Central Laboratory of the Ministry of Finance) proposed using activated charcoal. Charcoal used to remove impurities from alcohol could also be used in a gas mask. Zelinskii was familiar with charcoal, since the Ministry of Finance supervised the purification of alcohol for tax purposes. Zelinskii promoted the use of activated charcoal for gas masks, while working to find the best methods.[93] He gave talks to the Experimental Commission of the Medical Commission for the All-Russian Union of Zemstvos and Towns (Zemgor), the Central WIC, and the WCC.[94] By August 1915, the Experimental Commission recognised the superiority of Zelinskii's method and asked him to make a systematic study of factors such as the diameter of the filter and the container for the charcoal. Professor A. E. Favorskii conducted experiments in his Petrograd University laboratory that demonstrated the effectiveness of Zelinskii's method. Shortly afterwards, the engineer E. L. Kummant developed a rubber mask with a container to hold the activated charcoal. The combination of Zelinskii's activated charcoal and the Kummant's rubber mask produced the first effective gas mask for Russian troops.[95]

During the summer, while Zelinskii was developing his mask using activated charcoal, professors at the Mining Institute in Petrograd began to develop their own dry mask using as their model an existing mining mask, which used soda lime to trap the poison gases. The Petrograd Section of the Experimental Commission became interested and by late September decided to place large orders for the 'Mining Institute' mask. This mask was effective against chlorine, but was cumbersome and complex. The Experimental Commission in Moscow decided to test the two masks. The results, in late October, showed that the Mining Institute mask was 'completely unsuitable for general use.'[96] Despite this result, the SCASES decided to support the Mining Institute mask instead of the Zelinskii-Kummant mask, perhaps owing to the influence of N. A. Ivanov, head of the Petrograd Section of the Experimental Commission. Ivanov was appointed the head of the gas mask section of the SCASES, where he continued to champion the Mining Institute

mask, all the while making changes to overcome its obvious defects, including adding a separate chamber for activated charcoal. Not content to work on its own mask, the SCASES tried to put roadblocks in the path of the Zelinskii-Kummant mask. The SCASES controlled the supply of charcoal, and only small amounts were released to Zelinskii. Moreover, according to Ipat'ev, Zelinskii kept secret his method for activating charcoal. Apparently, Zelinskii and Kummant were interested in obtaining royalties for each gas mask produced.[97]

By the end of 1915, the General Staff was becoming nervous about the slow progress of research on a gas mask. Military leaders believed that the Germans would resume the offensive, using chemical weapons in the spring, and wanted their own troops supplied with gas masks. At the end of November 1915, the General Staff asked Prince Oldenburg to place 'especially urgent orders' for a suitable mask by spring. The General Staff repeated this at the end of December, asking Prince Oldenburg to report the number of masks he had ordered. In early January, Oldenburg's assistant replied that six million Mining Institute type had been ordered, although a different type of mask would be needed to protect against phosgene and cyanide.[98] The General Staff was not satisfied and pressed Oldenburg and the SCASES to develop a more universal mask. At the end of January 1916, the General Staff wrote to Oldenburg, stating that it would be 'undesirable' to place orders only for the Mining Institute mask, and that the Zelinskii mask appeared to meet the criterion of universality. Still, the SCASES placed only a small order for the Zelinskii-Kummant gas masks with the WIC.[99]

By February 1916, the General Staff was complaining about the 'inertness' of the SCASES and asked the War Ministry to take over matters relating to gas masks.[100] In fact, by this time, the General Staff had decided to place orders for one million Zelinskii-Kummant masks with the WIC, even though placing such orders was not part of the General Staff's responsibilities.[101]

It was at this point – in February 1916 – that the General Staff decided to create a War-Chemical Committee to coordinate the production of masks as well as gas warfare and the instruction of troops. The War Minister supported the creation of this new organization and on 16 February 1916, wrote to Tsar Nicholas II stating that it was 'unsuitable' to order the Mining Institute mask when it was clear that the Zelinskii-Kummant mask was superior. Moreover, the minister argued that the army had not yet received a satisfactory gas mask because there was no unifying organization.[102] The Tsar approved the creation of the War-Chemical Committee on 2 March 1916.[103]

Prince Oldenburg did not easily relinquish control. He hurried to the Stavka near the front where the Tsar was directing the war, insisting that he retain control over all 'sanitary' matters, and demanded that the Special Council for Defense, which included representatives from the General Staff, be prohibited from taking action. He further demanded that the Central WIC be prohibited from dealing with gas masks. Oldenburg stated 'that he might not be able to prohibit civilian organizations from preparing these [Zelinskii-Kummant] masks...[and] that they could make as many as they wished, but he would not allow them to be delivered to the army'.[104]

However, Prince Oldenburg was unsuccessful, and on 19 March, the War Minister made a resolution 'to immediately place an order for the Zelinskii type of gas mask in a quantity sufficient to provide them for all of the army, and for the immediate provision of the charcoal for [these masks].'[105] The new War-Chemical Committee of the General Staff soon placed orders for three million Zelinskii-Kummant masks with the Central WIC, and for 800,000 with the All-Russian Union of Zemstvos.[106]

THE CHEMICAL COMMITTEE

The creation of the War-Chemical Committee by the General Staff came as a complete surprise to the GAU, as the GAU had jurisdiction over some tasks now given to the Committee. However, a few days after the War-Chemical Committee was formed, General A. A. Polivanov was replaced as War Minister by General D. S. Shuvaev. The Chief of the GAU, General A. A. Manikovskii, persuaded the War Minister that his new organization would function better under the GAU. Manikovskii argued that all matters relating to chemistry – including masks, explosives and all raw materials – should be united in one organization. Further, this new organization should come under control of the GAU, since it already had the CPE and CPAG under its authority. Grand Duke Sergei supported Manikovskii's proposal. On 4 April 1916, the War Minister asked Ipat'ev to draw up regulations for this new Chemical Committee, together with a list of staff members. Ipat'ev's draft regulations were approved on 7 April and ratified by the Tsar on 16 April 1916.[107]

However, as often was the case in Russia, the creation of a new Chemical Committee (CC) in the GAU did not mean the abolition of the War-Chemical Committee of the General Staff. The General Staff had created a Council for the War-Chemical Committee, and this continued to function. While the CC had day-to-day control of the production of chemicals and products, the Council for the War-Chemical Committee retained oversight over the CC.[108] The relationship between the two organizations is not clear, although Ipat'ev obviously saw the Council for the War-Chemical Committee as an unwarranted intrusion into his sphere of influence.[109]

Ipat'ev was appointed the first chairman of the CC, reporting directly to General Manikovskii, Chief of the GAU. The chairman of the CC was also to keep in touch with General M. V. Alekseev, Chief of Staff to the Tsar. The CC was composed of five branches: 1) explosives, 2) poison gases, 3) incendiaries and flamethrowers, 4) gas masks, and 5) acids. Each branch held meetings and formed commissions. Decisions were made in general meetings held at least once a week. The permanent members of the CC included representatives from the military, academe, and private non-governmental organizations, including two members of the Academy of Sciences, the Directors of the Scientific-Technical Laboratories of the War and Naval Ministries, representatives from the WICs and Zemgor, a representative from the War-Chemical Committee of the Russian Physical-Chemical Society, the heads of each individual branch of the CC, and representatives from the GAU and the General Staff. The CC could also invite consultants to its meetings and

ask them to conduct investigations. According to Ipat'ev, the consultants most often used were professors at the various higher educational institutions in Petrograd, including N. S. Kurnakov, L. A. Chugaev, A. E. Favorskii, A. A. Iakovkin, G. V. Khlopin, V. E. Tishchenko, and several others.[110]

From its very beginning in April 1916, the CC employed the regional bureaus already established by the CPE to coordinate chemical activities, and expanded the regional bureaus in Petrograd, Moscow, Kazan, the Upper Volga region [in the town of Kineshma], Kharkov [for the south], and Baku [for the Causcasus region]. A separate bureau to deal with benzene was set up in Kharkov to supervise factories in the Donets Basin. While these regional bureaus were under the control of the chairman of the CC (and ultimately, under the Special Council of Defense), they were given considerable autonomy. Ipat'ev had great respect for the capabilities of those chosen to head the regional bureaus.[111] Finally, in addition to regional bureaus, the CC had a chemical battalion to instruct soldiers in the fourteen commands at the front.[112]

The Chemical Committee at the GAU began to function even before its official ratification on 16 April 1916. Its most urgent task was to speed up the production of the Zelinskii-Kummant mask. Large orders had already been placed with the Central WIC and Zemgor, but they had been given neither specifications, nor activated charcoal, since Prince Oldenburg had released none to Zelinskii. Accelerating the production of the Zelinskii-Kummant gas mask would prove to be difficult, because Prince Oldenburg had managed to retain control over the production of the Mining Institute mask for the SCASES, forcing a struggle over raw materials. Oldenburg insisted that his orders be filled first. Not only that–Prince Oldenburg and the SCASES secured the right to appoint the head of the gas mask branch (branch IV) of the CC.[113]

On 8 April 1916, Ipat'ev convened in Petrograd a meeting of people involved in different aspects of gas mask production, and called for commissions in Petrograd and Moscow to work out the specifications. The two commissions called for assistance from chemists who were already consultants in other fields supervised by the CC. Zelinskii was sent to Moscow to supervise the production of activated charcoal at several alcohol warehouses. Chemists active in the Petrograd commission included Khlopin, Favorskii, Chugaev, and I. I. Andreev, head of the inorganic section of the Central Scientific-Technical Laboratory of the War Ministry. Ipat'ev noted that these commissions worked hard to determine specifications, and to accelerate production in time for the summer offensive.[114]

Gradually, the consultative committees and the CC increased production and delivery of the Zelinskii-Kummant mask According to official reports, on 8 September 1916, troops on the Western Front had 631,219 Zelinskii-Kummant masks; 300,000 of the improved wet gauze masks; 146,000 of the imported English helmet-type gas masks; and 80,000 of the Mining Institute type of gas mask.[115] On 7 September, the War Ministry issued an order to stop production of the Mining Institute mask, and a few weeks later sent another order to discard the Mining Institute masks and to replace them with the Zelinskii-Kummant masks.[116] On

4 October, the General Staff wrote to the CC that 'unfortunately, up to the present time, over one million of the completely unsuitable Mining type gas masks have been delivered to [the army] while the full provisioning of the army with the [Zelinskii-Kummant] activated charcoal type has been held back until now. While the Zelinskii-Kummant gas masks have significant deficiencies, they do save lives from the deadly effects of asphyxiating and poison gases.'[117]

Increasing the production of the Zelinskii-Kummant mask was not an easy task for the CC, as it had to deal with Prince Oldenburg, as well as to cope with the problems involved with manufacturing in Russia. The CC was forced to accept Prince Oldenburg's choice as the head of the Gas Mask Section. This was N.A. Ivanov, a professor at the Military-Medical Academy who worked at SCASES. Ipat'ev was reluctant to accept this appointment, since Ivanov was a supporter of the Mining Institute mask. Ipat'ev was overruled, but before Ivanov could take up his duties, Prince Oldenburg offended the military command to such an extent that it transferred gas mask orders to the CC.[118]

Although the Zelinskii-Kummant mask was effective against many gases, it had significant flaws. When the activated charcoal was broken up into a powder during movement to the front, it lost much of its effectiveness. The charcoal also had a tendency to fall out of its container, so a stopper was added. Unfortunately, poorly trained troops often forgot to remove this stopper. When they could not breathe, they tore off their masks, which left them exposed.[119] Work by Prince Avalov added an exhaust valve, easing problems with respiration and the inhalation of charcoal dust. Modified masks were sent to the front during the closing months of 1916.[120]

In the summer of 1916, the CC set up its laboratory. In October, G. V. Khlopin was appointed head. There, he worked with I. I. Zhukov, N. T. Prokof'ev, and M. V. Tarle to investigate the absorbing properties and the influence of moisture on charcoal. One of the laboratory's successes was Prokof'ev's development in the autumn of 1916 of an improved type of wet mask. This mask received the name 'Chemical Committee' and was given to troops in late 1916.[121] Scientists at other laboratories continued to share in the work. One such was the laboratory of the Central Scientific-Technical Laboratory of the War Ministry, headed by I. I. Andreev, whose work was conducted mainly during the second half of 1916 and the first half of 1917.[122]

By the second half of 1916, the strain of the war on Russia's social and economic system was acute. The organizations set up to manage the chemical industry struggled valiantly. However, as time went on, problems arose that could not be overcome. One was transportation. Even at the beginning of the war, the railroad system in Russia was not sufficient to meet the large demands placed on it. As rolling stock and personnel were committed to transporting troops and supplies, Russian industry suffered. One of the main problems was that many Russian factories were located far from the sources of their raw materials. For example, sulfuric acid factories were built along the Baltic in order to use imported pyrites. When the imports were cut off, they were forced either to switch to domestic sources or stop production. However, since domestic sources were found only in the distant Urals,

the chemical industry was faced with one of two unpalatable choices: either use tremendous amounts of hauling capacity to transport bulky materials to existing factories, or else build new factories closer to the source. The second choice was not optimal because many factories had to be built at the same time, and the construction industry was overextended. In effect, the government decided to transport large quantities of pyrites to existing factories and at the same time to build a smaller number of new factories. This solution worked reasonably well, and sulfuric acid production gradually increased throughout 1916.[123]

Similar problems arose with other chemicals. For example, in early 1915, crude benzene was produced in the Donets Basin region, but there was not a single factory that could fractionate the crude benzene into purified benzene and toluene that could be used for explosives. Thus, the crude benzene had to be shipped to Petrograd, where it was purified. The toluene was shipped to the Samara-Sefiev explosives factory (on the lower Volga River) to produce TNT, while the benzene was shipped to Moscow to make phenol and then back to the Solvay factory to produce picric acid.[124] Eventually, new factories were built in the Donets Basin region that could fractionate the crude benzene, but these of course required considerable resources and time to build. Ipat'ev and the Chemical Committee tried to cope with the transportation problems by having a special 200 soldier military command under their control. The Chemical Committee would assign soldiers to help assure that the supplies actually arrived at the factories and the front. Otherwise, some of these supplies would be commandeered by others needing these supplies and products. Ipat'ev noted that it was particularly difficult to ship supplies to factories in the Moscow region because there were so many other defense factories there needing these same types of supplies that the Chemical Committee's shipments often were diverted.[125] It is interesting to note that many of these same types of problems arose during the intense industrial growth of the First Five-Year Plan (1928–1932) under Stalin.

The experience of Branch III (incendiaries and flamethrowers) of the CC illustrates the problems facing the chemical industry in 1916. As with so many products, incendiaries were not normally manufactured in Russia before the war. So the CC had to find sources of red and yellow phosphorous, barium and strontium nitrates, powdered aluminum, metallic magnesium, antimony sulfide, and many other chemicals. The Russian military did not do much work with these products before the formation of the CC in 1916. And by that time, according to Ipat'ev, it was becoming difficult to set up new factories to produce items not previously made in Russia. The CC managed to set up only a few factories to produce phosphorous and barium nitrate, while factories to produce the other chemicals needed for this Branch were never finished. Some factories, such as a cyanamide factory in Grozny, remained on the drawing board, despite the plans of a special commission headed by Prof. D. P. Konovalov. As flamethrowers had never been used by the Russian army, the CC began to examine different mechanisms. Two types were ready for testing by early 1917, and were introduced to the chemical battalions. However, as with so many other products, Russian factories had no time to manufacture them in quantity before the country withdrew from the war.[126]

PLANNING FOR THE FUTURE

Perhaps for this reason, by late 1916, some far-sighted Russians began to make plans for the future. Chemists, in particular, looked to what the end of the war might mean for the chemical industry. Their writings were usually pleas that Russia not revert to conditions existing before the war. In 1916, these chemists began to take steps towards a peacetime economy. As Ipat'ev later noted, 'The greatest achievement of the Chemical Committee was its work simultaneously organizing for wartime production as well as preparing for the transition to peacetime conditions.'[127] He was acutely aware that the end of war with Germany would mean a great shift in demand for chemical products. All during his time as head of the CPE and the CC, Ipat'ev attempted to balance wartime needs with post-war expectations. For example, he knew that sulfuric acid would be vital for industry after the war, so he was willing to expand its production (whilst resisting what he considered to be excessive expansion). On the other hand, phosgene had limited uses in a post-war environment, so he was reluctant to build many new factories for its production.

In the autumn of 1916, M. I. Lisovskii, head of the Southern regional bureau of the CC in Kharkov, asked Ipat'ev to plan for a transition to a peacetime economy. Ipat'ev suggested organizing a meeting of all the owners of chemical plants in southern Russia. At the same time, Ipat'ev organized similar meetings for chemical industrialists in Moscow and Petrograd. To these meetings came not only chemical industrialists, but also academic specialists who had taken part in chemical industry during the war. This attempt to maintain contact between academic chemists and industrialists was one of the most important fruits of the war. These meetings led to a special Preparatory Commission, assigned to survey and collect information about chemical manufacturing in Russia. The meeting in Petrograd included representatives from chemical organizations that had been involved in the war, including the War-Chemical Committee of the Russian Physical-Chemical Society and the Society for the Assistance and Development of the Chemical Industry in Russia.

The Moscow meeting also proposed the formation of a new organization to bring together the regional bureaus of the CC, the War-Chemical Committee of the Russian Physical-Chemical Society, and the various WICs, under the direction of the CC. Factory owners supported the idea and collected funds for the new organization. However, Ipat'ev was reluctant to have the CC assume this role, and proposed that the War-Chemical Committee take on this task. Eventually, after much discussion, Ipat'ev agreed to petition the GAU to allow the CC to participate in the demobilization of the chemical industry. The GAU approved his petition and a Preparatory Commission was formed, along with a Central Organization in Moscow. Ipat'ev was elected chairman, with P. I. Walden, who lived in Moscow, taking over day-to-day activities.[128] By August 1917, the Preparatory Commission had gathered a substantial amount of data, but the Bolshevik Revolution of October 1917 changed the situation. In early 1918, the Preparatory Commission and its data were placed under the authority of the newly-organized chemical section of the Supreme Council of the National Economy.[129] A new era had begun.

CONCLUSION

What can we conclude from the experience of Russia's chemical mobilisation and its wartime agencies? Probably the clearest finding is that Russia's attempts to provision its army were chaotic, haphazard, and disorganized, with many overlapping and competing committees, commissions, and jurisdictions. The gas mask story is perhaps the best example of the range of difficulties besetting the system. Several organizations competed with – and actively hindered – each other, significantly delaying the provision of gas masks to troops at the front. There was no one organization with the authority to coordinate production, even after the creation of the CC. Adding to the chaos, many non-governmental organizations also attempted to contribute to wartime production. For example, in September 1914, the Imperial Russian Technological Society formed a 'Commission for Industry connected to the War'. In June 1915, in the wake of the shell crisis and the retreat along the Eastern front, nineteen societies and social organizations joined together and used this commission as a basis for forming the "Committee for Military-Technical Assistance."[130] This committee had separate sections for gas masks, poison gases, raw materials, and other items. It is not hard to imagine how difficult it was to coordinate so many different combinations of governmental and non-governmental organizations.

The supply of explosives appears to have been the best organized sector of Russia's chemical mobilisation, but even here there were problems. The first major decision faced by the military was whether to produce explosives by expanding domestic production or to rely on imports. Historical practice had been to negotiate contracts abroad for war materials greater than domestic industry could produce. That is, the Russian military was unwilling to expand domestic production above peacetime levels, for fear of having excess capacity after the war. This was the path taken in the first few months of the war. However, it soon became apparent that foreign orders would not arrive in time to meet immediate needs. This situation forced Ipat'ev to organize an increase in domestic production. The organizations he set up gradually increased production, although they never were able to meet the demands of the military. The main problem Ipat'ev faced was not to increase the production of any one component too fast, lest he divert resources from other targets. Thus he resisted dramatic increases in sulfuric acid production, as he knew that a large increase would hurt other sectors of industry. These attempts are significant because 'outsiders' tried to impose their views on the military. Moreover, Ipat'ev, as head of the CPE and later the CC, was forced to defend his actions, with the implication that had he not been persuasive, the military would have agreed to calls for greatly increased production.

The chaotic conditions surrounding chemical mobilisation were a natural consequence of a lack of planning for a long war. Since the Russian military did not expect a long war, they did not think beyond their usual reliance upon foreign orders. When it was necessary to turn to Russian sources, there was no coordinating structure. By the summer of 1915, it was glaringly obvious to impartial observers that foreign orders could not meet demand, although many members of

the military high command continued to put their hopes in foreign orders rather than trying to develop domestic production. The crisis with the production of military goods, such as shells, eventually grew so severe that politicians gained considerable influence over industrial policy. Thus, the lack of planning, coupled with the extreme demands, opened up the way for a large number of non-governmental organizations to participate in producing military goods. However, these organizations often had definite political agendas, which complicated the coordination with governmental organizations. The all-too-frequent result was paralysis in production.

Nonetheless, by the time industrial production collapsed in 1917 due to problems with transport, lack of raw materials, etc., many concrete steps had been taken to prepare the future of Russia's chemical industry. Whereas before the war, Russia produced few raw materials for chemical industry, the war forced the country to search for domestic sources of supply. This effort continued throughout the 1920s and 1930s, and resulted in the Soviet Union discovering a wide range of new resources, especially in Siberia. The discovery of these domestic sources of raw materials was a crucial factor that made it feasible for Stalin to turn the Soviet Union towards economic autarky after the late 1920s. Wartime Russia also began building factories to produce many products needed by the Russian chemical industry, instead of relying on imports. This effort would also continue after the war. In addition, the number of workers at chemical plants markedly increased during the war. In 1913, the Russian chemical industry employed 33,000 workers. This number rose to 54,000 in 1915 and peaked at 117,000 in 1917.[131] After the end of the war, these experienced workers were available to be tapped for skilled labor during the Soviet period. Finally, Russian academic chemists began to participate in solving problems for industry. The cooperation of industry and academia continued after the wartime emergency, opening new channels for the organisation of applied science (particularly under the aegis of the Academy of Sciences) in the Soviet Union. In the history of Russia's chemical industry, The Great War witnessed the beginning of a new order rather than the end of an old regime.

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NOTES

[1] See N. N. Smirnov (ed.), *Rossiia i pervaia mirovaia voina* [*Russia and the First World War*] (St. Petersburg: Izdatel'stvo 'Dmitrii Bulanin', 1999), 9–10 for a discussion of work on the Russia's involvement in the war.

[2] Norman Stone, *The Eastern Front: 1914–1917* (New York: Charles Scribner's Sons, 1975).

[3] L. F. Haber, *The Poisonous Cloud: Chemical Warfare in the First World War* (Oxford: Clarendon Press, 1986).

[4] Alexei.Kojevnikov, 'The Great War, the Russian Civil War, and the Invention of Big Science', *Science in Context* XV (2), (2002), 239–275.

[5] For example, Alexander Vucinich's massive two-volume *Science in Russian Culture* (Stanford: Stanford University Press, 2 vols., 1963, 1970) devotes only a few pages to science in Russia during the war. Likewise, Loren Graham's *Science in Russia and the Soviet Union* (Cambridge: Cambridge University Press, 1993) almost entirely ignores the war.

[6] See Kojevnikov, *op. cit.* note 4; Nathan M. Brooks, 'Chemistry in War, Revolution, and Upheaval: Russia and the Soviet Union, 1900–1929', *Centaurus* 39 (1997), 349–367; David L. Hoffmann and Peter Holquist (eds.), *Cultivating the Masses: The Modern Social State in Russia, 1914–1941* (Ithaca: Cornell University Press, 2002); Peter Holquist, *Making War, Forging Revolution: Russia's Continuum of Crisis, 1914–1921* (Cambridge: Harvard University Press, 2002).

[7] For example, see V. S. Lel'chuk, *Sozdanie khimicheskoi promyshlennosti SSSR* [*The Creation of the USSR Chemical Industry*] (Moscow: Nauka, 1964), and A. L. Sidorov, *Ekonomicheskoe polozhenie Rossii v gody pervoi mirovoi voiny* [*The Economic Condition of Russia during the First World War*] (Moscow: Nauka, 1973). These volumes very briefly mention the production of explosives and munitions, or the role of chemists in the chemical industry. But see E. V. Trofimova, 'Proizvodstvo vzryvchatykh beshchestv v gody pervoi mirovoi voiny [The Production of Explosives during the First World War],' *Otechestvennaia istoriia*, No. 2 (2002), 147–152. This short article contains little information not available elsewhere, but does provide references to archival sources, making it an important starting point for further study.

[8] For example, see V. I. Kuznetsov and A. M. Maksimenko, *Vladimir Nikolaevich Ipat'ev, 1867–1952* (Moscow: Nauka, 1992).

[9] Zemgor was the 'Joint Committee of the Union of Zemstvos and of Towns for the Supply of Military Equipment and Munitions'. It was created in June 1915 as an aid to the military effort after the disastrous defeats suffered by the Russians in Galicia and Poland. For more information, see Paul Gronsky and Nicholas Astrov, *The War and the Russian Government* (New Haven: Yale University Press, 1929), 175.

[10] Betweeen 1892–1895, the Imperial Navy engaged Dmitrii Mendeleev to undertake research on different types of smokeless gunpowder. Mendeleev conducted investigations, eventually producing a type that he termed superior to that used by the French and British. However, the Naval Ministry rejected Mendeleev's gunpowder, despite the support it received from younger, lower-ranking officers. See Michael D. Gordin, 'A Modernization of "Peerless Homogeneity:" The Creation of Russian Smokeless Gunpowder', *Technology and Culture*, 44 (2003), 677–702. Also see A. G. Beskrovnyi, *Russkaia armiia i flot v ZIX veke* [*The Russian Army and Navy during the 19th century*] (Moscow: Naula, 1973), 391–5, for statistics on the production of smokeless gunpowder.

[11] Sidorov, *op. cit.* note 7, 364.

[12] *Ibid.*, 85–86.

[13] V. N. Ipat'ev and L. F. Fokin, Khimicheskii komitet pri Glavnom Artilleriiskom Upravlenii i ego deiatelnost' dlia razvitiia otechestvennoi khimicheskoi promyshlennosti [The Chemical Committee of the Main Artillery Administration and its Activities in the Development of the Domestic Chemical Industry] (Petrograd: Nauchnoe Khimiko-tekhnicheskoe Izdatel'stvo, 1921), 5.

[14] E. R. Goldstein, 'Military Aspects of Russian Industrialization: The Defense Industries, 1890–1917' (Unpublished Ph.D. dissertation, Case Western Reserve University, 1971), 148. At this time, the official exchange rate was two rubles to the U.S. dollar.

[15] For example, see L. F. Haber, *The Chemical Industry, 1900–1930: International Growth and Technological Change* (Oxford: Clarendon Press, 1971), 22–24; and Lel'chuk, *op. cit.* note 7, 15–38, for examples of Russian chemical imports during these years.

[16] For an extensive discussion of some of the many blunders in Russian planning, see Stone, *op. cit.* note 2, chapter 1. Stone emphasizes the mal-distribution of types of artillery as one of the root causes of the artillery's poor performance, while downplaying the actual shortage of shells.

[17] Reprinted in Frank A. Golder (ed.), *Documents of Russian History, 1914–1917* (Gloucester, Mass.: P. Smith, 1964), 190–2.

[18] V. A. Sukhomlinov, 'Rossiia khochet mira, a gotov k voine' [Russia wants peace, but is prepared for war], *Birzhevye Vedomosti* (27 fevralia 1914 goda), reprinted in Mikhail Lemke, *250 dnei v tsarskoi stavke (25 sentiabria 1915-2 iiulia 1916)* (St. Petersburg, 1920), 6.

[19] Bruce W. Menning, *Bayonets Before Bullets: The Imperial Russian Army, 1861–1914* (Bloomington: Indiana University Press, 1992), 246–247. Note that shortly after war was declared, Tsar Nicholas II decided to change the name of St. Petersburg to Petrograd, as the old name allegedly sounded German (although it was actually derived from the Dutch).

[20] 'Perepiska V. A. Sukhomlinova s N. N. Ianushkevichem' [*The Coreespondence of V. A. Sukhomlinov with N. N. Ianushkevich*], *Krasnyi arkhiv*, No. 1 (1922), 247–8.

[21] A. A. Manikovskii, Boevoe snabzhenie russkoi armii v mirovuiu voinu [The Military Supply of the Russian Army in the World War], (Moscow: Gos. Izd-vo, Otdel voennoi lit-ry,, 2nd ed., 1930), vol. I, 124.

[22] Goldstein, *op. cit.* note 14,173–180.

[23] Sidorov, *op. cit.* note 7, 27–9.

[24] For a discussion of Russian attempts to purchase supplies in the United States, see Dale C. Rielage, *Russian Supply Efforts in America during the First World War* (Jefferson, North Carolina: McFarland, 2002).

[25] Stone, *op. cit.* note 2, 157; Sidorov, *op. cit.* note 7, 598.

[26] Vladimir N. Ipatieff, *The Life of a Chemist* (Stanford: Stanford University Press, 1946), 195.

[27] Rielage, *op. cit.* note 24, 23–28.

[28] *Ibid.*

[29] Ipatieff, *op. cit.* note 26, 196. Ipat'ev received his training in chemistry at the Artillery Academy and worked after graduation with Baeyer in Munich.

[30] This view permeates Ipat'ev's memoirs. Even though the memoirs were written years after these events, the desire for a domestic chemical industry was shared by many Russian chemists during the war and afterwards. For example, see L. Chugaev, 'O merakh k razvitiiu v Rossii khimicheskoi promyshlennosty [Measures for the development of the chemical industry in Russia]', *Delovaia Rossiia*, No. 14–15, (26 April 1915), 2–3; No. 15, (4 May 1915), 2–3. Also see N. N. Liubavin, 'Voina s Germanii i Russkaie khimiki [*The War with Germany and Russian Chemists*]', *Biulleteny Russkoi khimicheskoi literatury* (vesennyi sem. [spring semester], 1916), 6–8; and 'Peredovaia [Editorial]', *Zhurnal khimicheskoi promyshlennosti*, I (1), (Nov.-Dec. 1924), 3.

[31] Ipatieff, *op. cit.* note 26, 196. Note that Ipatieff is an alternative transliteration of Ipat'ev.

[32] *Ibid.*

[33] Stone, *op. cit.* note 2, 150.

[34] Lewis H. Siegelbaum, *The Politics of Industrial Mobilization in Russia, 1914–17: A Study of the War-Industries Committees* (New York: St. Martin's Press, 1983), 37–39. The Special Council is important because it brought industrialist into the process for the first time. However, at first only the largest industrialists—mainly the traditional suppliers located in Petrograd–were allowed to participate. This provoked smaller industrialists—in Moscow and elsewhere—to set up their own institution: the War-Industries Committee.

[35] Ipatieff, *op. cit.* note 26, 197.

[36] Ipat'ev and Fokin, *op. cit.* note 13, 16–17. A number of different Commissions were set up at about this time to oversee the production of military goods.

[37] Ipatieff, *op. cit.* note 26, 198.

[38] *Ibid.*, 199.

[39] *Ibid.*, 202 for figures on production.

[40] Ipat'ev and Fokin, *op. cit.* note 13, 21.

[41] *Ibid.*, 21.

[42] Bernard Pares, *The Fall of the Russian Empire*, (London: J. Cape, 1939), 230.

[43] Stone, *op. cit.* note 2, chapter 9, claims that the shell crisis of 1915 was exaggerated by politicians in order to obtain a greater role in the conduct of the war.

[44] Lel'chuk, *op. cit.* note 7, 20. Haber, *op. cit.* note 15, 171, gives Russian production of sulfuric acid in 1913 as 165,000 metric tons.

[45] L. F. Fokin, *Obzor khimicheskoi promyshlennosti v Rossii* [Survey of the Chemical Industry in Russia] (Petrograd: Nauchnoe Khimiko-tekhnicheskoe izdatel'stvo, 1920), part 1, 16–17.

[46] *Ibid.*, 9, 16.

[47] *Ibid.*, 18.

[48] Trofimova, *op. cit.* note 7, 148.

[49] *Ibid.*

[50] Ipat'ev and Fokin, *op. cit.* note 13, 32.

[51] *Ibid.*, 32–33.

[52] *Ibid.*

[53] *Ibid.*, 33

[54] Ipatieff, *op. cit.* note 26, 203–204.

[55] Trofimova, *op. cit.*, note 7, 150.

[56] *Ibid.*, 150.

[57] Ipat'ev and Fokin, *op. cit.* note 13, 33–34.

[58] *Ibid.*, 34. Note that this is according to Ipat'ev and Fokin. This conclusion needs to be verified using archival documents.

[59] For information about KEPS, see A. V. Kol'tsov, *Sozdanie i deiatel'nost Komissii po izucheniiu Estestvennykh Proizvoditelnykh Sil Rossii, 1915–1930* [The creation and activities of the Commission for the Study of Natural Resources of Russia, 1915–1930], (St. Petersburg: Nauka, 1999); and Kojevnikov, *op. cit.*, note 4.

[60] Ipat'ev and Fokin, *op. cit.*, note 13, 34–36. For more details about the construction of this plant, see: A. K. Kolosov, 'Vozniknovenie v Rossii proizvodstva azotnoi kisloty okisleniem ammiaka po sposobu I. I. Andreeva' [The origin in Russia of the production of nitric acid by the oxidation of ammonia according to the process of I. I. Andreev], *Materialy po istorii otechenstvennoi khimii* (Moscow: Akademiia Nauk SSSR, 1953), 196–209.

[61] For a detailed description of the WICs, see Siegelbaum, *op. cit.* note 34. The War Ministry tended to rely on a small group of large industrialists in Petrograd to provide the bulk of military orders. By the spring of 1915, the problems with supplying needed military goods were clear to all observers. This opened the door to a wider range of producers.

[62] Ipat'ev and Fokin, *op. cit.*, note 13, 28–9.

[63] *Ibid.*, 29.

[64] See Zelinskii's report about this work: *Zhurnal Russkogo Fiziko-Khimicheskogo Obshchestva*, 47, (1915), 1807. Zelinskii continued this work after the revolution, and this process became an important one for the Soviet chemical industry. Y. Yuriev and R. Levina, *Life and Work of Academician Nikolai Zelinsky* (Moscow: Foreign Languages Publishing House, 1958), 89–94.

[65] Ipat'ev and Fokin, *op. cit.* note 13, 29–30.

[66] *Ibid.*, 30–31.

[67] Sidorov, *op. cit.* note 7, 118. During the entire course of the war, Russia produced only 40,000 of these very heavy shells; more than twice this amount came from imports. During 1916, the GAU recognized the need for more of these shells, but claimed that it was impossible to increase production due to problems with the lack of metal, labor, and transport. The Russians had sufficient quantities of all types of heavy shells to help produce a breakthrough of the Austro-Hungarian lines in the summer of 1916, although the Russian generals pleaded for more shells. *Ibid.*, 120.

[68] *Ibid.*, 119.

[69] A. A. Manikovskii, *Boevoe snabzhenie Russkoi armii v voinu 1914–1918 gg.* [The military supply of the Russian army during the war 1914–1918], part 3 (Moscow: n. p., 1920), 560.

[70] Haber, *op. cit.* note 3, 36–39.

[71] M. V. Krasil'nikov, 'K istorii snabzheniia russkoi armii protivogazom N. D. Zelinskogo', in N. A. Figurovskii, *Ocherk vozniknoveniia i razvitiia ugol'nogo protivogaza N. D. Zelinskogo* [*A sketch of the Origin and Development of the Charcoal Gas Mask of N. D. Zelinskii*] (Moscow: Akademiia Nauk SSSR, 1952), 193, quoting archival documents. The exact numbers according to these archival documents are 8,932 gas casualties, 1,101 gas fatalities.

[72] Quoted in Kojevnikov, *op. cit.* note 4, 245. In January 1915, the Germans had attacked Russian troops with about 1,800 shells filled with tear gas. However, the gas was not effective, probably due to the cold temperatures, and the Russians suffered no casualties from this attack. See Ia. M. Fishman, *Voenno-khimicheskoe* delo (Moscow, 1929), p. 16. This attack perhaps stimulated the Russian military to begin discussing the possibility of gas warfare.

[73] Ipat'ev and Fokin, *op. cit.* note 13, 36–37. Ipat'ev claims that he also thought of the use of phosgene independently of this engineer.

[74] According to Haber, the Germans probably used a mixture of chlorine and phosgene, expecting the Russians not to notice the addition of phosgene. Haber, *op. cit.*, note 3, 37.

[75] Ipat'ev and Fokin, *op. cit.* note 13, 37.

[76] Joachim Krause and Charles K. Mallory, *Chemical Weapons in Soviet Military Doctrine: Military and Historical Experiences, 1915–1991* (Boulder: Westview Press, 1992), 20. This must be used with caution as it contains many errors.

[77] The main sources were all written by Ipat'ev, so archival research will be necessary to confirm his accounts.

[78] Ipat'ev and Fokin, *op. cit.* note 13, 37.

[79] *Ibid.*, 37–38.

[80] Augustin M. Prentiss and George J. B. Fisher, *Chemicals in War; A Treatise on Chemical Warfare* (New York: McGraw-Hill, 1937), 658, 661. However, Kojevnikov, *op. cit.* note 4, 246, citing archival documents, claims that no more than two tons of all types of gases were ever delivered to the front by the time Russia stopped fighting in 1917. The reason for this discrepancy is not clear.

[81] Ipat'ev and Fokin, *op. cit.* note 13, 39.

[82] Ipat'ev and Fokin do not mention the exact method used for the simpler production of chlorine at these plants. Ibid., 38.

[83] *Ibid.*, 38.

[84] *Ibid.*, 39.

[85] *Ibid.*, 40.

[86] B. G. Klimov, ed., *Opytnyi zavod Gosudarstvennogo Instituta Prikladnoi Khimii, 1916–1926* [The Experimental Factory of the State Institute of Applied Chemistry, 1916–1926], (Leningrad, 1927), 26.

[87] Ipat'ev and Fokin, *op. cit.*, note 13, 40.

[88] See Brooks, *op. cit.* note 6.

[89] *Trudy Voenno-khimicheskogo komiteta*, No. 2 (1918), 66.

[90] *Ibid.*, 8–10.

[91] For information about the founding of the Institute of Applied Chemistry and the early work performed there, see the Russian State Archive of the Economy [RGAE], f. 3429, op. 7, d. 1083, ll. 1–111. Also see: Iu. I. Solov'ev, *Nikolai Semenovich Kurnakov 1860–1941* (Moscow: Nauka, 1986), 139–146; and Klimov, ed., *op. cit.* note 86.

[92] M. M. Dubinin, 'Predislovie [Foreword]', in N. A. Figurovskii, *Ocherk vozniknoveniia i razvitiia ugol'nogo protivogaza N. D. Zelinskogo [A Sketch of the Origin and Development of the Charcoal Gas Mask of N. D. Zelinskii]* (Moscow: Akademiia Nauk SSSR, 1952)), 5. Also see M. M. Dubinin, 'O razvitii protivogazovogo dela v Sovetskom Soiuze [The develoment of gas masks in the Soviet Union]', *Materialy po istorii otechestvennoi khimii* (Moscow: Akademiia Nauk SSSR, 1953), 163–172.

[93] N. D. Zelinskii and V. S. Sadikov, 'Ugol' kak sredstvo bor'by s udushaiushchimi i iadovitymi gazami. Eksperimental'noye issledovannye *1915–1916 gg. [Charcoal as an agent in the fight with asphyxiating and poisonous gases. Experimental work of 1915–1916]*', in N. D. Zelinskii, *Sobranie trudov* [Collected works], (Moscow: Akademiia Nauk SSSR, 1960), vol 4, 59–145. Also see N. A. Figurovskii, *Ocherk vozniknoveniia i razvitiia ugol'nogo protivogaza N. D. Zelinskogo [A sketch of the origin and development of the charcoal gas mask of N. D. Zelinskii]* (Moscow: Akademiia Nauk SSSR, 1952).

[94] Krasil'nikov, *op. cit.* note 71, 194–195.

[95] Figurovskii, *op. cit.* note 93, 112. For a brief description in English of Zelinskii's gas mask and its development, see Ipatieff, *op. cit.* note 26, 218–225.

[96] Quoted in Figurovskii, *op. cit.* note 93, 95.

[97] Ipatieff, *op. cit.* note 26, 218. However, Figurovskii categorically denies that Zelinskii tried to keep his method of activating charcoal a secret, pointing to numerous letters Zelinskii sent to various people. Moreover, Figurovskii claims that Zelinskii never wanted royalties. Unfortunately, Figurovskii does not quote any document to support his claims, nor does he cite any references. Figurovskii, *op. cit.* note 93, 113–114. It appears likely that there was conflict or jealousy between Ipat'ev and Zelinskii, and probably not only concerning gas masks. For example, by the summer-autumn of 1916, after Ipat'ev had taken control of all gas mask production, he excluded Zelinskii from further research on improving methods to activate charcoal. *Ibid.*, 126–127. This time Figurovskii does quote from letters from Zelinskii.

[98] Krasil'nikov, *op. cit.* note 71, 196.

[99] *Ibid.*

[100] *Ibid.*, 197.

[101] Ipat'ev and Fokin, *op. cit.* note 13, 45.

[102] Krasil'nikov, *op. cit.* note 71, 197.

[103] *Ibid.*

[104] *Ibid.*, 198.

[105] *Ibid.*

[106] *Ibid.*

[107] Ipat'ev and Fokin, *op. cit.* note 13, 46.

[108] *Ibid.*, 49.

[109] Ipatieff, *op. cit.* note 26, 221. It also is not clear how long the Council for the War-Chemical Committee continued to function.

[110] Ipat'ev and Fokin, *op. cit.* note 13, 47.

[111] Ipatieff, *op. cit.* note 26, 220–221.

[112] Ipat'ev and Fokin, *op. cit.* note 13, 47. For information on the chemical battalions, see N. N. Ushakova, *Nikolai Aleksandrovich Shilov* (Moscow: Nauka, 1966), 33–47. Shilov, a professor at Moscow Higher Technical School, became the commander of one of the three main chemical battalions.

[113] *Ibid.*, 48.

[114] *Ibid.*, 49.

[115] Krasil'nikov, *op. cit.* note 71, 200, citing archival sources.

[116] *Ibid.*, 201.

[117] *Ibid.*

[118] Ipat'ev and Fokin, *op. cit.*note 13, 52.

[119] *Ibid.*, 54.

[120] Krasil'nikov, *op. cit.* note 71, 200–201.

[121] Dubinin, *op. cit.* note 92, 10–11; Ipat'ev and Fokin, *op. cit.* note 13, 49.

[122] Dubinin, *op. cit.* note 92, 11.

[123] Ia. M. Bukhshpan, *Voenno-khoziastvennaia politika [Military-Economic Policies]* (Moscow-Leningrad: Ranion – Institut Economiki, 1929), 365.

[124] Ipat'ev and Fokin, *op. cit.* note 13, 26.

[125] *Ibid.*, 65–66.

[126] *Ibid.*, 70–71.

[127] *Ibid.*, 72.

[128] Walden was a member of the Imperial Academy of Sciences, elected in 1910.

[129] Ipat'ev and Fokin, *op. cit.* note 13, 72–3.

[130] L. V. Darda and N. A. Figurovskii, 'Organizatsiia promyshlennosti khimicheskikh reaktivov v Rossii (1900–1917) *[The Organization of the Chemical Reagent Industry in Russia (1900–1917)],' Istoriia i metodologiia estestvennykh nauk*, XXVIII (1982), 13–19.

[131] S. Strumilin, 'Khimicheskaia promyshlennost' SSSR', *Problemy ekonomiki*, no. 2 (1935), 118.