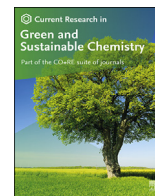


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Beyond the beaker: benign by design society

Daniele Cespi^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, MB, 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



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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 and thoughtful reflections favoring the development of new ways of thinking to guarantee a sustainable future to the Earth and its inhabitants. This approach emphasizes the necessity of union between all the actors (policy, science, economy and science) to find more sustainable solutions in the real world, recently defined as an integrated system of systems strictly interconnected [1].

In this context, an interesting description of a new research “field”, namely neobiology, has found space and we believe it will attract an increasing interest from the industrial, governmental and academic sectors. Neobiology is the study of the creation of new life forms, characteristics, attributes and functions that did not evolve in the natural world. Concerning this, the concept of neobiology should be critically linked to that of B-B-D developed in the early 1990's [2]. The ability to design a genetic sequence can help scientists to solve critical issues. The right side of this revolution should be characterized by a high awareness of the entire process and a rigid ethical code focused on the respect for the environment and human rights, from the definition of the problem to the

post-treatment procedures. In this scenario, why could neobiology be so interesting for the scientific community?

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 synthesized 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

* Corresponding author.

E-mail address: rcucciniello@unisa.it (R. Cucciniello).

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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.

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