Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Beyond the beaker: benign by design society

Daniele Cespia a, Ilaria Esposito b, Raffaele Cucciniello c,*, Paul T. Anastas d, e, f

a NIER Ingegneria SpA, Via C. Bonazzi 2, 40013, Castel Maggiore, BO, Italy
b OPIS srl, Via Alessandro Volta, 94, 20832 Desio, MI, Italy
c Department of Chemistry and Biology, “Adolfo Zambelli” Università di Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano, SA, Italy
d School of Forestry and Environmental Studies, Yale University, New Haven, CT, 06511, USA
e Centre for Green Chemistry and Green Engineering, Yale University, New Haven, CT, 06511, USA
f School of Public Health, Yale University, New Haven, CT, 06510, USA

ARTICLE INFO

Keywords:
COVID-19
Green chemistry
Green engineering
Benign by design
Neobiology

ABSTRACT

In this work we discuss the necessity for Green Chemistry & Green Engineering to look out of the laboratory and consider the social aspects with greater attention to pursue peace and equality.

The expression “beyond the beaker” means green chemistry and engineering (GC&GE) should start looking at molecules while considering their origins and the interactions outside of the laboratory gate following the dream to pursue a benign by design (B-B-D) society.

The COVID-19 pandemic, that on one hand has strongly affected all the aspects of our daily-life (social relations, economic sphere, health, environmental impacts of our activity, habits), while on the other hand has stimulated significant health, environmental impacts of our activity, habits), while on the other hand has stimulated significant

The willingness to intervene on biological mutations and their potential for harm has always been a great challenge for researchers. If we were able to apply the range of manipulative techniques to the known biology we could intervene on the toxicity of some processes, which with current techniques could never be improved. Therefore, neobiology could be applied on:

- rare and degenerative congenital disease (i.e. CRISPR/Cas9 system, used to make a genuine “cut and sew” on DNA to eliminate or modify sequences that can cause mutations and/or degenerative diseases) [3].
- unknown viruses and bacteria; through their sequencing, functionalized nanoparticles could be synthetized bearing surface markers specifically recognized by the virus to selectively compete with their biological target and prevent the pathogenic mechanism of viral infection. In a B-B-D view, access to the cures derived by neobiology should be distributed equitably based on need.

In addition to neobiology, the B-B-D approach can also favor the development of new catalysts, especially for environmentally relevant applications (i.e. Fenton process). Following the GC&GE principles, a green catalyst should be prepared starting from Earth-abundant (i.e. iron, aluminum, etc.) and well distributed worldwide metals in order to prevent the usage of materials classified as “critical”, in terms of abundance and zone of extraction (i.e. conflict area [4,5]). This aspect is crucial and could help society in...
Reducing inequalities and social conflicts. Other objectives should favor the use of metals salts precursors from industrial by-products (i.e. iron from red mud) or metals-contaminated soils [6]. All these aspects should be considered and integrated with societal impacts. We hope that a catalyst will be considered good not only for its efficiency and capability of respecting GC&GE principles, but also it does not involve the usage of resources able to produce geopolitical conflicts.

In summary, we believe that, within our daily life, GC&GE can advance sustainability by achieving new functions and new products that will promote equality and improve wellness [7]. We ask, what will be the transformation of GC&GE for their first fifty years? We believe, GC&GE should move from environmental-oriented disciplines to more complex social sciences to be able to embrace societal aspects and to work in reducing conflicts and inequalities. With complex challenges such as climate change with social, economic and technological aspects, a BBD version of GC&GE should have a pivotal role in promoting adaption for the already unavoidable consequences.

Declaration of competing interest

The authors declare no conflict of interest.

Acknowledgements

The authors received no specific funding for this work.

References

[1] J.B. Zimmerman, Forward together, Environ. Sci. Technol. 54 (2020) 4697.
[2] P.T. Anastas, Benign by design chemistry, ACS Symposium Series 577 (Chapter 1) (1994) 2–22.
[3] A. Mokhtarzadeh, R. Eivazzadeh-Keihan, P. Pashazadeh, et al., Nanomaterial-based biosensors for detection of pathogenic virus, Trends Anal. Chem. 97 (2017) 445–457.
[4] OECD, OECD due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas, 3rd ed., OECD Publishing, Paris, 2016 https://doi.org/10.1787/9789264252479-en.
[5] P.T. Anastas, J.B. Zimmerman, The periodic table of the elements of green and sustainable chemistry, Green Chem. 21 (24) (2019) 6545–6566, https://doi.org/10.1039/C9GC01293A.
[6] V. Escande, C.H. Lam, C. Grison, P.T. Anastas, EcoMnOx, a biosourced catalyst for selective aerobic oxidative cleavage of activated 1,2-diols, ACS Sustainable Chem. Eng. 5 (2017) 3214–3222, https://doi.org/10.1021/acsuschemeng.6b02979.
[7] P.T. Anastas, The transformative innovations needed by green chemistry for sustainability, ChemSusChem 2 (5) (2009) 391–392, https://doi.org/10.1002/cssc.200900041.