Monatshefte für Chemie - Chemical Monthly (2021) 152:1045–1051
https://doi.org/10.1007/s00706-021-02814-7

ORIGINAL PAPER

Chemophobia cured by chemists: chemists as children of the Sun

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Received: 16 May 2021 / Accepted: 21 June 2021 / Published online: 11 August 2021

Abstract
The success of chemists in the fight against COVID-19 provides us with a unique opportunity for strengthening the position of chemistry in society and suppressing chemophobia which has badly affected the image and development of chemistry over several decades. By highlighting the unique merits of chemistry in controlling infections and healing diseases, we propose developing a communication strategy "Chemists as children of the Sun". The time is ripe for chemists to take control of the story of chemistry. We believe that chemists must help the public to see chemistry in a whole new light. Only a positive perception of chemistry and the chemical profession will secure a sufficient supply of new talents, ideas, and also financial resources for the development of this unique and irreplaceable science for humanity.

Graphic abstract

#healingscience

Keywords Communication strategy · Didactics of chemistry · Fears of chemistry · Healing science · Identity of the chemist · Public image of chemistry

Introduction

It seems that the COVID-19 pandemic, similarly to chemophobia, has a more radical effect on the story of chemistry than any other phenomena. Some chemists describe the pandemic as a new-defining moment [1], while others consider its first year as one of the worst in their lifetime [2], or as one student puts it: "It feels like my life and career have been put on pause, and I'm just treading water while waiting for the world to hit play again." [3].

In her book *Wounded Heroes* [4] Boston Professor Marina Berzins McCoy emphasizes the importance of human vulnerability. For her, to be vulnerable is central to the human experience, recalling Aristotle when suggesting that vulnerability is needed for friendship. Based on the account of her studies of ancient Greece, Berzins McCoy reminds us that being a witness of suffering usually means that one is more responsive to vulnerability in oneself and others.

The fact that the world of chemistry is not free of emotions may seem surprising to the outside world. After all, chemists themselves are not used to talking about their feelings. Yet, it is precisely these emotions that can help us find a closer understanding between chemists and the public who have been badly affected by over 60 years of chemophobia. We can start

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by sharing the collective feeling of pain that many chemists feel in connection with the COVID-19 epidemic.

Situation analysis

Human society is now recovering from the anti-chemistry amnesia it experienced for decades. People willingly accept the results of the work of chemists. The powerful chemical triad—disinfectants, drugs, and protective materials—have become indispensable in the fight against COVID-19. At the same time, hope is being placed on the immunization of society through vaccines, another result of the work of chemists. Does this spell the end of chemophobia?

The scenery may have changed, but the problems remain the same, although they seem less obvious. The public image of chemistry remains an important issue for the global community of chemists. There continues to be a perceived inability of chemistry to trigger the interest of the general public and there is a need to find a "remedy to this unfortunate situation" [5]. A raising of the prestige and relevance of chemistry has been identified as an essential motivational factor for studying chemistry, as students find chemistry boring, and when they are shown a set of pictures relevant to chemistry (e.g., a car, lipstick, medication), they did not "see the chemistry there" [6]. And a study *The Chemical Industry in The Public Eye: Between Devil's Work and Solutions,* commissioned during the COVID-19 pandemic by the German chemical trade associations, highlights the importance of "factually presented success stories that exemplify the benefits of the chemical-pharmaceutical industry" [7].

We may live in a time when "far too many people" continue to keep "making money misleading customers by labeling their products as chemical-free" [8]; however, today's biggest problem caused by chemophobia is the lack of qualified chemists. It clearly demonstrates how irrational claims made in the past may cast long shadows. As an illustration, Mr. Goran Persson, Swedish Prime Minister in the years 1996–2006, claimed that his "political goal was to make Sweden completely free from chemicals" [9]. Obviously, he did not succeed in his effort, though his ill-considered statement fuelled the negative attitudes toward chemistry leading to a shortage of qualified chemists, creating an obstacle to the scientific research underpinning technological innovation. This situation is not helped by the fact that chemical education is under threat from the lack of qualified teachers [10], the negative effects of the epidemic [11, 12], and possible self-imposed restrictions on laboratory teaching [13].

Contrasting the story of chemistry

In our previous communications [14–16], we have addressed the most sensitive or up-to-date needs of chemistry communication. Today, with the expected post-pandemic negative impact of COVID-19 on research and chemistry education, persisting public chemophobia, and the experience of vaccine communication, it is clear that there is much more to be done.

We need to tell the contrasting story of chemistry. Facts about chemistry once told can be more eloquent than the negative picture of our science painted by the adversaries of chemistry. As pointed out by Kovács et al. [17], there is an inverse relationship between chemophobia and chemical knowledge, because fears about chemicals decrease the more one knows about chemistry.

We are proposing a new communication strategy, "Chemists as children of the Sun", where we suggest drawing public attention to the neglected fact of chemists' contributions to public health. By emphasizing the merits of chemists—in fact, their indispensability—in the treatment of diseases, we want to cultivate the image of chemistry as a healing science. In addition, we want to use this strategy to exercise better control over the general reputation of chemistry and gradually improve it.

The challenge of communication

In the defense of chemistry, we often emphasize the benefits of chemistry to "health, happiness, and future way of life" [18], for "solving today's challenges" [19], or we resort even to historical comparisons "Faraday changed society more than Marx did" [20]. However, we need to be more articulate in these efforts. The public must be told what specifically chemists have done for humanity, so that they can think reasonably about chemistry. Only then will we shake off the negative hashtags (e.g., #impurescience) and set chemistry free from stereotypes [14, 21].

In the shadow of COVID-19, the communication needs of chemistry have changed. They are related to the challenges posed by the COVID-19 pandemic and to their financial side, e.g., disruption of scientific research and its impacts [22], "COVID-ization of research funding" and the future of chemistry education [23]. If we chemists want our field to be sustained and survive in competition for funding, new talents, and other tangible values of institutionalized knowledge, the ability to communicate effectively is of the utmost importance. Once recommended being carved into the walls of chemical laboratories [24], Humphry Davy's words cease to apply (Fig. 1).

CONSOLATIONS IN TRAVEL,

OR

THE LAST DAYS

OF

A PHILOSOPHER.

BY

SIR HUMPHRY DAVY, BART.

LATE PRESIDENT OF THE ROYAL SOCIETY.

LONDON:

JOHN MURRAY, ALBEMARLE-STREET.

MDCCCXXX.

That he should be humble-minded, you will readily allow, and a diligent searcher after truth, and neither diverted from this great object by the love of transient glory or temporary popularity, looking rather to the opinion of ages, than to that of a day, and seeking to be remembered and named rather in the epochas of historians than in the columns of newspaper writers or journalists.

Fig. 1 The first edition of *Consolations in Travel* (1830) by Humphry Davy, an immensely popular mixture of poetry, thoughts on science and philosophy, where Davy characterizes an ideal chemist

We chemists can no longer follow his advice [25] to look "rather to the opinion of ages, than to that of a day", and seek "to be remembered and named rather in the epochas of historians, than in the columns of newspaper writers or journalists".

Let us remember though that it was Davy (1778–1829) who was able to present chemistry with the greatest power of communication appeal attracting new audiences for chemistry. This man was dubbed a "mercurial chemist", reflecting his fluid and changeable personality [26], and was "determined to mould himself upon the age to make the age mould itself upon him" [27].

Most chemists do not pursue communication merely as a source of fulfilling their inner needs; it is rather connected with their sense of duty or awareness of necessity. What they find sometimes superfluous about communication as an activity is futility or emptiness. However, only effective communication can bring change.

For inspiration, they should turn to the world of medicine and its ability to shape a distinctive medical ethos, engage with the public, and legitimate its own power in society. More than 500 years of dialogue with chemistry have made a significant contribution to the success of medicine. During that time, chemistry broke with its humble role as an auxiliary adjunct science to medicine and attained the position of a well-respected science in its own right and an autonomous academic discipline [28].

Mother of COVID vaccines

For a chemist, it is a delight to find one's own aspirations in another person and realize that they share the same values. The announcement on 2 December 2020, of the first COVID vaccine being fully tested to be approved for emergency use, made the chemist Katalin Karikó, according to the media, "mother of Covid vaccines" [29]. The success, described as a triumph of speed and ingenuity [30], was echoed by unprecedented media attention. Playing a vital role in the development of mRNA therapeutics [31], the Hungarian born chemist appeared, e.g., on the front page of the Austrian weekly *profil* and the German weekly newspaper *Die Zeit*, and her life was covered in the British newspaper *The Guardian* and elsewhere.

The news of Karikó's success may remind some chemists of Gorky's play *Children of the Sun* (1905). Here, the main character, the chemist Protassoff, explains: "But we … are the children of the sun, of the radiant source of life, we shall

conquer the dark fear of death … It is the sun glowing in our veins, which gives birth to proud and fiery ideas, illuminating the darkness of our ignorance, it is an ocean of energy, beauty and joy that intoxicates the soul" (Fig. 2). Using his solar metaphor, Maxim Gorky (1868–1936) summed up the essence of chemists' efforts. Comparing chemists to the Sun he celebrated, perhaps unconsciously, *Naturalis historia* (The Natural History), once a standard reference book of all natural scientists. In this work, Gaius Plinius Secundus (AD 23/24–79), known better as Pliny the Elder, famously describes the Sun: "taking into account all that he effects, we must believe him to be the soul, or … the mind, of the whole world … he furnishes the world with light and removes darkness, he obscures and he illumines the rest of the stars, … he dissipates the gloom of heaven and even calms the storm-clouds of the mind of man, … he is glorious and preeminent, all-seeing and even all-hearing" (Fig. 3).

It is no surprise that Karikó is considered an ideal example of a chemist: hard-working, determined to pursue a goal, and aware of the importance of her mission. At the same time, she is able to communicate with journalists without any problems.

Science communication has changed dramatically over the past year and a half as the public has closely followed what scientists can do under pressure [23]. However, the scientists who were thrust into the spotlight were not fully prepared. While some of them excel in communication with the media, others lack these skills, or as the British magazine *The Economist* points out, "scientists are accustomed to talking about ranges and living with uncertainty" and have "differing views." And as this British weekly dryly summed it up: "The public might find that harder" [32].

Chemists as children of the sun

We may be unaware of it, but doing chemistry is about owning the future. The decisions we make in our laboratories—in this realm, where our "intuition and tacit knowledge is sovereign" [21]—have weight and the actions we perform have consequences. We clothe, house, feed, and cure humankind and as a consequence make the world a better place to live [16]. And it is the promise of chemistry to solve the problems of humanity and namely its ability to deliver that legitimises its existence. However, over the past 60 years, unable to reassert itself against the dominant discourse, chemistry is undergoing a profound transformation.

Paradoxically, on one hand, chemistry is becoming increasingly important for the sustainable development of humanity, but on the other hand, it often lacks confidence and is not able to convince people of its attractiveness. Chemists thus have a number of interesting and in a way exciting tasks ahead of them (e.g., related to the threats of new diseases and pandemics, but also to environmental damage, aging and increasing populations, and urbanization [33]), but they face a lack of new talents. This is the consequence of chemophobia which we [14–16, 34] define as a long-lasting and persistent irrational fear of chemistry and chemical substances and a strenuous effort to avoid them, causing people to become hypersensitive or even intolerant in this respect.

The dynamics imposed on chemistry by chemophobia threaten its healthy development. It took the shape which persists to this day during the first 20 years of its modern

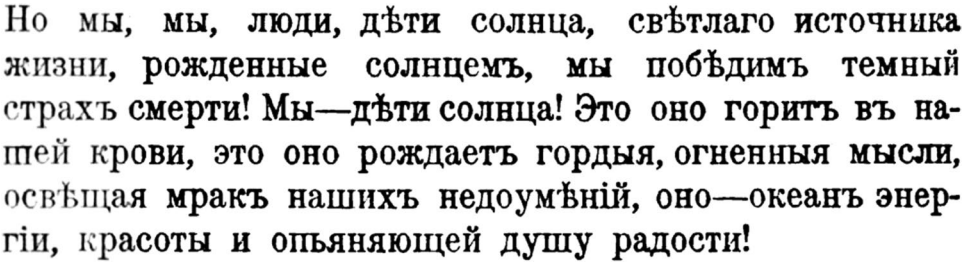
Но мы, мы, люди, дѣти солнца, свѣтлаго источника жизни, рожденные солнцемъ, мы побѣдимъ темный страхъ смерти! Мы—дѣти солнца! Это оно горитъ въ нашей крови, это оно рождаетъ гордыя, огненныя мысли, освѣщая мракъ нашихъ недоумѣній, оно—океанъ энергіи, красоты и опьяняющей душу радости!

Fig. 2 Extract with a proposition on the importance of chemistry from the first edition of Maxim Gorky's play *Children of the Sun* (Saint Petersburg, 1905), shortened translation in text

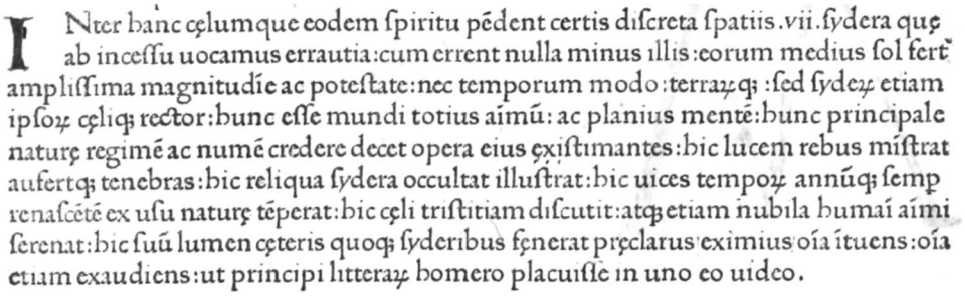
INter hanc cęlumque eodem ſpiritu pẽdent certis diſcreta ſpatiis .vii. ſydera quę ab inceſſu uocamus errautia: cum errent nulla minus illis: eorum medius ſol fert ampliſſima magnitudie ac poteſtate: nec temporum modo: terrą; q; : ſed ſydeꝝ etiam ipſoꝝ cęliq; rector: hunc eſſe mundi totius aimũ: ac planius mentẽ: hunc principale naturę regimẽ ac numẽ credere decet opera eius exiſtimantes: hic lucem rebus miſtrat auferto; tenebras: hic reliqua ſydera occultat illuſtrat: hic uices tempoꝝ annũq; ſemp renaſcẽtẽ ex uſu naturę tẽperat: hic cęli triſtitiam diſcutit: atq; etiam nubila humaí aimi ſerenat: hic ſuũ lumen cęteris quoq; ſyderibus fęnerat prędarus eximius oía ituens: oía etiam exaudiens: ut principi litteraꝝ homero placuiſſe in uno eo uideo.

Fig. 3 Extract with Pliny's compliment to the Sun from his *Naturalis historia* (first printed edition by Conradus Sweynheym, and Arnoldus Pannartz in Rome 1470), shortened translation in text

form (we consider the phenomenon of chemophobia to be much older [14]). The following examples illustrate this dynamic and, taken as a whole, they paint a disturbing picture of the world of chemistry falling apart:

- In 1960, the newly constructed American Chemical Society headquarters were unveiled as a "tangible symbol of conviction and self-respect", reflecting "the belief of chemists in the public worth of chemistry", while "radiation of self-respect" was viewed as "a primary step in deserving the esteem of others" [35].
- A year later, a warning "silent is not the way for a chemist to be" [36] followed the publication of "Rachel Carson's best-seller *Silent Spring*." "A chemist in the classroom" was asked to break the silence, because "many others whom our students hear will not be silent", more specifically "those with an axe to grind", whose "merging of information into speculation and on to a misconception is hard to detect."
- Less than 10 years later "against the backdrop of a growing hostility on the part of the man in the street toward scientific advances" [20], the year 1970 seemed "either going to be a landmark in the process of self-renewal [of chemistry]", or "the time when a decaying art held its last rites" with chemistry possibly becoming "like trigonometry—valuable, but not pursued in its own right." The "steadily decline" observed in students' interest in studying chemistry has been linked to the public's overall indifference to chemistry.
- A report published in 1971 [37] observed "self-doubt within the chemical industries about their own research and development programs", as well as "disillusionment about science in the society and especially among today's students".
- Six years later, it was observed that "in the minds of the general public, the chemist does not merit the importance, the status, and income of the physician, the lawyer, the dentist, because the general public has no way of knowing that the chemist merits them" [18].
- In the 1980s, the situation stabilized and the image problems became constant [38]. Chemists were "getting increasingly upset about their public image" as they perceived it "to be either rather poor or, at least, not nearly so good as it truly deserves to be." Moreover, they found it "inferior to that apparently enjoyed by physics and biology." Its inadequate reputation was also believed to negatively impact the state's support for chemistry, and weakening citizens' ability to make informed judgments on science-related public issues.
- And finally, in 1989, wide-spread belief was reported in "the pending demise of the chemical sciences owing to the decreasing interest in these fields by young people today" [39].

The fate of chemistry was never simple. The story of chemistry, however successful in solving the problems of mankind, is in fact the history of the struggle for the recognition of chemistry by society [15, 28, 40]. Chemists are aware that public acceptance secures better conditions for research, a larger budget, and an influx of young talent, hence a prerequisite for fulfilling chemistry's mission for the benefit of humanity.

There is often a lack of specific concise and clear facts that chemists could use in their daily communication with various publics, e.g., when they need to shape a distinctive chemical consciousness, want to change the general narrative about chemistry, or simply encourage an interest in our science. The application of our new strategy "Chemists as children of the Sun", inspired by the success of Katalin Karikó, could be an effective solution.

Being of robust character, this metaphor may open new paths of chemistry communication, strengthening the position of chemistry and suppressing chemophobia. The essence of this metaphor is to emphasize the role of chemistry and chemists in controlling disease and healing humanity.

To meet the demands of this strategy, we have compiled an overview of chemists whose names are associated with the discovery of drugs and vaccines. By renewing the interest in these illustrious chemists, we move beyond the traditional horizon of chemistry communication, reconnect with our professional past, and bond the broken fibers of our collective memory.

We recommend keeping this strategy universal and open to suitable examples from both the past and the present of chemistry, with the prospect of expansion to the future, because the very fear of disease is universal and affects everyone.

There are a number of ways to use the overview. It can serve as an argument in the debate about the importance of chemistry. Or serve as an inspiration to better know the lives of these chemists and the motivation behind their success. It can also be used to talk about diseases and treatment options with the help of chemists. However, this overview can also serve as a basis for communication on social networks or anywhere else where it is necessary to tell the truth about chemistry.

The most telling examples of the contribution of chemists to the treatment of diseases, and thus to the quality of life of humanity, include the following:

- Dutch physician and chemist Herman Boerhaave (1668–1738) was one of the first to deal with diagnostics based on chemical analysis of urine, which enabled effective treatments for numerous diseases to be found, e.g., diabetes, and thus to help many human beings [41, 42].
- The name of English chemist Sir Humphry Davy (1778–1829) is firmly linked with the beginnings of anesthesia,

which enables conducting operations without pain [43, 44]. Today's modern inhalation anesthetics are mainly the work of British chemist Charles Walter Suckling (1920−2013) [45].

- By isolating morphine from opium in 1804, German chemist and pharmacist Friedrich Sertürner (1783–1841) enabled its accurate and safe dosing in pain relief [46].
- German chemist Justus von Liebig (1803–1873) is the founder of physiological chemistry. It allows us to understand the chemical aspects of the body's activities and to find ways to effectively treat numerous diseases [47].
- French chemist Louis Pasteur (1822–1895) was—among his many other fundamental discoveries—the first to create effective vaccines against many serious diseases (e.g., anthrax, rabies). Thus, he is still saving hundreds of millions of lives today [48].
- German organic chemist Adolf von Bayer (1835–1917, 1905 recipient of the Nobel Prize in Chemistry) synthesized barbituric acid, the parent compound of the barbiturates [49, 50]. They are a numerous family of hypnotics that help many people overcome sleeping disorders, as well as drugs used in the treatment of epileptic seizures.
- Although he was not a chemist by education, German Nobel laureate Paul Ehrlich (1854–1915) was an excellent chemist who contributed to a number of medical fields. His most famous achievement was the synthesis of salvarsan, the first really effective compound in controlling human syphilis (incurable until his discovery) [51–53]. This compound virtually saved and healed myriads of people.
- In 1897, German chemist Felix Hofmann (1868–1946) synthesized acetylsalicylic acid, one of the most successful drugs of all time [54]. For more than a century, the compound has been widely used to reduce pain, fever, or inflammation, and as a preventive treatment for heart attacks and strokes. Hundreds of tons of it are produced each year.
- French chemist Ernest Fourneau (1872–1949) helped establish the fundamental laws of chemotherapy that have saved so many human lives [55]. In the 1930s, he started the systematic development of antihistamines, which culminated in 1950 when French organic chemist Paul Charpentier introduced the first neuroleptic chlorpromazine, the compound that brings relief to millions.
- Polish American chemist Leo Sternbach (1908–2005) is credited for the synthesis of benzodiazepines in 1955 [56]. This class of psychoactive drugs, which are designed for the treatment of anxiety, fear, and other disturbances of the mind, is globally one of the most prescribed medications.
- American chemist Gertrude B. Elion (1918–1999) was a co-discoverer of many excellent drugs for diseases affecting humanity, such as 6-mercaptopurine for leukemia, acyclovir as an antiviral agent, or azidothymidine for HIV/AIDS [57]. Millions of people owe their restored health and quality of life to her. In 1988, she was awarded the Nobel Prize in Physiology or Medicine, but as she had said "The Nobel Prize is fine, but the drugs I have developed are rewards in themselves." [58].
- American chemist Carl Djerassi (1923–2015) authored the first oral contraceptive compound in 1951 and changed the lives of millions of women when he gave them control over their pregnancies [59, 60].
- Czech chemist Antonín Holý (1936–2012) synthesized many successful antivirals and thus helped millions of people with serious diseases such as HIV/AIDS or hepatitis [61, 62].
- Japanese chemist Akira Endo (born 1933) initiated research into the relationship between fungi and cholesterol biosynthesis, which led to the development of statin drugs [63]. These are lipid-lowering medications, reducing illness, and mortality from cardiovascular disease, and are some of the best-selling pharmaceuticals in history.

These examples, of course, can be arbitrarily supplemented according to locality, time, or other requirements, e.g., chemists from a certain period, graduates of a particular university or doctoral advisor, chemists by nationality.

Conclusions

Human society may recover from its anti-chemistry amnesia, but the problems for chemistry remain the same. Being overshadowed by chemophobia, the science still suffers from its deadly dynamics. The fight against chemophobia and pro-active communication of chemistry must therefore be a matter of importance for every chemist: students, industrial chemists, laboratory workers, teachers, and researchers. The easiest way to bring our science closer to the public is to incorporate emotions and examples from everyday life (as discussed in our previous publication [14]). Representing the fundamental contribution of chemistry in the fight against disease, the communication strategy "Chemists as children of the Sun" as proposed here allows us to target one of the most general human emotions—concern for health, self-integrity, and life. The history of chemistry provides ample illustrations of chemists whose discoveries have benefited millions of human beings and helped long after the deaths of their discoverers. Being very universal and easy to use, the proposed communication strategy represents a very effective and useful tool for improving the position of chemistry and suppressing chemophobia.

Acknowledgements We are grateful to the project Progress Q46 of Charles University for financial support.

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