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Development of Chemical Technology in Europe and America in the 20th Century

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Abstract
The rapid progress in basic sciences and the quick changes in the ways of life in the 19th and 20th centuries led to the possibility and necessity of applying new technologies in the production of different materials. This paper deals with the noticeable development of chemical industries in Europe and America in this period. Meanwhile, it focuses on the relevant process in Czech Lands. The impact of the first and the second World Wars on such trends are also considered.

Keywords: Chemical technology, Europe, America, Czech Lands

Introduction

Twentieth century, the century of unbelievable technical and scientific progress, but also the century of many political and social turns, gives us many occasions to think about what was the driving force of the development of new technologies, why the production of some goods was increased, whereas some products weren't produced anymore. Economic and political situation of the society was often the motive power of development of the science and technologies, which on the contrary retroactively affected the society. Successes in scientific research are dependent on many factors, including the situation in society, contemporary trends of the society, level of educational institutions and support from the state.

In the context of all-European development, even the chemical industry was developing. Chemical technologies were gradually taking

over new scientific theories and technical solutions and their development was dependent on the progress in chemistry, physics, medicine, biology, and in many other fields.

The quality of life in the 20th century was radically changed by the emergence of transport, better distribution of electricity, by introduction of the batch production and last but not least, by both World Wars. To understand the whole process of production, we have to know that the production consists of two types of technologies: firstly, technology of the product, which creates its characteristics and qualities, and secondly the process technology that encompasses the whole system of the production.

The introduction of new manufacturing processes desperately needed some special education of future scientific experts. That's why I mention the beginning and the rise of chemical engineering and the first educational training centers that appeared all around the world.

At the time first contacts between the scientific research and industry were arranged, the scientific companies were the first ones to engage. The state assistance and support from private sector came soon.

At the end of the 19th and the beginning of the 20th century, many specialized research institutions were founded, mostly in Germany and in the USA. Chemical companies started to organize and financially support their own research centers.

Ever-growing requirements of mankind demanded development in chemical industry. Due to chemical products, people can live longer (disinfectants, pharmaceuticals) as well as the lives of millions of people can end (chemical and nuclear weapons). Chemical products also changed the fashion and dressing style (synthetic fibers). Plastic materials are inherent part of every single industrial branch. In fact, modern society is totally dependent on chemical products. It is estimated that approximately one third of chemical products is sold within the chemical branch and specialized companies use it for production of goods with higher value (for instance automotive, oil, textile, pharmaceutical, paper and rubber industry or building industry and

agriculture). Concerning the volume of products, chemical industry alone is the number one consumer.

The situation of the chemical industry from the late 19th century till the beginning of WWI

Throughout the 19th century, chemistry flew both theoretically and technologically vertically upwards and therefore made the application of new discoveries possible. In Europe and in the USA, there was a big hunger after new scientific findings and also perceptible scientific euphoria showed up, mostly because of really quick advancements in physics.

Chemistry started to differentiate itself into separate branches (for example general, inorganic, organic and analytic chemistry) and also some boundary branches appeared (physical chemistry and biochemistry).

Because of the need of rationalization of the production (catalysis, thermodynamics, knowledge of chemical reactions), chemical industry gradually derived benefits from scientific researches.

Concerning scientific research and production in the early 20th century, Germany was definitely world's number one in both branches. Thanks to constant support from the state, Germany was at least at this time the country with the best developed knowledge and scientific base. Universities were deeply wedded to the industry, university labs tried to solve problems that appeared throughout the production and the dons were often advisors to these companies, which of course supported the universities, allowed their students to practice in factories and greeted graduates, who wanted to start working as scientists, with open arms.

The representatives of industry tried to convince chemists to elaborate some concrete problems and also tried to provide them with good financial and material conditions; for example Fritz Haber, Carl Bosch or Friedrich Bergius could be mentioned.

In 1911, the "Kaiser – Wilhelm – Gesselschaft" (KWG) was founded and therefore, better cooperation between universities and industrial

companies was guaranteed. Just one year later, two institutes were established: Kaiser – Wilhelm – Institut für Chemie led by Emil Fischer and Kaiser – Wilhelm – Institut für physikalische Chemie und Elektrochemie led by Fritz Haber. With this unusual connection between research institutes and chemical industry, Germany started its successful effort to link those two branches.

The concept of applied research was firstly mentioned at that time, and more and more companies were founding their own testing laboratories. Industrial companies insisted on fast and efficient work of well-paid and precisely selected scientists. At the International Exhibition in Paris in 1900, Germany presented many by that time singular exhibits. Before the war, Germany was the number one producer of many chemical products, for example one fifth of pharmaceuticals came from Germany. Increasing consumption of ammonia that was widely used in agriculture and in production of chemicals, led to deeper elaboration of the method of ammonium synthesis, which was discovered by Fritz Haber (1868–1934) and Carl Bosch (1874–1940). The first industrial synthesis of ammonium took place in BASF factory in Ludwigshafen. Problem with high consumption of ammonium was solved and Germany was virtually independent of the import of natural nitrates from Chile and since then, BASF supported this research significantly. Fritz Haber, the inventor of industrial synthesis of ammonium, was awarded a Nobel Prize in 1918. He was an excellent scientist with outstanding education and he experienced various and inconsistent stages, both in his personal and his professional life.

The synthesis, which was named after him, secured Germany with supplies of nitrogen fertilizers. On the other hand it prolonged the war, because the blocked Germany was able to stay independent from import for a longer time.

British industry along with French industry was on its peak in the first half of the 19th century. British and French chemists were the pioneers of cooperation between science and final production. Thanks to the effort of George Davis (1850–1906), the first society that associated chemical

engineers was founded (Society of Chemical Industry, SCI, established in 1881). Although French and British scientists were excellent, there was a lack of cooperation with industry. That's why France had to relinquish her chemical superiority to Germany.

Though there were some top scientific institutions, which often worked in harness with departments of universities and even the level of polytechnic schools was high, the most of discoveries weren't put in practice.

Chemistry in other European states was at the beginning of its development and specialized on one certain type of product. Switzerland produced aluminum, calcium carbide, acetylene, bicarbonate, explosives, cellophane, dyes and substances that were used for perfumery and food processing industry. Italians had huge resources of sulphur in Sicily and therefore they produced superphosphates. Italy was also the first to produce blue vitriol, which was used as a herbicide.

Belgian chemical companies were mainly focused on the production of bicarbonate, for example Solvay (established in 1863) manufactured over 90% (in some of the cases in cooperation with local producers) of worldwide production of bicarbonate.

In Sweden, Alfred Nobel's company manufactured dynamite. Also the production of fertilizers was very important and after establishing the AGA in 1904, Sweden was ready to become world's number one producer of technical gases.

Norwegian company Norsk Hydro (established in 1905) produced nitric acid and nitrates. The situation in czarist Russia was much more complicated. Although Russia had unbelievable amounts of mineral resources, it wasn't able to use it properly and only collaborated with Germany and some other countries. Russian scientists were on a relatively high level, nevertheless, their discoveries were used improperly and misapplied.

In the USA, chemical industry had good conditions to develop and gain momentum. Cooperation with universities played an important role in the development of American industry. Lewis Norton (1855–1893)

established the "Course X", lectures on chemical engineering in MIT (Massachusetts Institute of Technology, founded in Boston in 1861 and moved to Cambridge US in 1916). Top scientists from all around the world were trying to investigate various technical problems there. They were, among others, very well financially supported and therefore more motivated. Lots of scientists studied in Europe, mostly in Germany or Switzerland and then went to the USA to continue in their careers. Many prominent businessmen of that time invested in scientific research, for example industrialist and owner of steelworks and railways Andrew Carnegie (1835–1919) founded the Carnegie Institution in 1902. Brothers Andrew W. Mellon and Richard B. Mellon established the Mellon Institute of Industrial Research in 1913.

Another type of organization was represented by a society, which was founded in 1909 by Arthur D. Little (1863–1935). This society was established in order to do researches ordered by their clients, more plainly it was the first research center, which was established to make money. Little and his colleagues William H. Walker (1869–1934) and Warren K. Lewis (1882–1975) were the first to stake out chemical engineering as an independent branch. Having its own research institute was a keystone of success for a company.

Eastman Kodak (1893), B. F. Goodrich (1895), General Electric (1900), DuPont (1902), Standard Oil or Colgate were among the first companies which had their own research centers.

Plastic materials were firstly used to substitute expensive materials (ivory etc.), but soon they came to be used in many other branches. Belgian Leo H. Baekeland (1863–1944) was the first to successfully produce synthetic plastic – the bakelite (in 1909, NYC). He was using a special autoclave.

The petrochemical industry has its roots in the middle of the 19th century. John D. Rockefeller (1839–1937) established the Standard Oil in 1868 and in 1913 this company began with thermal cracking of oil. During the next years, many refining plants were built and developed with the aim of getting a wide spectrum of oil products. The USA was

independent of import in the sphere of pure chemicals, but this situation was soon to be changed.

Pfizer (established in 1849), one of the oldest pharmaceutical companies, produced a variety of pharmaceuticals, from disinfectants to citric acid, which became very popular in those days, because it was used in beverage production.

Although Japan entered the world of chemistry later, it was able to get on the top very soon. Before the WWI, Japan was the number one producer of camphor, which was used for making celluloid, and was also the superior producer of iodine.

Many fertilizer-producing companies (Japan Nitrogenous Fertilizers, Nichitsu, Sumimoto Fertilizer Factory) were also important for Japanese industry and research, which assimilated the knowledge of western countries and took over the German know-how of organizing scientific education.

The situation of chemical industry in the Czech Lands from the middle of the 19th century till 1914

The chemical industry in our area came to existence in the middle of the 19th century. By then, only small-scale production of basic chemical substances appeared. Among others sulphuric acid, hydrochloric acid, nitric acid, bicarbonate, alum, blue vitriol, potash, dyes, saltpeter, and sulphur were produced here. In this period, also the first Czech scientific schools were established, mostly focused on inorganic and analytic chemistry.

At the turn of the 20th century, Czech chemistry became internationally known and Czech chemists often worked abroad after graduation, mostly in Germany, Switzerland and France.

When judging the situation in our country, we have to consider that a German minority lived by the Czech border. Many of the factories belonged to German industrialists and the know-how and experience were often brought by foreign experts. Production of our national industry was based mostly on foreign patents and licences. The best

known were Starck factories, Kinzelberger's company, chemical factories in Petrovice and Hrušov and United Chemical and Metallurgical Production in Ústí nad Labem. In this period, the later company played an important role in all-European scale. The main items of its production were sulphuric acid, bicarbonate and hydrochloric acid. Thanks to the effort of Max Schaffner (1830–1906), the first research center of the company was established. It was the first research institute in monarchy and due to its discoveries the Society was able to keep pace with worldwide research and progress. Soon it became the member of many international cartels of bicarbonate, sulphuric acid and superphosphate producers and also had a share in international cartel of alizarin convention.

At the turn of the century, electricity was introduced into chemical factories and enabled the progress of electrochemistry.

The beginning of production of fertilizers is closely connected with Adolf Schram (1848–1927), who founded a factory (established in 1904, nowadays known as Lovochemie) that produced sulphuric acid and superphosphates.

In step with the worldwide trend, the consumption of grease skyrocketed and its production was in the hands of Johann Schicht (1855–1907), who was, besides Tomáš Baťa (1876–1932) or Emil Škoda (1839–1900), one of the most important industrialists in our country. In 1911, the first European grease-hardening plant was built and Georg Schicht (nowadays Setuza) company was the greatest of its kind in Europe.

The petrochemical industry firstly appeared at the end of the 19th century and the refineries were built during the years 1887–1901, when plants in Ostrava, Pardubice, Kralupy nad Vltavou and Kolín were founded.

The First World War

The First World War affected the lives of millions of people in many countries and almost all the technical branches had to focus their

researches and production on war. In fact, war accelerated the progress of chemistry and WWI is sometimes called the "chemical war", because of the first use of chemical weapons and war gases.

Fast progress of armament industry revealed the weaknesses of technologies and contributed to a closer connection between research and production. The first state-owned organizations were founded, whose objective was to support and coordinate the cooperation of research institutions and industry. In this respect, Germany was the most developed. Every single branch that had something to do with war or armament was largely supported by the state. The situation in Great Britain was similar, armament industry and scientific research were properly organized and in 1916, even the Department of Scientific and Industrial Research (DSIR) was founded. France had its Commission Supérieure des Inventions (CSI), which was responsible to the Ministry of Defense. In the USA, the National Research Council (NRC) was established.

During the WWI, governments got to know that the army must be necessarily supported by industry, which must, on the other hand, be supported by scientific research. Since then, many research institutions were financially sponsored by private sector and chemistry became a military branch. The most remarkable impact of chemistry on war was the use of war gases, firstly used by the German troops (chlorine) in the battle of Ypres in 1915. In the battle of Verdun, Germans used phosgene instead of chlorine and later, in 1916, yperite was used.

Chemical industry in Czech lands during the First World War

The Czech chemical industry experienced some remarkable changes. The work of factories was narrowed because many employees were enlisted as soldiers, external relations were interrupted and there was a lack of raw materials. In contrast to Germany, Austro-Hungarian government did not adjust the scope of the chemical industry and even didn't have a crisis plan of importing important base materials. At that time, the most

important chemical company in the Czech Lands, United Chemical and Metallurgic Production, switched its production to military technologies.

Interwar period

The return to peace in 1918 wasn't easy, because the conditions in the whole world were diametrically different. Germany was defeated, Austria-Hungary split and some few new states came into existence. War decimated countries had to deal with millions of casualties and face up to the economic collapse.

In 1920, the League of Nations was founded in order to keep the world in peace, to demilitarize Germany and to potentially stave off any other conflict. According to the Treaty of Peace of Versailles, Allies were free to use German patents, trademarks and technologies. The only state that profited from the war was the USA. All the European states were damaged badly and the US companies seized an opportunity and started to trade with them. The end of the war meant the stoppage of production of some chemical products, mostly militarily focused products that were useless in the time of peace.

Germany lost its pre-war position and was forced to stop its oversea trades and let it to the Allies, mostly Americans. American industry and research switched its focus back to pre-war problems and profited from the fact, that many German scientists and other experts went to the USA to continue in their researches and therefore helped the USA in rebuilding and improving its position.

Many cartels were founded at that time and a lot of smaller companies incorporated themselves into one huge corporation, which enabled them to "stay alive". Europe had two gigantic companies of this kind, British ICI (Imperial Chemical Industries, established in 1926) and German IG Farben (in 1925, AGFA, Casella, BASF, Bayer, Hoechst, Hüls and Kalle merged together). While German, British and American companies tried to associate themselves into bigger corporations, French companies stayed independent.

The USA founds the Department of Chemical Engineering in 1920 as a part of MIT (Massachusetts Institute of Technology). The most important American companies in the interwar period were for example DuPont, Allied Chemical & Dyes, Union Carbide & Carbon (UCC), American Cyanamid Company (ACC), Dow Chemical, Hercules Powder, Eastman Kodak, Rohm & Haas, US Rubber, B. F. Goodrich, Goodyear Tire & Rubber, Firestone, Charles Pfizer, Merck, Eli Lilly and others.

The appearance of new chemical products came hand in hand with the progress in technology and was often a reaction to the needs of new industrial branches. Typical example of this close connection is the cooperation between automotive and chemical industry.

Due to the expansion of automotive industry, there was a growth in demand for rubber. Natural resources were not sufficient and therefore, research institutes had to deal with the synthetic preparing of rubber. The quality of petrol had to be increased too. The main objective was to develop anti-knock fuel additive, which would increase the efficiency of the engine. Thomas Midgley (1889–1944), industrial scientist who worked for General Motors, invented tetraethyllead, which improved the efficiency of combustion.

Some other considerable improvements came with the invention of catalytic cracking of oil, which was patented by Standard Oil. French engineer Eugène Houdry (1892–1962) who cooperated with Socony Vacuum and Sun Oil was another important scientist. He invented silicon-aluminum catalyzer, which was used for the production of high-octane Nu–Blue Sunoco petrol. Thanks to this Frenchman's invention, Allied forces were a bit stronger, because the RAF (Royal Air Force) imported 100-octane US petrol instead of 87-octane petrol which they used before the war.

Germany coped with its own after-war situation relatively successfully. In 1925, two German scientists Franz Fischer (1877–1947) and Hans Tropsch (1889–1935) discovered a new way for making petrol from coal. First synthetic petrol appeared in 1926 in the factories of IG

Farben, which invested into this research. However, synthetic petrol wasn't able to compete with petrol made from at that time cheap oil. In the interwar period, most of the vitamins and hormones were discovered and described, but their industrial production was the question of the after-war period, because special technical equipment and analytic methods were needed.

The growth of population and civilization advance entailed the problem of the production of food. Moreover, more efficient fertilizers were discovered and scientists tried to improve herbicides, fungicides and insecticides. The most important discovery in the sphere of insecticides was the DDT, which was described by Paul Müller (1899–1965) from the J. R. Geigy's company. Germany also launched its research in the field of macromolecular chemistry. First macromolecules, formed by chaining smaller molecules, were prepared by Herrmann Staudinger (1881–1965) who worked for the BASF. Staudinger's work was the beginning of polymer chemistry. Chemists tried to connect more and more monomer units into longer chains and polymer chemistry was in the greatest progress in that time. DuPont founded Experimental Station for polymer research, which was led by Wallace Carothers (1896–1937). Their first success was neoprene, synthetic rubber, which was patented and its production started in 1931. The next goal of DuPont was to find synthetic fiber. This fiber, called nylon, was patented in 1935 and implemented in 1939 in New York. Nylon was the first completely synthetic fiber in the history.

World crisis

The economic depression that began in 1929 in the USA afflicted the whole world and caused cut-down of investments into industrial production. Companies wanted to cut the costs to minimum and as expected, the research laboratories were affected by this policy too.

Germany was the most affected country in Europe. Germans tried to find the sources of energy, food and materials that would be applicable both in the time of peace and in war. Nazis expected that if another war

appeared, Germany would be completely isolated from other sources. The research of synthetic fuels was reinforced and largely supported. Herrmann Göring, who was responsible for the economy in Hitler's Germany, subordinated whole national industry to his own company, Reichswerke Herrmann Göring. More than that, the power and range of his "empire" was magnified by confiscations of Jewish property. Göring's company had collusions with for example IG Farben, the most generous sponsor of Hitler's election campaign.

The expectations of IG Farben were fulfilled during the WWII, when IG was the only supplier and producer of explosives and synthetic petrol in Germany. The Nazi ideology didn't wish well towards scientific research and many outstanding scientists, doctors and technicians of Jewish origin had to leave the country.

Interwar period in the Czech Lands

The Czech universities were still isolated from the most of the industrial production. Many new scientific schools were founded by people who spent some time in foreign universities, mostly in Germany or in Great Britain. There was a lot of chemical industry in Czechoslovakia, but the export possibilities were narrowed by the existence of a really strong competition with Germany. Nevertheless, during the twenties and thirties of the 20th century, Czechoslovakia was one of the economically strong states in Europe. The first-republic industry had a wide range of products and some of them were able to compete with the products of foreign states (for instance alkaline hydroxides, adducts of chlorine, active carbon or citric acid). Czech chemical industry mostly used some foreign patents or worked under the license of a foreign company the influence of the Czech scientists on industrial research was minimal in the thirties (many foreign scientists, mostly from Germany, Hungary and Austria worked in Czech laboratories). The Czech research workers were focused mainly on fertilizers, sugar industry, alcohol industry and agricultural industry and most of them were university teachers.

In 1920, the University of Chemical and Technical Engineering (VŠCHTI) was founded, and concerning industry, the United Chemical and Metallurgical Production was still dominant.

Second World War

The needs of WWII started the implementation of discoveries from the interwar period, and the results of research were more important than ever before. Huge amounts of money were invested in military research and some projects had virtually unlimited access to money (for example Project Manhattan).

Not only weapons, but also pharmaceuticals recorded a considerable development (mainly in preparations that were used against infectious diseases). In 1939, Australian Howard Florey (1898–1968) along with German biochemist Ernst Chain (1906–1979) isolated the *Penicillium notatum* mould, which was described by Scottish microbiologist Alexander Fleming ten years before. The US Government wanted to fasten the production of penicillin and entrusted 21 chemical companies with the production of this pharmaceutical. The first company that introduced penicillin was Merck in 1942 and two years after, Pfizer started to produce penicillin in large amounts and became the world's number one producer. This miraculous pharmaceutical was used for treatment of allied forces and world stepped into the era of modern medicine.

Czech chemical industry during the Second World War

The Czech chemical industry suffered from the German occupation, because it was used unevenly, according to the needs of the German occupants. Jewish property was confiscated and redistributed to the supporters of the regime. Czech universities were closed on 17th November 1939 and buildings were given over to German institutions. Some of the students were forced to work in German factories, few research workers were allowed to continue their work in German research institutions, but most of the students and teachers were simply

fired.

Postwar chemical industry till 1973

After the Second World War, the chemical industry totally changed. The refinement of oil and the development of polymers are the main objectives of the chemical research. Oil industry was developing really fast, because it was obvious that resources of coal are exhaustible. Polymer products came to be produced in large amounts and they literally flooded the market.

The situation was different in socialist countries, because they started to use the oil and natural gas a bit later than the western countries. Although the chemical industry was dependent upon the licenses and patents of western countries, it was very hard to obtain it, especially during the Cold War. The industrial production was often subordinated to political interests and therefore some of the products became useless and unnecessary.

New economical crisis appeared at the beginning of seventies, when OPEC (Organization of the Petroleum Exporting Countries) suddenly started to increase the prices of oil.

Czech chemical industry in the postwar period

The Czech industry after the WWII was remarkably changed. It was subordinated to the international agreements within the RVHP (Council of Mutual Economical Support). Scientific instruments from abroad were rare and when they occasionally appeared, it was a donation from UNRRA (United Nations Relief and Rehabilitation Administration). In 1952, Czechoslovak Academy of Sciences was established.

The Czech chemical industry was one of the most energy-consuming branches. At the beginning of its postwar development, the Czech chemical industry was mainly focused on the so-called “heavy chemistry”.

Chemical products from the seventies till the end of the millennium

In seventies, industrial companies started to care about the energy savings and ecology. In Europe, the USA and in Japan, the issue of research and development became the part of economic planning that cannot be thought apart from.

The first oil shock in 1973 only confirmed that the world inheres in a deep, long-lasting crisis. Especially the overproduction of plastics and artificial fibers was the problem; some of the companies were producing reserves, because they expected that the prices would increase. It was necessary to reduce the production of oil products and reorient priorities.

Today's chemistry needs absolutely precise products and therefore the technologies must be precise too. Of course this preciseness is compensated with high financial requirements.

Czech chemical industry from seventies till the end of 20th century

Chemical industry lost its connections from communist era and soon was separated from its Slovakian partners. All the big industrial groupments and business infrastructures of large companies fell apart. Czech chemical industry can base on the experience of scientists from the Academy of Sciences, universities and companies research centers.

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