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NANOTECHNOLOGY TOWARDS ENVIRONMENTAL SUSTAINABILITY

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Abstract: Nanotechnology has moved from the realm of science-fiction to reality at more than expected speed. Various areas in which nanotechnology presently seem to be having a decisive role to play is still in the state of tip of the iceberg and once it is exponentially deployed and employed there will be hardly any sphere of life which will not have a nano-touch in it and by that time world might be known as nano-world. With this at the backdrop the answer to the problem for sustenance of the planet will also have to come from nanotechnology. In the visible spectrum the planetary medicine aspect of artificial photo-synthesis seems to be the answer, once effectively arrayed on ground. If that is to be the case, the ethical aspect of its fructification will need to be conceptualized and formulated and global regulatory system will need to be put in place. Needless to say, either ethics will have to catch up with the galloping nano-technology or the latter will have to slowdown to be in empathy with the former, in the overall interest of humanity and that of the planet.

Keywords: Anthropocentrism, Artificial Photosynthesis, Eco-centrism, Environmental Sustainability, Nano-governance, Nanotechnology, Nano-therapeutics, Planetary Medicine

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1. Introduction

> The present generation have the responsibility to bequeath to future generations an earth which will not one day be irreversibly damaged by human activity. Each generation inheriting the earth temporarily should take care to use natural resources reasonably and that life is not prejudiced by harmful modifications of the ecosystems and that scientific and technological progress in all fields does not harm life on the earth.[1]

We are now in the fourteenth year of the present century, the first century after 3.5 billion years life on earth in which one species, i.e., homo sapiens, is considered on the verge of jeopardising the planet's future. Armed with the so called social enlightenment and scientific revolution, the human beings often consider nature as a valueless realm, governed by mechanistic casual forces. Philosophy and theology are predominately anthropocentric. Cobwebs of future somewhat started getting cleared in the second half of the last century, ironically, when human beings started having more knowledge about natural processes and more power to manage them, with their increasing industry and technology.

We now live at a change of epoch, new geological period, i.e., anthropocene[2] when human beings are the most important geomorphic agents on the earth surface.[3] Evolutionary history has been going on for billions of years encompassing thousands of years of cultural history of mankind. Here onwards, however, it is a determined fact that, it is high technology culture, which

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[1]"Preservation of Life on Earth," Article 4, UNESCO Declaration, November 1997.

[2]Paul J. Crutzen, "Albedo Enhancement by Startospheric Sulfur Injunctions: A Contribution to Resolve a Policy Dilemma," *Climatic Change*, 2006, Vol. 77, 2011-2020. Jan Zalasiewicz, Mark Williams, Will Steffen, and Paul Crutzen, "The New World of the Anthropocene," *Environmental Science and Technology*, Vol. 4, Issue 7, 2010, 2228-2231.

[3]Bruce H. Wilkinson and Brandon J McElroy, "The Impact of Humans on Continental Erosion and Sedimentation," *GSA Bulletin,* 119 (1/2), 2007, 140-156.

will determine natural history. It will be the human beings who will manage the planet with the tools provided by scientific and technological research. "One of the greatest challenges facing society in the twenty-first century is providing better living standards to all people while minimizing the impact of human activities on the global environment and climate as the world population reaches 8-10 billion by 2050."[4] Nano-technology is the latest tool with which humankind could shape the futuristic plan.

This paper, having introduced the subject of developmental sustainability (anthropocentricism), environmental sustainability (echo centrism) and nanocentrism, will endeavour to analyse various ethical nuances of nanotechnology enabled environmental sustainability of the planet. The first documented event in this regard was establishment of Earth Day in 1970 by US senator Gaylord Nelson. Environmental concern, according to Paul Hawken[5] is the largest movement in the world, considering the number and force of environmental organizations around the globe.

2. Anthropocentricism

Anthropocentricism, as the word says, has human beings at the centre of interest and perceives humanity as standing apart from nature. It "involves the foundational assumption that human beings, and the way in which they value the nature, are the modus operandi of any attempt to think about the green

[4]Mamadou Diallo, Bruce Tonn, Pedro Alvarez, Philippe Bardet, Ken Chong, David Feldman, Roop Mahajan, Norman Scott, Robert G. Urban, and Eli Yablonovitch, "Implications: Convergence of Knowledge and Technology for a Sustainable Society," *Convergence of Knowledge, Technology, and Society: Beyond Convergence of Nano-Bio-Info-Cognitive Technologies*, *Science Policy Reports*, ed. Mihail C. Roco, William S. Bainbridge, Bruce Tonn, George Whitesides, New York: Springer, 2013, 371–424.

[5]Paul Hawken, *Blessed Unrest: How the Largest Movement in the World Came into Being and Why No One Saw It Coming*, New York: Viking, 2007, 1-7.

environment."[6] According to Gifford Pinchot, a father figure in the American conservation movement,

> There are only two things in the natural world—people and natural resources. As a cache of resources, a necessity for human survival and prosperity, nature is regarded only to have instrumental value. Emergence of environmental concern is limited to only such situations, where natural resources are scarce or in situations, when the resources are being threatened by natural forces or intentional/ unintentional effects of human behaviour.[7]

Taking forward from the arguments put forward by Postma and Pinchot, we need to analyse the natural habitation of humankind. According to Aristotle human beings are by nature political animals, and they are residents of earth on six continents living in urban, rural and wild environments. 80% of human population, however, are urban living in organized towns, cities and suburbs. Further, the rural facet of nature is always required to support urban living, primarily for its food supply and other natural essentials. Between the anthropocene and ecocene, what remains is the wild nature; i.e. the areas that we ought to preserve to achieve ecocentrism that have nothing to do directly with what we perceive as our planet. There are still some places inaccessible by humankind for living. Further there is a 'seventh continent', within the realm of imagination and scientific reality, but virtually uninhabited. Some strong supporters of wilderness conservation argue: "Wilderness is for people. This is a principle that bears restating. The preservation goals established for such areas are designed to provide values and benefits to society. Wilderness is not set aside for the sake of its flora or fauna, but for people."[8] Thus while anthropocentrism

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[6]Dirk Willem Postma, *Why Care for Nature?* New York: Springer, 2006, 107.

[7]Freya Matthew, "Deep Ecology," *A Companion to Environmental Philosophy*, ed. Dale Jamieson, New York: Wiley-Blackwell Publishers, 2003, 218–233.

[8]John C. Hendee, George H. Stankey and Lucas C. Robert, "Wilderness Management", *United States Department of Agriculture,*

limits itself towards human centred sustainable development, there is a growing realization that to make it sustainable in true sense efforts will need to be made to enhance the concentric circle to include the 'seventh continent' thus reaching up to environmental sustainability, i.e., ecocentrism.

3. Ecocentrism

Ecocentrism emerges out of the concern with the restricted analysis of environmental problem. Ecocentrism moving beyond the pursuit of human interest, and assuming for equal respect of all forms of life, i.e., biocentrism, is aimed at extending the environmental agenda to issues of natural integrity, biological diversity and preservation of biotic community. Against the postulation of anthropocentric policy of sticking to modern leap of technological progress, zest towards economic growth as means to solve ecological problems, the ecocentric thought have remained as dreams rather unfolding as a solution. The followers of ecocentrism view environmental crisis as not so much a shallow problem of technical excellence but a deeper attitudinal impasse which need holistic approach towards sustainability of the universe. A pioneer in promoting ecocentrism, Arne Naess in his famous book *Deep Ecology* has brought out that identity of each individual form of life is a function of its relationship with others, and as such, one form of life flourishing is dependent on the flourishing other forms of life.[9] The proponents of ecocentrism are of the view that the natural world should be respected for its process and products to guard against their contamination. To achieve the respectability, low impact technology should be the preferred option, which will ensure localized self-sufficiency without impacting the intermediaries of wilderness.

Optimization of material resources, time and longevity of life were the goals, which the society was striving for till last century. Having exhausted all the resources within the realms of conventional science to achieve precision, miniaturization,

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Forest Service Miscellaneous Publication, Washington, DC: US Government Printing Office, Vol. 1365, 1978, 140-141.

[9]Postma, *Why Care for Nature?* 108.

automation and economy and not having found the ultimate solution, society was against a wall till the time when nanotechnology moved from the realm of science-fiction to reality and is in the process of occupying the centre stage in almost all societal and environmental divinity.

4. Nanotechnology

Nanotechnology envisages research involving engineered ultra small nano particles, who differ in their physical and chemical properties from bulk equivalents very usefully. To address global sustainability challenges facing the world,[10] nano-materials exhibit key physico-chemical properties that make them particularly suitable as functional materials for sustainable technologies. On the prospective of utility, they have much larger and more active surface areas than conventional materials. They can also combine with chemical groups, capable of targeting undesirable biochemical constituents and metabolic/signalling agents of waterborne bacteria and viruses including their networks. According to Nano enthusiasts,

> Nano-materials are also providing unprecedented opportunities to develop functional materials with superior electronic, optical, catalytic and magnetic properties. These novel functional materials can be processed into various forms and factors including water-soluble supramolecular hosts, particles, fibres and membranes.[11]

[10]Jeffrey C. Brinker, David Ginger, "Nanotechnology for Sustainability: Energy Conversion, Storage, and Conservation," *Nanotechnology Research Directions for Societal Needs in 2020,* ed., Mihail C. Roco, Mark C. Hersam, Chad A. Mirkin, New York: Springer, 2011, 261–303.

[11]Mamadou S. Diallo, Neil A. Fromer, Myung S. Jhon, "Nanotechnology for Sustainable Development: Retrospective and Outlook," *Journal of Nanoparticle Research*, Springer, 2013, 15:1-16.

5. Nano-Governance and Sustainable Development

Various ecological disasters looming on the horizon create a moral imperative that the existing situation should alter. Nano-governance (a term describing the coherence of nanotechnology and science based natural law governance at individual, community, national and global level) is a solution for the sustainability of human society and the resilience of the ecosystems on earth. Nano-governance means use of nanotechnology at local and global levels to alleviate many of the major problems associated with human overpopulation and destruction of ecosystems. Social scientists are of the firm opinion that humanity and our world may not survive for long or may not have the steam to flourish, unless nano-governance in its all nuances is adopted.[12]

A commission of the United Nations defined "sustainable development" as "that which meets the needs of the present without compromising the ability of future generations to meet their own needs."[13]

> Currently, the world is facing great challenges to meet their rising demands for basic commodities (e.g., food, water, and energy), finished goods (e.g., cars, airplanes and cell phones) and services (e.g., shelter, healthcare and employment) while reducing the emission of greenhouse gases and the environmental footprint of agriculture and industry.[14]

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[12]Thomas Faunce, *Nanotechnology for a Sustainable World: Global Artificial Photosynthesis as Nanotechnology's Moral Culmination,* Northampton, MA: Edward Elgar Publishing, 2012, 65.

[13]Gro Harlem Burndtland, "Towards Sustainable Development" in *Our Common Future: Report of the World Commission on Environment and Development*, Chapter 2, A/42/427, 1987, <http//:www.un-documents.net/ ocf-02.htm> (10 June 2014).

[14]Hugh Charles Jonathan Godfray, J. R. Beddington, I. R. Crute, L. Haddad, D. Lawrence, J. F. Muir, J. Pretty, J. S. Robinson, S. M. Thomas, and C. Toulmin, "Food Security: the Challenge of Feeding 9 Billion People," *Science,* 2010, 327: 812–818.

The notable economist Robert Solow in his *An Almost Practical Step Towards Sustainability* defined sustainability as a social virtue arising from consistent application of the ethical principles that the next human generation must be left with "whatever it takes to achieve a standard of living at least as good as our own and to look after the next generation similarly."[15]

To address global sustainability challenges facing the world,[16] nano-materials exhibit key physicochemical properties that make them particularly suitable as functional materials for sustainable technologies. On the prospective of utility, they have much larger and more active surface areas than conventional materials. They can also combine with chemical groups, capable of targeting undesirable biochemical constituents and metabolic/signalling agents of waterborne bacteria and viruses including their networks.

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Nano-technology is going to have a significant impact on global society. Richard Smalley, Nobel laureate in Chemistry, believes that the impact of nano-technology on health, wealth, and the standard of living for people will be at least the equivalent of the combined influences of microelectronics, medical imaging, computer aided engineering, and manmade polymers in this century.[18] Major industrial countries are incorporating nano-

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[15]Robert M. Solow, *An Almost Practical Step Toward Sustainability*, John Hopkins University Press, 1992, 15.

[16]Jeffrey C. Brinker, David Ginger, "Nanotechnology for Sustainability: Energy Conversion, Storage, and Conservation," *Nanotechnology Research Directions for Societal Needs in 2020,* 261–303.

[17]Diallo, Fromer and Jhon, "Sustainable Development," 15:1-16.

[18]Richard E. Smalley, "US Congress Testimony," 1999, 2 <http:/www.sc.doe.gov/besSenate/smalley.pdf> (15 June 2014).

technology in their innovation systems. There are applications that are about to be introduced into the market, Nanomix, for example, nanotube based sensors for detecting gasoline vapours, that will help protect refineries, chemical plants, and pipeline stations from leaks, which will be ten times less expensive than current sensors, and can operate for a year on a watch battery.[19]

6. Environmental Sustainability

Environmental sustainability, as perceived, is a foundational social virtue and is uniquely non-anthropocentric. Environmental sustainability, whether perceived as virtue or ethical principle, requires consideration of good of the greatest possible number of stakeholders, now or in future. Environmental sustainability, as the primary social virtue of planetary nanomedicine, an emerging area of nanotechnology based research, wherein, the planet is treated as a patient in a doctor-patient relationship, can also be linked with ecocentric or biocentric ethics. This sub branch is also known by the terms such as Gaia Theory or Deep Ecology and finds semi-formal expression in documents like Earth Charter or Earth Manifesto. This involves two key moral or ethical principles. Firstly, the diverse and flourishing non-human life form in nature has intrinsic value requiring policies, charters and technologies that reduce the number of human beings and their demands on those non-human species. Secondly, the human flourishing itself requires to have deepening respect for the right relations with the ecosystem, which should be based on a noble technology as nanotechnology.[20]

7. Nanotechnology based Environmental Sustainability (NES)

It is a moot question as to whether environmental sustainability is a primary social virtue (moral/ethical consideration) or it need to be prodded further and deep, particularly in the light of the

[19]Anisa Mnyusiwalla, Abdallah S. Daar and Peter A. Singer, "Mind the Gap: Science and Ethics in Nanotechnology," *Nanotechnology*, Institute of Physics Publishing, 2003, 14.

[20]Postma, *Why Care for Nature?* 108-109.

fact that it does not come anywhere near the interest of humankind to pursue a global NES project. Will promoting human developmental sustainability (Anthropocentrism) over environmental sustainability (Ecocentrism) be a more wise and prudent course to assert our most contemporary technology i.e. nanotechnology? Does the nanocentric path leading to anthropocentrism further get extrapolated to ecocentrism?[21] Various schools of ethics need to search for solutions to these moot questions in the backdrop of the universal ethical principles and theories.

Fragility of our ecosystem and interdependence of human survival and environmental sustainability are resonating in all corners of media and civil society. Neither in the utilitarianism, nor the deontological idealism and not even ethical works derived from religious traditions, we find the needed credence to the sustainability issue except the fact that the concept of sustainability is implicit in the core religious concepts of Buddhist compassion, Christian conscience and Islamic *Taqwa*.[22]

Peter Singer argues that it is now time to restructure ethical thinking regarding animals and remove speciesism. Singer felt that it is high time that society needs to ponder over inclusion of non-human species as well while giving due consideration to certain human based forms of discrimination, such as sexism and racism as it is a proven fact that the non-human species as well have a common degree of suffering.[23]

Environmental sustainability looms as the primary virtue of planetary medicine and thus is at the core of related ethical system. Whether conceived as a virtue or ethical principle, environmental sustainability, on most formulations, necessarily require consideration of the greatest good of greatest possible number of stake holders now, and also in the future.[24]

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[21]Faunce, *Nanotechnology for a Sustainable World*, 29.

[22]Faunce, *Nanotechnology for a Sustainable World*, 31.

[23]Peter Singer, *Practical Ethics*, Cambridge: Cambridge University Press, 1993, 62-64

[24]Faunce, *Nanotechnology for a Sustainable World*, 31.

Planetary medicine envisages the principles that should govern the emerging technologies such as nanotechnology, which may assist in resolving global material, health and environmental problems. Two articles involving scientific journals – *Global Theme Issue on Poverty and Human Development* and *Nature Nanotechnology* – published in 2007 were of immense value in this direction.[25] Experts have encouraged nanotechnology to systematically contribute for the realisations of the United Nations Millennium Development goals particularly energy storage, conversion and production, agricultural productivity enhancement, water treatment and medication.[26] One of the main ways nanotechnology may assist in all such issues concerns artificial photosynthesis, meeting all possible and unique public and environmental aspirations of humankind, may even be termed as moral culmination of nanotechnology.[27]

Contemporary ethicists and non-governmental organisations interested in nanotechnology are more focused on the risks of the same and the role of precautionary principles in addressing them. Some advocate a moratorium on nanotechnology for the time being as the most ethical policy proposition as some of the medical and material applications of nanotechnology may create societal upheavals and anarchy.[28]

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[25]Thembela Hillie and Mbhuti Hlophe, "Nanotechnology and the Challenge of Clean Water," *Nature Nanotechnology,* 2007, 2: 663–664. Richard Jones, "Are Natural Resources a Curse?" *Nature Nanotechnology*, 2007, 2, 665–666.

[26]Fabio Salamanca-Buentello, Deepa L. Persad, Erin B Court, Douglas K Martin, Abdallah S. Daar, Peter A. Singer, "Nanotechnology and the Developing World," *Public Library of Science (PLOS) Medicine 2*, 2005, 97.

[27]Thomas Faunce, "Governing Planetary Nanomedicine: Environmental Sustainability and a UNESCO Universal Declaration on the Bioethics and Human Rights of Natural and Artificial Photosynthesis (Global Solar Fuels and Foods)," *Nanoethics* 6.1, 2012, 15-27.

[28]Faunce, "Governing Planetary," 5-6.

Apprehensions against the use of nanotechnology through artificial photosynthesis could be anything between climate change (or other pathologies in the field of planetary medicine), impractical distributive justice, the lack of reciprocity of future generations to the present, the problematic ethical status of the 'interests' of future generations, the unpredictable numbers of them likely to be impacted and the potential attenuation of moral responsibility with increased remoteness in time.[29]

8. Ethics of Planetary Nanomedicine

Conceptualizing the ethical foundations of planetary nanomedicine could be by extrapolating ethical systems, generally applied in healthcare and doctor-patient relations. Here the planet is regarded as a patient and the ethical norms concerning the use of new technologies for environmental sustainability can be construed as doctor and thus the system of basic ethical principles can be applied to the traditional doctor-patient relationships. Having drawn the analogy, 'Principles of Biomedical Ethics', as given by Tom Beauchamp and James Childress, with four basic principles of medical ethics (autonomy, non-malfeasance, beneficence and justice) can be effectively used to advocate the ethical aspect of planetary nanomedicine.

In bioethical principle, autonomy is defined as 'respect for the deliberated self-rule of patients (or research participants),' linking it to Kant's 'Categorical Imperative' i.e. to treat human beings as ends, complete in themselves, not as means to other goods.[30] Alternatively, autonomy could be defined from a utilitarian perspective as requiring a constraint on the principle of paternalism. As John Stuart Mill advocates that the only purpose for which power can be rightfully exercised over any member of a civilised community, against his or her will, is to

[29] Faunce, *Nanotechnology for a Sustainable World*, 34.

[30] Herbert James Paton, *The Categorical Imperative: A Study in Kant's Moral Philosophy*, Philadelphia: University of Pennsylvania Press, 1971, 245-247.

prevent harm to others. His or her own good, either physical or moral, is not a sufficient warrant.[31]

Extending the above rationale of Kant, the autonomy (or respect for intrinsic dignity) to the planet as a whole may support the ethical principle that our world should be treated as a type of collected consciousness and not as an entity for the good of others (for example, economic growth). Respect for autonomy appears to require some capacity to consult and follow the independent will of another entity.

The principles of beneficence and non-malfeasance are jointly supposed to ensure net medical benefit to patients with minimal harm. Beneficence was importantly, additionally, associated with the ethical duty to undertake research and participate in professional education and training. Beneficence likewise was held to be demonstrated through sensitivity to risk of harm, potential of benefit, welfare and interests of involved parties, as well as the ability to reflect on the social and welfare implications of research. The ethical principles of beneficence and non-malfeasance can readily be taken across to the humanity-planet relationship. Indeed, global public health physicians could regard themselves as acting in accordance with such ethical obligations towards the sustainability of planetary ecosystems.

The principle of justice, in relation to health and medical research ethics, has three ethical obligations, i.e., to ensure fair distribution of scarce resources (distributive justice), to respect patients' rights (rights-based justice) and to respect morally acceptable laws. Justice is deemed to be present in medical research, where the benefits and burdens are fairly distributed and the recruitment of participants and review is procedurally fair. Justice is a foundational social virtue as well as a basic principle of medical ethics and also readily translatable to a focus on the interests of the planet as a whole.

If these principles could be viewed as applying to the planet as patient, then this might strengthen public

[31] Faunce, *Nanotechnology for a Sustainable World*, 33.

understanding of the ethical foundations of nanotechnology applied through artificial photosynthesis to foster environmental sustainability.[32]

9. Artificial Photosynthesis and Enlightenment Theory

Planetary nanotherapeutics could also be construed as an element of enlightenment theory. It is an ethical fact that society is ever consciously evolving as a part of natural evolutionary progression to adapt itself to changed needs and situations. There is an evolutionary progression in human reason and conscience as well which intersects well with the notion that the uses of new technology facilitate environmental sustainability.[33] It seems to be a natural extension of life and consciousness in this universe.

Immanuel Kant, the philosopher arguably central to enlightenment theory, summarised the idea by stating that virtue arises from consistent voluntary decisions to act (despite internal or external obstacles) upon principles capable and worthy of application by all rational human being.[34] The use of new technology such as nanotechnology to support sustainability of human development fits squarely within this influential moral framework. Sustainability of the environment (as a non-rational, non-thinking, non-human entity) on a superficial analysis has a more uncertain moral place within it.[35]

10. NES and Steady State Economics

Often fundamental ethical principles of planetary nanomedicine are being viewed by some economists to frame the ethics of sustainability, what are known as 'steady state' theories of economics. They have been striving to factor in our moral obligations towards the limited and fragile resources of the

[32]Faunce, *Nanotechnology for a Sustainable World*, 32-34.

[33]Bryan Furnass, "From Anthropocene to Sustainocene: Challenges and Opportunities," *Public Lecture, Australian National University*, 21 March 2012.

[34] Faunce, *Nanotechnology for a Sustainable World,* 65.

[35]Faunce, "Nanoethics," 9-10.

planet, and into their policy recommendations. Ecoeconomists such as the E. F. Schumacher (with his concept of 'small and local is beautiful') and Kenneth Boulding (with his idea of 'Spaceship Earth' as a closed economy requiring recycling of resources) have been successfully championing the virtues of ecological sustainability and environmental integrity. In doing this, the former drew upon Buddhist ethical principles and virtues, while the latter relied upon those from the Quaker tradition.[36]

11. Universal Declaration

"Nanotechnology, though bestowed with lots of novelty and promise, still has a problematic place in the popular imagination owing to unresolved safety issues."[37] Till the time an appropriate ethical regulatory structure is in place, NES project could well be promoted through domestic and international media as a defining symbolic endeavour of planetary nanomedicine.[38] Many of the nanotechniques and structures as well will be the subject of patency and other claims of intellectual monopoly privileges.[39] Therefore, in order to deal with such issues, creating governance principles will be an arduous and complex process, which could start with a universal declaration like Universal Declaration on Bioethics and Human Rights (UDBHR), a template for a UNESCO Declaration on the Bioethics and Human Rights of Natural and Artificial Photosynthesis.

This UDBHR has many features that would be relevant to shaping the ethical and human rights principles governing natural and artificial photosynthesis. These include, first, application to individuals, communities and private corporations and as well as States (article 1); second, a focus on 'access to adequate nutrition and water'; third, 'improvement in

[36]Faunce, *Nanotechnology for a Sustainable World,* 38-39.

[37] Faunce, "Governing Planetary Nanomedicine," 24

[38] Faunce, "Governing Planetary Nanomedicine"24

[39]Joachim Henkel, Maurer SM, "Parts, Property and Sharing," *Nature Biotechnology,* 2009, 12: 1095.

living conditions and the environment' and finally, 'reduction in poverty and illiteracy' (article 14).[40] The UDBHR also emphasises the need to recognize the importance of freedom of scientific research and equitable access to medical, scientific and technological developments (article 2), sharing its benefits with particular attention to the needs of developing countries (article 15) and safeguarding and promoting the interests of the present and future generations (article 2). UDBHR article 21.3 likewise relevantly requires that states and public and private corporate actors should recognize the "importance of research contributing to the alleviation of urgent global health problems."[41]

There are, however, ethical issues that might be much more specific to natural and artificial photosynthesis that could be raised initially by means of a specific UNESCO Declaration.[42] These could be as to whether photosynthesis in its natural form should be considered subject to common heritage of humanitarian principles (like, under specific United Nations Declarations and Conventions, the human genome, the moon, outer space, the deep sea bed, our natural or cultural world heritage) or indeed a part of a new category of ethical and international law principles in the category of planetary common heritage.[43]

12. Conclusion

A recent way of bridging sustainable development and a sustainable biosphere is to think of a 'safe operating space for

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[40]Thomas Alured Faunce, and H. Nasu, "Normative Foundations of Technology Transfer and Transnational Benefit Principles in the UNESCO Universal Declaration on Bioethics and Human Rights," *Journal of Medicine and Philosophy*, 2009, 34, 296-321

[41] Faunce, "Governing Planetary Nanomedicine," 25

[42]Thomas Alured Faunce, "Future Perspectives on Solar Fuels," *Molecular Solar Fuels Book Series: Energy,* ed. T. Wydrzynski, and W. Hillier, Cambridge: Royal Society of Chemistry, 2012, 506–528.

[43]Thomas Alured Faunce, "Governing Nanotechnology for Solar Fuels: Towards a Jurisprudence of Global Artificial Photosynthesis," *Renewable Energy Law and Policy*, 2011, 2: 163-168.

humanity'. Johan Rolckstrom argues (using scientific data) that there are nine planetary systems on which human beings depend.[44] These can be seen by analysis of chemical pollution, climate change, ocean acidification, stratospheric ozone depletion, biogeochemical nitrogen-phosphorous cycles, global freshwater use, changing land use, biodiversity loss and atmosphere aerosol loading. For at least ten thousand years (what geologists call Holocene times) these systems have remained stable. But since the Industrial Revolution, due to excessive human activity, in three of these systems, the boundaries have already been exceeded: biodiversity loss, climate change, and the nitrogen cycle.[45] Thus evolution of Holocene into Sustainocene will need technocentric environmental sustainability.

Evolutionary history has been going on for billions of years, whereas, whole cultural history is on for about hundreds thousands of years. However here onwards, it is a fact that, it will be high technology culture, which will determine natural history. It will be the human being that will manage the planet and scientific research will be the tool for doing that. Further, nanocentrism is the latest tool humankind has to shape the futuristic planet.

[44]Johan Rockstrom, Jeffrey D. Sachs, Marcus C. Ohman, Guido Schmidt-Traub, "Sustainable Development and Planetary Boundaries," 2013, 1-3, <http://unsdsn.org/wp-content uploads/2014/02/130508-Sustainable-Development-and-Planetary-Boundaries.pdf>(June 10, 2014)

[45]Johan Rockström, "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society*, 2009, 14(2): 32.