Academic chemistry and related fields in Wrocław: Density-equalizing mapping studies over the past decades

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Abstract

Chemistry and related areas of science have a strong background in Wrocław with 3 Nobel laureates. The aim of this study was to assess the evolution of scientific excellence and productivity after the Second World War, when Polish scientists rebuilt academic life in these important areas. The present approach used the established platform of the New Quality and Quantity Indicators in Science (NewQIS) project and density-equalizing mapping calculations.

In total, 15,267 original research articles related to chemistry published by Wrocław scientists were identified in the Web of Science between 1972 and 2016. They were cited 170,606 times. The highest citation numbers were reached in the years 2001 and 2004. In total, 4,362 research collaborations were performed with 83 different countries, leading to a percentage of 28.6%. Wrocław chemistry institutions established a vast international network with the USA (688 articles), France (658 articles) and Germany (679 articles) as their main partner countries. Besides chemistry, the main research fields are biochemistry and molecular biology, as well as physics, with 2,177 and 2,007 articles, respectively.

This study visualized the great success and virtue by which Polish scientists rebuilt a scientific community in the area of chemistry in Wrocław after the Second World War. Wrocław is now a key Central European player in chemistry and related areas, which serves as a nodal point between Eastern and Western countries.

Key words: scientometrics, chemistry, Wrocław, density–equalizing maps
Introduction

Chemistry and related areas of science have represented the cornerstone of the academic life in Wrocław for centuries. Here, 3 Nobel laureates in chemistry lived, studied or worked. Eduard Buchner (1860–1917) was awarded the Nobel Prize in chemistry in 1907. He is also called the father of biochemistry in a test tube and the father of experimental molecular bioscience.1–3 Fritz Haber (1868–1934) was awarded the Nobel Prize in 1918 for his studies on the fixation of nitrogen from the air. Haber was the first scientist to introduce poison gas to warfare. As stated by his nephew Fritz Stern and others, Haber’s life encompassed triumph and tragedy.3–5 Lastly, Friedrich Bergius (1884–1949) was awarded the Nobel Prize in 1931 for his contributions to the invention and development of chemical high-pressure methods. This fruitful academic life was destroyed by Nazi Germany. The former University of Wrocław ceased to exist in 1945. In the Nazi period, more than 250 doctorate degrees of the scientists in Wrocław were nullified. Directly after the war, thanks to the scientists from the University of Lviv, a new Polish state university was established.6,7 Today, research related to academic chemistry is conducted at the University of Wrocław, sister universities such as Wrocław University of Science and Technology, Wrocław Medical University or Wrocław University of Environmental and Life Sciences, and other research institutions.

While there are numerous excellent historical articles about the development of Wrocław academic chemistry after 1945, a concise scientometric study that addresses the evolution of postwar chemical research activities is still missing. Therefore, the aim of the present study was to assess the scientific evolution, using the New Quality and Quantity Indicators in Science (NewQIS) methodology.8,9

Material and methods

New Quality and Quantity Indicators in Science platform

The NewQIS studies were established in 2008 and 2009 at the Charité – Universitätsmedizin Berlin, Germany, by an interdisciplinary team, consisting of computational science, economy, engineering, and medical experts.8,9 Since then, more than 50 studies have used this methodology, which combines advanced visualization techniques with scientometric approaches.10–14 One key technology are the density-equalizing mapping procedures (DEMP) developed by Gastner and Newman.15 Recently, the platform has been used to assess various areas of science in Wrocław.16

Search strategy

The present study is part of the NewQIS-Wrocław project of NewQIS. Data was retrieved from the Web of Science database as carried out in former NewQIS studies: “Wrocław” was entered as the target parameter in the address field.17 As the next step, the search was restricted to publication type “articles” in order to focus solely on original research. Then, the data set was scanned for research categories that are linked only to the fields of chemistry. The search was carried out on August 26, 2016.

Density-equalizing mapping

In 2004, Gastner and Newman published an algorithm for density-equalizing mapping.15 This approach was used in the present study and DEMP was integrated as described in previous NewQIS studies, with the territories of the countries being re-distributed according to the chosen variable, e.g., the number of joint research articles with Wrocław institutions.18–24

International collaborations

International research collaborations in the field of chemistry were analyzed in order to depict a sketch of the global research network that has been built by Wrocław scientists over the past decades. All affiliations of foreign scientists who jointly published original research contributions together with the scientists from Wrocław were analyzed as previously described.25,26 Bilateral collaborations between Poland and another country were defined as at least 1 author originating from Wrocław affiliations and at least 1 other co-author originating from an affiliation outside of Poland. After the total numbers were assessed, a special matrix with all networking countries was computed to visualize scientific networking activities.

Results

Wrocław research activity

In total, a number of 15,267 original articles were identified from 1972 to 2016 in chemistry and related fields (Fig. 1). Regression analysis demonstrated a significant increase in research activity (correlation coefficient (r²) = 0.9237) with a maximum yearly output of 727 articles in 2014. Density-equalizing mapping of Wrocław chemistry research output with the cooperating foreign scientists led to a research architecture depicted in Fig. 1, with Poland in the center, accompanied by strong partners, including the USA, France and Germany. When the numbers of institutions were analyzed, more than 300 institutions were devoted to research in the areas of chemistry in Poland, followed by more than 200 different American institutions and more than 150 French and German institutions (Fig. 2A,B).
Network analysis of Wrocław chemical research in cooperation with other countries

In the next step, the proportion of cooperation research was analyzed and a total of 4,362 research collaborations were found. These collaborations of Wrocław scientists encompassed a total of 83 different countries, leading to a percentage of 28.6% of all research activities. When the international research collaborations were further analyzed, 3,246 were found to be bilateral between one of Wrocław institutions and a foreign institution. There were also 888 collaborations between Wrocław and 2 other countries, and 175 with 3 other countries. The analysis

![Fig. 1. Publication output](image_url)
of time evolution demonstrates that there has been an increase in international research collaborations since 1972. Especially after 1990 there is a strong increase in these numbers with the year 2015 exhibiting a record number of 254 collaborations.

Network analysis diagrams were then used to visualize the global Wrocław research network with contributions from the USA (688 articles), France (658 articles) and Germany (679 articles). One can also observe strong bonds with Russia (409 articles) and Ukraine (406 articles), followed by Italy (373 articles) and the UK (322 articles). Network diagrams also illustrated frequent collaborations with Sweden (152 articles) and Spain (161 articles) (Fig. 3A,B).

**Semi-qualitative indicators: citations and Hirsch index**

Surrogate parameters of quality were based on citation analysis and the semi-qualitative markers of total
Fig. 3. International collaborations

A – international network; B – density-equalizing map of the number of articles per partner country.
citations, Hirsch index (h-index) and citation rate per article were calculated. In total, the 15,267 original articles from Wrocław were cited 170,606 times (Fig. 4). The articles with cooperating American institutions were cited 16,304 times. Maxima were observed for the articles from the years 2001 (8,568 citations) and 2004 (9,438 citations). The increase from 1972 to 2007 was significant with $r^2 = 0.8455$. Density-equalizing mapping for h-indices illustrated h-indices for Poland (h-index = 96), followed by those for the USA (h-index = 56), France (h-index = 45) and Germany (h-index = 44) (Fig. 4).

**Research areas**

Among different fields of science related to chemistry, the subject area “chemistry” dominated by far with 11,516
articles. It was followed by the field of “biochemistry & molecular biology” and the field of “physics” with 2,177 and 2,007 articles, respectively (Fig. 5A). The analysis of citation trends in the different research areas revealed a relative homologous citation rate (cr): cr = 10.94 for “chemistry”; cr = 13.12 for “biochemistry & molecular biology”; and cr = 12.40 for “physics”. The highest cr of the most assigned subject areas was noted for the articles published in the
field of “biophysics” with cr = 15.52, whereas the lowest cr was found for the articles which were related to “engineering” (cr = 4.74) (Fig. 5B).

When the relative proportion of subject areas was assessed, a clear dominance of the area „chemistry” was present, beginning with more than 74% of all articles in the period 1972–1976 to about 50% currently, in the period 2012–2016 (Fig. 6A).

When the subject nature of the international collaborations was analyzed for the top cooperating countries, it became evident that “chemistry” dominated all collaborations with the proportion of over 60%. However, some countries have special subject area links to Wroclaw scientists, i.e., “metallurgy & metallurgical engineering” is related to research collaborations of Wroclaw scientists with Russia and Ukraine (Fig. 6B).
Discussion

A large number of excellent articles have described the historical background of Wroclaw academic life over the past centuries, with a special focus on the time after 1945, when primarily the scientists from the Jan Kazimierz University of Lviv established new universities in Wroclaw. Basing on these historical facts, the present study incorporates scientometric approaches, together with novel visualization techniques, in order to illustrate the evaluation of chemistry and related areas in Wroclaw. Scientometrics is a field of science, also termed as meta-science, that was propagated by key researchers such as Garfield or de Solla Price decades ago in world-renowned journals such as “Science” or “Nature”. The present approach uses established scientometric instruments such as the citation indexing, the Web of Science database, or Hirsch indices to illustrate the scientific advances in Wroclaw chemistry research in the postwar time, reaching to the end of 2016. It does not stop here, but extends the approach, using a combination with the so-called density-equalizing mapping visualization technique, which was established by Gastner and Newman in 2004 in the “Proceedings of the National Academy of Sciences of the USA” and incorporated to NewQIS in 2009.

The density-equalizing maps related to Wroclaw research in the areas of chemistry, including biochemistry and molecular biology, point to a strong development of these areas of science after the war. This is paralleled by a similar increase in other biomedical areas as shown recently. Thus, the heritage of 3 Nobel Prize laureates in chemistry, linked to Wroclaw, has been transformed into a vivid scientific community in the field of chemistry, although Nazi Germany completely destroyed academic life in Wroclaw. This reconstructive work has its foundation on the shoulders of a few scientists who came from Lviv, i.e., professors Bogusława Jeżowska-Trzebiatkowska, Wanda L. Mejbaum-Katzenellebogen, Henryk Kuczyński, and Lucjan Sobczyk. They lost their home universities and were thrown many years back in their scientific work due to the Second World War and repressions by Nazi Germany, but managed to rebuild their own scientific capabilities in Wroclaw. Their former students now represent the diverse faculties in Wroclaw universities and research institutions, and authored more than 15,000 original articles in the period 1972–2016. Within this vast amount of scientific works, also 4,362 international research collaborations with a total of 83 different countries were published by Wroclaw scientists. This is nearly 1/3 of all Wroclaw chemistry-related publications, symbolizing that Wroclaw scientists function as ambassadors of Poland to the world. Especially after 1990 there has been an increase in international collaborations with western countries such as the USA or France. This shows how important the new political area was for the fields of science with Wroclaw scientists being able again to carry out any scientific cooperation – not limited to communist countries, but directed toward the scientific background of the collaborating institutions.

The analysis of research areas demonstrated that research in Wroclaw is not narrow-focused, but open to all aspects of chemistry. With the core chemistry areas in the center, areas such as biochemistry also gained more and more attention. From a historical perspective, this is extremely fortunate, since the Wroclaw 1907 Nobel laureate Eduard Buchner (1860–1917) is also known as the father of biochemistry in a test tube or the father of experimental molecular bioscience – this legacy was continued at the Polish state university of Wroclaw half a century later by professors such as Wanda Mejbaum-Katzenellebogen, who published articles on biochemistry between the 1940s and the end of the 1980s. With regard to the prominent role of Mejbaum-Katzenellebogen and other female scientists from Wroclaw, it is enticing to speculate that Wroclaw scientific community can be characterized as more gender-balanced than other scientometric communities. This needs to be studied in further projects with a focus on gender issues.

To conclude, this study is the first combined density-equalizing and scientometric analysis that visualizes the great success of Polish scientists who rebuilt academic life in the area of chemistry after the Second World War. With the heritage of 3 Nobel Prizes for chemistry and the scientific field completely destroyed by Nazi Germany, they succeeded and regained scientific power in the following 50 years. The chemistry research of Wroclaw is again a leading Central European player with a fruitful international network to both Western and Eastern countries.

References


