Natural Products: An Indian Journal

Commentary | Vol 14 Iss 2

# The Green-Synthesis of Nanoparticles-Promise of a New Civilizational Breakthrough

**Joanna Kisała[1] and Dariusz Pogocki[1, 2*]**

[1]Department of Medicinal Chemistry and Nanomaterials, University of Rzeszow, Pigonia 1, 35-959 Rzeszow, Poland

[2]Institute of Nuclear Chemistry and Technology, Dorodna, Warsaw, Poland

[*]**Corresponding author:** Pogocki D**,** Chair of Biotechnology, Department of Medicinal Chemistry and Nanomaterials, University of Rzeszow, Pigonia 1, 35-959 Rzeszow, Poland, E-Mail: pogo@univ.rzeszow.pl

**Received:** October 03, 2018; **Accepted:** October 26, 2018; **Published:** November 06, 2018

## Commentary

There is an ongoing worldwide discussion on the role and perspectives of nanotechnology, potential impact on human life and the natural environment. Just recently the "Berlin Declaration on Nanomaterials" has been submitted to the Environment Council of the Council of the European Union (EU) by several EU-countries. The Berlin Declaration summarizes conclusions and recommendations of the 12th International Nano-Authorities Dialogue of Germany, Liechtenstein, Luxembourg, Austria, and Switzerland; and was acknowledged by the environment ministers of those countries at their annual meeting in June 2018 [1]. One of the declarations leading subject is a transversal definition of nanomaterials in all relevant regulatory contexts in the EU. There is no doubt that "size matters" (nano-sized materials possess different properties than the bulk-ones), and progress in nanotechnology gives a basis for another Industrial Revolution [2]. So far, the US-government founded National Nanotechnology Initiative program (https://www.nano.gov), defines nanotechnology as "manipulation of matter with at least one dimension sized from 1 to 100 nm"-one can see that this definition is quite broad and free of any environmental contexts.

There are numerous examples of nanostructures that are formed spontaneously in natural environments (among them metallic, metal oxides and composite nanoparticles [2-4]) which spark an idea of bio-nanotechnology [3]. Bio-nanotechnology briefly described as a usage of natural, cellular and molecular mechanism "from the bottom-up"-self-assembling of organic or inorganic nanostructures (structures of overall dimensions lover then 100 nm e.g. nanoparticles) from very small blocks; atom by atom, molecule by molecule, or nanoparticle by nanoparticle [5]. The idea of bionanotechnology meets halfway with the demand of "green-chemistry" i.e. eco-friendly chemistry having of low impact on natural environment. It needs mentioning, that the bottom-up techniques (contrary to more

**Citation:** Pogocki D, Kisala J. The Green-Synthesis of Nanoparticles-Promise of a New Civilizational Breakthrough. Nat Prod Ind J. 2018;14(2):123.

common the top-down techniques-methods of controlled “crumbling” of macroscopic materials by the mechanical or chemical manner until the size of the particles reaches the nanoscale [6]) can be quite sophisticated due to allowance of gradual increase of precursory particles i.e. nucleation, where every step of the synthesis may utilize different blocks (atoms, molecules etc.) [7]. On the other hand, the bottom-up methodology can be very difficult to control, especially when natural environments such as bacterial or fungal culture, or plant extracts, are applied. Therefore, the majority of the nanoparticle green-synthesis has been performed by counting on the spontaneous formation of the particles in the expanse of their rational design.

The “Lesson from Nature” [1] has already been taken and incredible potential of bionanotechnology has been recognized worldwide resulting in a plethora of nano-synthesis recipes published under the banner of “green-chemistry”. Each particular natural green-synthesis environment (i.e. cell-culture, plant extract etc.) has its own unique chemical-composition and properties-each offers unique “biological-reactor” and promises new, unique nanomaterial. (Sometimes, specific environments, self-assembly of noble metal nanoparticles may lead to the formation of highly-organised structures of very interesting collective physical properties [8]). The emergence of nanoparticle technology has come with the promising broad spectrum nanoparticle-antimicrobial agents of vast physiochemical and functionalization properties [5]. Nanoparticles are these days available on a scale similar to many biological molecules and anti-infectious agents, thereby opening the possibility of biological intervention at the molecular level. On the other hand, such supply meets a continuously growing demand for novel antimicrobial agents to destroy pathogenic multi-drug resistant microorganisms. Especially, the noble metals nanoparticles seem to be a promising alternative to antibiotics and sulphonamides. Therefore, practically all newly synthesized nanoparticles, such as silver and gold nanoparticles are examined against various microbial pathogens, together with cytotoxicity assessed in vitro on mammalian cell cultures [9-15].

Recently, we have published a chapter in the SNPC-book devoted particularly to green-synthesis of nanoparticles [16]. It covers the natural environments such as plant extracts, bacteria and fungi, and nanoparticles made of metals (Ag, Au, Cu), metal oxides (ZnO, $TiO_2$, $ZrO_2$, CuO), core-shell and bimetallic systems (Ti-Ni, Ag-Au, Au-Ag, Cu-$Cu_2O$). Wherever it was possible we tried to find commonalities in the different pathways of nanoparticle synthesis based on the physiochemical characteristics of the natural compounds involved in the processes. Frankly speaking, a green-synthesis here is probably not economically competitive with the classical synthesis but may offer nanoparticles of unique shape and morphology (Other week points are usually quite broad dispersions of sizes and complicated processes of isolation, fractionation and purification of nanoparticles). Particles obtained that way can be useful if strong emphasis will be put on the exploitation of their unique individual properties-that may happen for “medical” application. For instance, our personal experience with Ag-nanoparticles synthesized in turf extracts shows that some of them accelerate transport of certain small molecules into the plant cells but some inhibit the process. Observed pronounced difference seems to be strongly related to the nanoparticle size and morphology, as such might be potentially useful for nutrients or drug delivery. The size, shape and morphology of nanocarriers are crucial for drug-delivery through biological barriers including the most challenging; the blood-brain barrier. These days, theoretical approaches in nano-delivery design seems to be in a juvenile stage [17], therefore any nano-object of unique properties can be useful at least as a physical model of new drug nanocarrier.

On the other hand, the chemically inert, yet cell-stressing metal-oxide nanoparticles can be useful elicitor in the plant metabolic engineering, which is an alternative to the plant genetic-engineering.

In this commentary we would not like to repeat conclusions from the review mentioned above, but rather share some thoughts that we have gathered during its preparation. (However, our thoughts are illustrated referring mainly by papers which were not covered by the review).

Scientific nano-“gold rush”, a need for novel nanostructures (sometimes accelerated by aesthetic impressions given by their exceptional beauty [18]) resulted in literally thousands of papers published so far. With few exceptions, the usual structure of such paper consist of short, rather trite explanation of simple redox-chemistry and laboratory manipulation together with extensive characterization of the obtained nanoparticles using very sophisticated microscopic and spectroscopic techniques [4,19] and biological assessment [4,20,21]. Yet somehow we could not shake the feeling that majority of these days research is, at best, oriented toward generation of huge amount of metadata, and the green-nanotechnology research is a part of this general phenomenon.

We tend to believe, and are somewhat afraid of, that sooner or later the green-chemistry methods would become a part of combinatorial chemistry allowing preparation plenty of various nanostructures in single, fully automatized process. (Currently, the methods used in combinatorial chemistry are applied outside chemistry in areas like random mutagenesis by error-prone PCR [22] and phage-display [23]). The combinatorial chemistry already developed efficient strategies allowing identification of useful components out of the components libraries-there is nothing to prevent usage of these strategies also for nanostructures. Seems obvious that such perspective can have a huge impact on biomedical-applications and a rapidly growing translational medicine. On the other hand, our review clearly revealed some shortcomings that can affect successful “translation”: The main drawbacks that we noticed are generally poorly explained reaction mechanisms and deficit of chemical knowledge concerning the reaction environment. This airiness may result in barely understanding of the publication message and, in consequence, prohibit reproduction of the synthesis - especially when one is not able to exactly reproduce the reaction conditions. (It is only a little chance that one can have the identical natural synthesis environment at disposal).

The absence of precise information can be particularly regrettable if, based on published methodology, someone would like to obtain nanoparticles of special purpose (i.e. possessing unique physical properties)-practically any attempt to rational-design of the synthesis is doomed to fail. Nanoengineered special purpose materials with unique properties, such as nanometals, nanooxides, offer the potential for novel water technologies that can be easily adapted to customer-specific applications. For example, the persistent micro-pollutants are eliminated from the waste applying multi-stage process were so-called advanced oxidation processes (AOPs) [24] are use prior to biological stage to initially decompose the pollutants [25]. One of prominent and elegant method belonging to the

AOPs category is photocatalysis, while nanoparticles of semiconducting properties are frequently applied as photocatalyst converting the energy of light, preferably solar, into formation of highly reactive species arising on the surface of semiconductor [26,27]. The effect of nanoscale is adventurous here, since material like zirconia ($ZrO_2$), which is an electrical insulator (dielectric) at macro-scale, can become a semiconductor at nano-scale [28]. The transition from macro-to nano-scale allows engineering of the material properties crucial to its future functions e.g. the band gap, Fermi-level [22] (i.e. reduction-potential) and surface properties for potential photocatalyst. Such sophisticated engineering, even for the classical nanomaterial synthesis demands high experience and strong theoretical preparation on the side of the researcher and very well documented conditions of the synthesis. Unfortunately, it seems difficult to require reliable documentation from green-chemistry.

On the other hand, one has to keep in mind that in many cases the successful synthesis-methodology, curtly presented in a paper, can be a subject of careful explanation in a patent application already pending at a patent office [29-31]. Therefore, our expectation of clarity of the subject explanation, precision and reproducibility of applied methods etc., from published articles is somewhat naive and old-fashioned. That may be the case of people, who in their scientific life had the opportunity to touch one of the most significant resources for chemists like the Houben-Weyl Methods of Organic Chemistry (Ger. Methoden der Organischen Chemie) [32], established in 1909, since that time publishing preparative methods, which were treated comprehensively and critically; including “feasibility study” performed in their own laboratories.

In conclusion, we have approached field of nanotechnology from a view perspective of mechanistically-oriented organic chemistry, therefore we would like to see the nanoparticle green synthesis as a part of the exact sciences characterized by accurate quantitative expression, precise predictions and rigorous methods of testing hypotheses; involving quantifiable predictions and measurements. It can happen in the expense of mass production of meta-data. We believe that such conservative thinking on the research, fundamentally different than what seem to currently happen in majority of the laboratories, creates real perspectives for successful technical applications of green nanotechnology.

**Acknowledgement**
This work has been supported by a grant from the Polish National Centre of Science (NCN 2017/01/X/NZ9/00523).

## REFERENCES

1. Begeson LL, Hulton CN. Berlin declaration on nanomaterials submitted to environment council of the council of the eu. 2018.
2. Stark WJ, Stoessel PR, Wohlleben W, et al. Industrial Applications of Nanoparticles. Chem Soc Rev. 2015;44 (16):5793-805.
3. Goodsell DS. Bionanotechnology: Lessons from Nature. Wiley-Liss Hoboken New Jersey. 2004.

4. Khan I, Saeed K, Khan I. Nanoparticles: properties, applications and toxicities. Arab J Chem. 2017.

5. Radomskii SM, Radomskaya VI, Moiseenko NV, et al. Nanoparticles of noble metals in peat of the upper and middle amur region. Dokl Eart Sci. 2009;426(1);620-22.

6. Chen J, Herricks T, Geissler M, et al. Single-crystal nanowires of platinum can be synthesized by controlling the reaction rate of a polyol process. J Am Chem Soc. 2004;126(35):10854-55.

7. Prathna TC, Mathew L, Raichur AM, et al. Biomimetic synthesis of nanoparticles: science, technology and applicability. In Biomimetics IntechOpen. 2010.

8. Zhang L, Fan Q, Sha X, et al. Self-assembly of noble metal nanoparticles into sub-100 nm colloidosomes with collective optical and catalytic properties. Chem Sci. 2017;8(9):6103-10.

9. Yah CS, Simate GS. Nanoparticles as potential new generation broad spectrum antimicrobial agents. Daru 2015;23(1):43.

10. Oves M, Aslam M, Rauf MA, et al. Antimicrobial and anticancer activities of silver nanoparticles synthesized from the root hair extract of phoenix dactylifera. Mater Sci Eng C Mater Biol Appl. 2018;89:429-43.

11. Parlinska-Wojtan M, Kus-Liskiewicz M, Depciuch J, et al. Green synthesis and antibacterial effects of aqueous colloidal solutions of silver nanoparticles using camomile terpenoids as a combined reducing and capping agent. Bioprocess Biosyst Eng. 2016;39(8):1213-23.

12. Ravichandran A, Subramanian P, Manoharan V, et al. Phyto-mediated synthesis of silver nanoparticles using fucoidan isolated from spatoglossum asperum and assessment of antibacterial activities. J Photochem Photobiol B. 2018;185:117-25.

13. de Aragão AP, de Oliveira TM, Quelemes PV et al. Green synthesis of silver nanoparticles using the seaweed gracilaria birdiae and their antibacterial activity. Arab J Chem. 2016.

14. Saravanan M, Barik SK, MubarakAli D, et al. Synthesis of silver nanoparticles from bacillus brevis (ncim 2533) and their antibacterial activity against pathogenic bacteria. Microb Pathog. 2018;116:221-6.

15. Saravanan M, Arokiyaraj S, Lakshmi T, et al. Synthesis of silver nanoparticles from phenerochaete chrysosporium (MTCC-787) and their antibacterial activity against human pathogenic bacteria. Microb Pathog. 2018;116:221-6.

16. Kisała J, Hęclik K, Pogocki D, et al. Chapter 1-Natural environments for nanoparticles synthesis of metal, metal oxides, core–shell and bimetallic systems. Studies in Natural Products Chemistry. Elsevier. 2017;52:1-67.

17. Kisała J, Heclik KI, Pogocki K, et al. Essentials and perspectives of computational modelling assistance for cns-oriented nanoparticle-based drug delivery systems. Curr Med Chem. 2018.

18. Parilinska-Wojtan M. Beauty of nanoworld. Wydawnictwo Uniwersytetu Rzeszowskiego. Rzeszów. 2013.

19. Mourdikoudis S, Pallares RM, Thanh NTK. Characterization techniques for nanoparticles: comparison and complementarity upon studying nanoparticle properties. Nanoscale. 2018;10(27):12871-934.

20. Kumar V, Sharma N, Maitra SS. In vitro and in vivo toxicity assessment of nanoparticles. Int Nano Lett. 2017;7(4):243-56.

21. Bahadar H, Maqbool F, Niaz K, et al. Toxicity of nanoparticles and an overview of current experimental models. Iran Biomed J. 2016;20(1):1-11.

22. Ye J, Wen F, Xu Y, et al. Error-prone pcr-based mutagenesis strategy for rapidly generating high-yield influenza vaccine candidates. Virology. 2015;482:234-43.

23. Wu CH, Liu IJ, Lu RM et al. Advancement and applications of peptide phage display technology in biomedical science. J Biomed Sci. 2016;23(1):8.

24. Csay T, Homlok R, Ille E, et al. The chemical background of advanced oxidation processes. Isr J Chem. 2014;54(3):233-41.

25. Jurczyk Ł, Koc-Jurczyk J. Quantitative dynamics of ammonia-oxidizers during biological stabilization of municipal landfill leachate pretreated by fenton’s reagent at neutral pH. Waste Manag. 2017;63:310-26.

26. Kisch H. Semiconductor photocatalysis-mechanistic and synthetic aspects. Angew Chem Int Ed. 2013;52(3):812-47.

27. Paz Y. Specificity in photocatalysis. in photocatalysis: fundamentals and perspectives. The Royal Society of Chemistry. 2016:80-109.

28. Pizzini S. Physical chemistry of semiconductor materials and processes. John Wiley and Sons Ltd. Chichester UK. 2015.

29. Ray A, Mandal A, Joseph M, et al. Recent patents on nanoparticles and nanoformulations for cancer therapy. Recent Pat Drug Deliv Formul. 2016;10(1):11-23.

30. Caruso G, Raudino G, Caffo M. Patented nanomedicines for the treatment of brain tumors. Pharm Pat Anal. 2013;2(6):745-54.

31. Gulati M, Chopra DS, Singh SK, et al. Patents on brain permeable nanoparticles. Recent Pat CNS Drug Discov. 2013;8(3):220-34.

32. https://www.thieme.de/en/thieme-chemistry/sos-houben-weyl-54792.htm