Reception: **November 13, 2020** | Acceptance: **September 21, 2021** | Publication: **February 1, 2022**

Ethical reflections related to the use and research of nanotechnology

—

Santos Adriana Martel Estrada
mizul@yahoo.com

Department of Design, Institute of Architecture, Design and Art.
Universidad Autónoma de Ciudad Juárez, Chihuahua, México.

To quote this article:
Martel Estrada, S. A. . (2022). Reflexiones éticas relacionadas con el uso e investigación de la nanotecnología. *Espacio I+D, Innovación más Desarrollo, 11*(29). https://doi.org/10.31644/IMASD.29.2022.a05

— Abstract—

Currently, nanotechnology is an emerging interdisciplinary knowledge area; this discipline encompasses biomedical food, energy, arms, and its industrial uses. Despite its applications' potential, there is a need to ethically consider the benefits and risks that nanotechnology uses and development represent for natural, economic, and social ecosystems. This document analyzes ethical issues of nanotechnology use. Considering its bioethical dimensions, an analysis of the risk and regulatory aspects can be carried out. For these reasons, a reflection related to the ethical and bioethical implications of the different nanotechnological applications becomes relevant without neglecting their possible benefits and threats. In general, these reflections must drive researchers to influence the national and international regulatory framework, not to limit scientific progress. It also ensures that said progress does not threaten human beings' safety and the planet in general.

Keywords:

Bioethics; Nanotechnology; nanomaterials.

From the scientific tradition's point of view, we can identify memorable events that have become part of the social structure that gathers scientists in the same goals. In 1959, Richard Feynman gave the scientific community a speech called *Plenty of Room at the Bottom* (Feynman, 1959). This document became an educated prognosis of the scientific possibilities in the study of nanoscale, and somehow it summarized with great eloquence the path in which the scientists in the following decades would develop. However, despite the valuable speech, it omitted to mention the ethical implications of this technology.

Currently, nanotechnology encompasses the use of materials and devices in the medical and electronic industry, and various industrial issues (It burnishes, 2010). It is described as an emerging and interdisciplinary area of research with important commercial applications involving nanosciences, which will be a dominant research technology in New World economies (Stapleton, 2014). It has an interdisciplinary character covering areas of knowledge such as physics, chemistry, biomedical, and materials science (Berne & Schummer, 2005). It has been considered that it will have important contributions to the solution of the current challenges of environmental protection, health, and resource and energy limitations (Ferrari, 2014). As a discipline, it also covers the study and generation of nanodevices for diagnosis, security, and military applications. It has been described as an emerging technology that operates with objects (atoms and molecules) focused on a scale of about 100 nanometers and smaller (Khan, 2014; Stapleton, 2014).

Nanotechnology right now is more than a science fiction story. Many researchers consider it nature's last toy box, which includes atoms and molecules, and in which the possibilities of creating new things are limitless (Amato & Carroll, 1999). In this way, these dimensions impossible to see with the human eye, become an object of hope and dream for those who require a technological advance for an incurable disease, but they are also a cause of concern for the scientific community, given the impossibility of having a certainty of the repercussions of all the use of this technology in the short and long term.

Although many of the ethical concerns regarding nanotechnology are based on misconceptions in a very similar way to what Jonas argued (Van de Poel, 2008), for the public's imagination there is no difference between what is scientifically possible and what embraces fantasy.

Unfortunately, the implications of technology have commonly been brushed aside by the ethical and scientific discourse. Researchers, provided with freedom of research and eager to discover and learn from nature, embark on a race to immerse themselves in the nanometric world, to understand how particles and molecules are related to create and configure reality. In this context, despite Potter's arguments regarding the risks of boundless science (Rogotneva, Melik-Haikazyan, & Goncharenko, 2015), for theorists, technology has usually been considered morally neutral, and only its use or purpose has been the subject of a moral evaluation (Larrere, 2010). However, the bioethical implications of nanotechnology research should become the subject of reflection by scientific committees at different levels. In this sense, it is important to question and ensure that nanotechnology research is developed not only by an innate need to acquire knowledge, but also includes a visualization of its possible applications and therefore, the risks thereof (Brune, 2010). That is, it is necessary to ethically consider the benefits and risks that the use and development of nanotechnology represent for social, economic, cultural, and even more complex life, for life itself.

To this end, different proposals have been developed for the bioethical analysis of conflicts with the use of nanotechnology. Primarily, dilemmas have been addressed with a focus on risk management (Bawa & Johnson, 2007). However, given the ease of access to digital media, it is prudent to consider the method proposed by Brune where, from a search for information, ethical aspects not included in legislation or standards are evaluated, in such a way that it can be identified if there are differences between what is reported and what is actually done (Van de Poel, 2008).

For these reasons, a reflection related to the ethical and bioethical implications of the different nanotechnological applications is relevant, without neglecting their possible benefits and threats from an exhaustive analysis of the literature.

BIOETHICS RELATED TO NANOTECHNOLOGY

According to Pascussi, bioethics can be defined as "the study and methodical analysis of human behavior in the areas of scientific knowledge related to life and health from ethical and moral values, principles, and postulates" (Castro, 2016). This discipline can be analyzed from the bioethical principlism initially proposed by Beauchamp and Childress (Escobar López, 2012; Siurana Aparisi, 2010), and that considers the principles of autonomy, beneficence, non-maleficence, and that of justice. From these, a reflection of the bioethical implications related to the use and research of nanotechnology is precisely relevant.

The bioethical dimension has not been completely far from the scientific spaces. However, it has been placed in the realm of medical research mainly due to the terrible experiences documented in the Belmont Report (Siurana Aparisi, 2010), with limited participation in other scientific areas. Recently, the main concerns in the use of nanotechnology focus on the possibility that it will be used by governments to threaten privacy, as well as the safety of human and animal life.

On the other hand, in the bioethical discourse prevails the concern of Jonas' concept of ethical responsibility, in relation to the use and research with nanotechnology (Ferrari, 2014). In this regard, it is not clear whether this obligation should fall on public policy or the ethics of scientists and manufacturers. To this added the ignorance of those in charge of legislating in the matter, not only in developing countries but even in the most developed, who make decisions without having full knowledge of them.

On the other hand, the alternative of focusing attention on principles for ethical decisions related to developments in biotechnology and nanotechnology has been presented, among which it is considered to take as a reference the effects of similar technologies, as well as models of estimation of consequences or risks (Berube, 2011).

Unfortunately, in previous cases, such as the effects of asbestos on health, or the situation of genetically modified organisms in Europe, they have meant a public rejection of the technology (Barakat & Jiao, 2010). Larrere (2010) had already visualized that much of the discourse focuses on the concepts of security and justice. However, without downplaying the need for nanotechnology to prove its safety, and not affecting the possibility that people have access to it, the reflection must go beyond these moral aspects.

It is essential to understand that nanoscience is still at a very early stage of its development, and it is impossible to predict all the possible ethical issues that will need to be addressed at the different levels of related bioethics committees (van de Poel, 2008). Discussions and examples can demonstrate how ethical compromises derived from the use of nanotechnology should relate to the well-being of people (Stapleton, 2014). For this reason, there is a need to find and propose methods to discern ethical aspects involved in nanotechnological development. However, honest reflection in this area does not require new principles but demands the application of the ethical tenets to new domains.

Undoubtedly, the precepts enunciated in the Universal Declaration on Bioethics and Human Rights of UNESCO (2005), referring to the 15 principles of bioethics, indicate that the obligation to be a fundamental aspect in evaluating the implications of nanotechnology development prevails. In this regard, it should be noted that, regardless of the novelty presented by this type of research, respect for human dignity and human rights, harmful benefits and effects, respect for autonomy and individual responsibility, informed consent, respect for human vulnerability, privacy, and confidentiality, equality, justice and equity, non-discrimination, about cultural diversity, solidarity, social responsibility and health, sharing of benefits, protection of future generations and protection of the environment, remain a priority.

NANOTECHNOLOGY AS AN ASPIRATION TO ACHIEVE SOCIAL JUSTICE

Justice is a concept required to maintain social order and prevent the disintegration of communities, meeting their primary needs, such as the right to health care (León Correa, 2009; Siurana Aparisi, 2010). The Universal Declaration on Bioethics and Human Rights, in its articles 4 and 15, enunciates the need for the benefits of scientific research to be shared with the society of all countries, emphasizing that applications also occur in developing countries (unesco, 2005). For unesco (2012), "social justice is based on equal rights for all peoples and access to the benefits of social and economic progress for all, without discrimination." In this sense, it is therefore essential to address what has been the role of nanotechnology in promoting these long-awaited benefits among nations.

From a research point of view, there are uneven efforts between countries. For example, in 2005, 4,605 researchers per million inhabitants and 244 patents had been reported in the United States, while in Mexico those figures were 268 researchers and one patent, or in India 119 researchers and one patent (Kay & Shapira, 2009). From the regional point of view, it is important to mention that it is considered that Latin America, Brazil, Mexico, and Argentina are the countries that have most promoted the development of nanotechnologies in this continent, with contributions in infrastructure and scientific articles (Foladori, 2013).

At a global level, the resources and creativity of researchers are channeled to develop new applications of nanometric devices and materials. Table 1 summarizes some of the outstanding applications in industrial sectors. Different consumer products employ interfaces at the nanoscale, such as water-repellent materials, fire retardants, and UV protection. Society and individuals have benefited in many ways from them. In this way, the intellectual protection developed in the different countries ranges from applications for the treatment of diseases to support devices in natural disasters (O'Mathúna, 2007). In this sense, Richard Smalley, a Nobel Prize-winning scientist, considered that nanotechnology would play an important role in creating sufficient energy to mitigate population demand (Roco & Bainbridge, 2007). That is, it would allow democratic access to the benefits of technology (Berne, 2004).

However, in countries such as Brazil, nanotechnology has been promoted by scientific elites as a means of progress, efficiency, and competitiveness but poor communities do not appreciate its benefits, and critics argue that it has only contributed to increasing economic and social inequalities in the country (Kay & Shapira, 2009).

Table 1

Applications of nanotechnology in different manufacturing sectors

Sector	Technology	Example	Source
Medical	Diagnosis and controlled delivery systems of drugs and biosensors	Diagnosis and drug delivery systems and strategies based on polymeric, inorganic, lipid-based, hydrogel-based nanoparticles or stem and gene cell-based therapy, etc.)	(Chaichi, Sheikh, Mukhopadhyay, & Gartia, 2021; Dong et al., 2021; Huang, Qiu, Zhang, & Tan, 2021; Maddu, 2021; Wang, Rahimi, & Filgueira, 2021; Zhao et al., 2021)
Agricultural	Diagnosis and controlled release of pesticides and micronutrients	Diagnosis and treatment of diseases, delivery of pesticides, micronutrients, fertilizers, etc.	(Acharya & Pal, 2020; Salama, Abd El-Aziz, Rizk, & Abd Elwahed, 2021)
Food	Additives and nutraceuticals/sensors for the detection of toxic or pathogenic substances/packaging	Nano-additives, nutraceutical delivery systems, hazardous substances and pathogens detection, smart and biodegradable packaging, etc.	(Alfei, Marengo, & Zuccari, 2020; He, Deng, & Hwang, 2019; Krishna et al., 2018; Rodríguez-Ramos, Santana-Mayor, Socas-Rodríguez, & Rodríguez-Delgado, 2021; Sahani & Sharma, 2021)
Petroleum	Nanorobots and nanosensors/product storage structures	Nanosensors, nanorobots, and nanoreporters in various reservoir exploration and characterization fields, including hydrocarbon detection, flood front monitoring, and subsurface gas detection and monitoring. Fuel storage structures with silica nanoparticles in cement for adequate insulation.	(Kumar & Foroozesh, 2021; Maagi, Lupyana, & Jun, 2020)
Environmental	Water treatment and biofuel development	Membranes made with different materials with nanometric characteristics for water treatment. Use of nanometric materials to improve the process, generating more significant amounts of biofuels.	(Devi & Chaturvedi, 2021; Kumar Das, Prava Das, & Dash, 2021; Shukla, Anusha, Ramaiya, Lee, & Sadeq, 2021; Singha & Kumar Mishrab, 2020; Vasantha, Sharvari, Alfia, & Praveen, 2021)
Military	Weapons, fuels, and environmental sensors.	Layers to strengthen the hardness or softness of the surface. Nanoparticles as a fuel additive. Nanoparticles in weapons. Sensors to assess air quality in situations involving defense forces and emergency teams.	(Coyle & Diamond, 2010; Glenn, 2006; Umbrello & Baum, 2018)

Source: Own elaboration

From the perspective of its social relevance, it is vital to continue the discussion of the reasons why the legal framework of nanotechnology has not reached an agreement on the regulation of its use (Stapleton, 2014). Some ethical aspects have included opportunities in environment and health and the potential risk of nanoparticles, as well as in the privacy and control of threats arising from the use of nanodevices, the possibilities of treatment of human diseases, the ethical consequences in aspects of equity, global justice, distribution of benefits and risks, including ethical aspects for patients and ownership of rights (Van de Poel, 2008). Among the previous efforts, the declaration signed by more than one hundred organizations stands out, called Principles for the Oversight of Nanotechnologies and Nanomaterials, which delves into the need to apply reasonable doubt in products or processes that may pose a risk to health (Foladori, 2013). Although this effort is important, it, unfortunately, focuses on the risks and impacts of nanotechnology but does not establish any pertinent statements regarding the distribution of the benefits of applying it. That is, the benefits that different nanotechnological applications can bring to humanity cannot be denied, so their use should not be demonized, but it is also important to address certain issues that may affect fundamental rights or put lives at risk in general (Bennett-Woods, 2008). In this sense, some aspects have already been detected and published by different research entities. For example, in 2004 the journal Nature published the need for any nanomaterial produced to provide toxicity studies on any new nanomaterials (Stapleton, 2014).

Currently, this type of research is subject to such regulation in the main international agencies, such as the FDA in the United States, the Nanosafety Cluster (Nanosafety_Cluster, 2021), and the REACH and CLP legislations in Europe (European_Commission, 2021).

On the other hand, it may be surprising from the point of view of the principle of justice that unprecedented research in the nano can reach levels of manipulation of atoms in a tunneling microscope, but old diseases remain unsolved in poor countries. Global justice requires that nanotechnology research impact the income and health, not only of rich countries but also of the so-called Third World, where still 2.3 million people die from vaccine-preventable diseases (Hunt, 2008). Undoubtedly, the idea that diseases in developing countries where their problem has been shattered, among other things, by devastating diseases such as acquired immunodeficiency syndrome, acute respiratory syndrome, and the most recent and painful example, SARS-2-COV-19. However, even though the evidence shows that a nation's vulnerability to emerging viruses endangers the entire world, there are still no congruent actions that show that efforts will be global. Recently, nanotechnology has played a leading role in the development of at least three COVID-19 vaccines for use in humans, Pfizer/BioNTech, Moderna, and Novavax. However, technically the thermostability of this type of vaccine and the requirement of ultra-freezers has prevented its rapid distribution in low-income per capita countries. On the other hand, equity has also not been favored by the pre-orders of doses made by developed nations (Salamanca-Buentello & Daar, 2021)

Despite the above, there is no doubt that biotechnological advances will be key in the understanding of life and the use of its knowledge to benefit human beings (O'Mathúna, 2007). Applications of nano-level materials or devices have potential use in different scientific areas. In this regard, it is considered that drug delivery systems at the nanometer level will allow more efficient treatments. For example, in the field of medicine, many research projects are focusing on cancer treatments with the use of nanoparticles either for treatment, diagnosis, or theragnostically (Adach, *et al*., 2016; Chung, Kim, & Hong, 2020; Dinparvar, *et al*., 2020; Gorbet & Ranjan, 2020; Grall, *et al*., 2015; Indoria, Singh, & Hsieh, 2020; Miller, Samec, & Alexander-Bryant, 2021; Mohamed, Alqahtani, Ahmad, Krishnaraju, & Kalpana, 2021; Shim, *et al*., 2020). In this way, different approaches including nanoparticles are used to potentiate the effect of drugs on cancer cells (Grall, *et al*., 2015; Miller, *et al*., 2021; Shim, *et al*., 2020), of targeted therapy (Cerqueira, Lasham, Shelling, & Al-Kassas, 2017; Chung, *et al*., 2020; Ghorbani, Kokhaei, Ghorbani, & Eslami, 2020; Mohamed, *et al*., 2021; Nejabat, *et al*., 2020; Pang., *et al*., 2021; Shim, *et al*., 2020; Xu, *et al*., 2020; Zhang, 2015), immunotherapy (Wu, *et al*., 2020; Zhou, Li, Lee, & Xie, 2020) or particles that allow an adequate diagnosis (Adach, *et al*., 2016; Ghorbani, *et al*., 2020; Pavitra, *et al*., 2019). However, the bioethical principles that allow the development of research with living beings must remain the same, focusing on informed consent, risk management, and the protection of vulnerable populations (Conti, Satterfield, & Harthorn, 2011; Cunha & Garrafa, 2016; Laudisio, *et al*., 2020; ten Have, 2015; van de Poel, 2008). Likewise, the idea of justice must be very relevant when analyzing how these technological benefits are distributed, giving them mainly the possibility of accessing them to the populations of rich countries and leaving aside poor countries. In this sense, the contrasts are alarming, since in 2003 it was reported that, while people in developed countries had a life expectancy of 80 years, in some African countries it was 30 years (O'Mathúna, 2007).

NANOTECHNOLOGY'S RISK SEEN FROM PUBLIC POLICIES

Nanoscale science has associated uncertainty due to the possible evolution and potential of novel properties of nanomaterials, which from the point of view of public policies must include new ways of participation in decision-making, along with approaches to risk management (Groves, 2009). This approach should visualize the concept of autonomy, the military uses of these materials, and health hazards (Barakat & Jiao, 2010). Unfortunately, much of the governments' decisions are developed under a scheme of ignorance of the dangers and benefits of this type of technology.

Although nanomaterials are being widely used in products for daily living, little is known about public opinion on the subject (Joubert, *et al.*, 2020). Although cultural and demographic aspects are determinants in the perception of the benefit of nanotechnology, this idea does not imply that the risks are known, so an effort is necessary to ensure public policies that consider bioethical aspects related to the development of the same (Kamarulzaman, Lee, Siow, & Mokhtar, 2020).

Since 2000, the United States has developed a regulatory framework that contemplates the risks of nanotechnology, both in industry and in universities (Jung & Lee, 2014; Justo-Hanani & Dayan, 2015), because they consider it strategic for industrial competitiveness (Michelson, 2008; Motoyama, Appelbaum, & Parker, 2011). From the nanotechnological products' regulation and standardization's point of view, it is important to note that it is already contemplated by organizations such as ISO, IEC, and CEN (Soltani & Pouypouy, 2019). Despite not being official mechanisms, but competitiveness, regulations such as the ISO have filled the official regulatory vacuum in Latin American nations such as Mexico (Delgado-Ramos, 2014).

In the United Kingdom, relevant contributions have been made in this area. The instrument called Voluntary Reporting of Nanoscale Engineering Materials aims to stimulate the interest of both importers and those who manufacture them, to deliver data related to their toxicity and ecotoxicity (Wetmore & Posner, 2009). Similar efforts of non-mandatory actions have been developed through the Environmental Protection Agency in the United States, to understand the implications on environmental safety and health (Arnaldi, 2014).

On the other hand, when it comes to nanotechnology research, it is important to mention that the governments' expenditures such as the United States, Israel, and China, have been strongly focused on the development of the military industry. In the United States alone, between 2000 and 2004, 26% to 31% of federal funds were invested in nanotechnology for this sector (Stapleton, 2014). Under the protection that issues related to arms development are matters of national security, it is difficult for governments to disclose the possible impacts of the use of this technology on the populations where it could be used. In this way, in public policies, there is a preponderant focus on the benefits of using this technology to increase the military power of a nation, but the possible risk to the civilian population is not reported.

On the other hand, in many areas of knowledge generation, ethics impact the design of scientific experiments. Unfortunately, there is little research into the health and safety implications of using nanotechnologies in the workplace, even though workers and scientists are exposed to inhalation, dermal absorption, and ingestion of these substances (Saleh, 2020; Schulte & Salamanca-Buentello, 2007). In this sense, it had already been foreseen that the dimensions of ethical reflection in nanotechnologies can not only focus on the field of bioethics, but on ethics that allows students, engineers, and researchers to address it in any aspect of their activity (Barakat & Jiao, 2010). Although the use of nanomaterials in the field of work and research is carried out with the voluntary acceptance of risk, autonomy is compromised, given that both research and jobs are at stake (Kühnel, *et al*., 2019; Schulte & Salamanca-Buentello, 2007).

In this framework, any research with participating humans or animals must be reviewed and regulated (O'Mathúna, 2007). However, this is not a reality at all levels. In China, two projects have been developed with the interest of regulating the use of nanoparticles in research, such as the Toxicological Effects of Carbon Materials of 2004-2008 and the Impact of Ultrafine Particles on the Environment and Health of 2006-2010 (Dalton-Brown, 2012). Similarly, the Strategic Approach to International Chemicals Management, with a vision in nanotechnologies and the protection of human health and the environment (Foladori, 2013). For example, although it is true that when it is intended to carry out research *in vivo*, compliance with the corresponding bioethical permits and compliance with the regulatory framework is automatically requested in both companies and universities, in countries such as Mexico, within academic laboratories, no authority regulates the use of such particles with potential for damage, by penetrating the skin by contact or by the respiratory tract, not only to researchers but to their students. For example, even though some studies have shown that carbon nanotubes are toxic particles (Ahmadi, *et al*., 2017; Kunal Bhattacharya, Andon, El-Sayed, & Fadeel, 2013; K. Bhattacharya, *et al*., 2016; Ema, Gamo, & Honda, 2016; Harik, 2017; Zhu, *et al*., 2017) and that fullerenes show the risk of causing oxidative damage in the brain (Lenk & Biller-Andorno, 2007), mitochondrial damage (Yang, *et al*., 2016), DNA damage in human lung fibroblasts (Ershova, *et al*., 2016), etc., there are constant investigations with this type of particles inside universities without being regulated or with strict safety measures.

Another aspect that must be considered is that nanotechnologies on an industrial scale consume thousands of tons of cubic meters of resources, so consumption must be regulated from the point of view of sustainability, as well as in the abundance of non-reusable garbage they can generate (Have, 2007). One of the dangers is the final disposal of the products when their life span ends, generating a high environmental impact. For example, digital garbage dumps with a high impact on health and the environment have been carried out in Ghana (Stapleton, 2014).

Finally, it should be noted that one of the greatest effects of nanotechnology takes place in the fields of biology, biotechnology, and nanomedicine (Bawa & Johnson, 2009), concerning basic human rights issues, where there are also inherent risks to evaluate. One of its applications is in tissue engineering and regenerative medicine (Danie Kingsley, Ranjan, Dasgupta, & Saha, 2013; du Toit, Kumar, Choonara, & Pillay, 2018; Hasan, *et al*., 2016; Shakhkumar, 2015). In this area, it is pertinent to question what natural functions and mechanisms of the human body are genuinely human qualities, particularly when there is the transfer of non-human organs to patients. This implies that innovations in nanotechnology medicine can intervene in our idea of human identity, since devices that radically change our definition of the human being can be used, through the implantation or transfusion of small particles (Lenk & Biller-Andorno, 2007). They can even go further with diagnostic nanodevices that have the potential in the near future to be able to identify abnormalities at a cellular level, which could imply a person's predisposition to suffer from a disease (Bawa & Johnson, 2009), and therefore the risks of discrimination that this means.

FINAL THOUGHTS

The need for a bioethical assessment of emerging technologies requires considering different approaches. One of those that could be used would be based on the heuristics of fear from Hans Jonas. In agreement with this philosopher, in the Age of Technology, the range of consequences of human actions are broader than the traditional ethical approaches proposed (van de Poel, 2008). On the other hand, Habermas focuses on collective responsibility as an imperative for analyzing emerging technologies (Zullo, 2014). In this sense, Habermas' idea of not being able to decide for others and therefore minimizing the possible risk is highlighted but maximizing the freedom of research and experimentation. This contrasts with other positions of researchers who highlight the precautionary principle considering the moral duty to assign risks to the use of nanotechnology vs the personal freedom to use economic resources for the development of devices or nanomaterials for advanced treatments of diseases (Boisseau & Loubaton, 2011).

However, approaches seem to be more situated in the framework of potential risks, than in the certainty that they exist. One of the previously proposed approaches to discern ethical aspects was proposed by Brune, highlighting the search for literature on ethics and nanotechnology, to subsequently evaluate the material and review if there are ethical aspects not included in the regulatory frameworks. In the end, it is proposed to identify the possible differences between what has been reported and current research schemes (Van de Poel, 2008).

As can be seen in this proposal, there is no focus on the local analysis of small investigations within the laboratories of companies and universities, but on the publications and the risks reported by them (Brune, 2010). However, the allocation of short- and long-term risks from the use and research of nanoparticles remains relevant.

It is for this reason that, in the absence of properly developed criteria for the ethical analysis of this technology, it must be recognized that the principles of bioethics must be used for the reflection and discussion of the new dilemmas arising from this type of research. Given the benefits and dangers involved in the use of nanotechnology, researchers have a moral duty to influence so that the national and international regulatory framework does not limit the development of scientific progress. However, they must also ensure that such progress does not undermine the security of human beings and the planet at large.

REFERENCES

Acharya, A., & Pal, P. K. (2020). Agriculture nanotechnology: Translating research outcome to field applications by influencing environmental sustainability. *NanoImpact, 19*, 100232. doi: https://doi.org/10.1016/j.impact.2020.100232

Adach, K., Fijalkowski, M., Gajek, G., Skolimowski, J., Kontek, R., & Blaszczyk, A. (2016). Studies on the cytotoxicity of diamond nanoparticles against human cancer cells and lymphocytes. *Chem Biol Interact, 254*, 156-166. doi: https://doi.org/10.1016/j.cbi.2016.06.004

Ahmadi, H., Ramezani, M., Yazdian-Robati, R., Behnam, B., Razavi Azarkhiavi, K., Hashem Nia, A., Abnous, K. (2017). Acute toxicity of functionalized single wall carbon nanotubes: A biochemical, histopathologic and proteomics approach. *Chemico-Biological Interactions, 275* (Supplement C), 196-209. doi: https://doi.org/10.1016/j.cbi.2017.08.004

Alfei, S., Marengo, B., & Zuccari, G. (2020). Nanotechnology application in food packaging: A plethora of opportunities versus pending risks assessment and public concerns. *Food Research International, 137*, 109664. doi: https://doi.org/10.1016/j.foodres.2020.109664

Amato, I. & Carroll, L. (1999). *Nanotechnology: shaping the world atom by atom*. National Science and Technology Council, Committee on Technology.

Arnaldi, S. (2014). Introduction: Nanotechonologies and the quest for responsability. In S. Arnaldi, Ferrari, A., Magaudda, P., Marin. F. (Ed.), *Responsability in nanotechnology development*. New Yoirk: Springer Science.

Barakat, N., & Jiao, H. (2010). Proposed Strategies for Teaching Ethics of Nanotechnology. *NanoEthics, 4*(3), 221-228. doi: https://doi.org/10.1007/s11569-010-0100-0

Bawa, R., & Johnson, S. (2007). The Ethical Dimensions of Nanomedicine. *Medical Clinics of North America, 91*(5), 881-887. doi:https://doi.org/10.1016/j.mcna.2007.05.007

Bawa, R., & Johnson, S. (2009). Emerging issues in nanomedicine and ethics. In *Nanotechnology & Society* (pp. 207-223): Springer.

Bennett-Woods, D. (2008). *Nanotechnology. Ethics and society.* Boca Raton, FL: CRC Press.

Berne, R. W. (2004). Towards the conscientious development of ethical nanotechnology. *Science and Engineering Ethics, 10*(4), 627-638.

Berne, R. W., & Schummer, J. (2005). Teaching societal and ethical implications of nanotechnology to engineering students through science fiction. *Bulletin of Science, Technology & Society, 25*(6), 459-468.

Berube, D. (2011). Decision ethics and emergent technologies: The case of nanotechnology. *European Journal of Law and Technology, 2*(3).

Bhattacharya, K., Andón, F. T., El-Sayed, R., & Fadeel, B. (2013). Mechanisms of carbon nanotube-induced toxicity: Focus on pulmonary inflammation. *Adv Drug Deliv Rev, 65*(15), 2087-2097. doi:https://doi.org/10.1016/j.addr.2013.05.012

Bhattacharya, K., Mukherjee, S. P., Gallud, A., Burkert, S. C., Bistarelli, S., Bellucci, S., Fadeel, B. (2016). Biological interactions of carbon-based nanomaterials: From coronation to degradation. *Nanomedicine, 12*(2), 333-351. doi:10.1016/j.nano.2015.11.011

Boisseau, P., & Loubaton, B. (2011). Nanomedicine, nanotechnology in medicine. *Comptes Rendus Physique, 12*(7), 620-636. doi:10.1016/j.crhy.2011.06.001

Brune, H., Ernst, H., Grunwald, A., Grünwald, W., Hofman, H., Krug, H., Janich, P., Mayor, M., Rathgeber, W., Schmid, G., SImon, U., Vogel, V., Wuyrwa, D. (2010). *Nanotechnology. Assessment and Perspectives*. Germany: Springer.

Castro, J. (2016). Ética y bioética: límites y alcances. *Revista de bioética latinoamericana, 17*, 75-96.

Cerqueira, B. B. S., Lasham, A., Shelling, A. N., & Al-Kassas, R. (2017). Development of biodegradable PLGA nanoparticles surface engineered with hyaluronic acid for targeted delivery of paclitaxel to triple negative breast cancer cells. *Mater Sci Eng C Mater Biol Appl, 76*, 593-600. doi: https://doi.org/10.1016/j.msec.2017.03.121

Chaichi, A., Sheikh, E., Mukhopadhyay, S., & Gartia, M. R. (2021). Trends in Nanotechnology Development in Medical Applications. In *Reference Module in Materials Science and Materials Engineering*: Elsevier.

Chung, H.-J., Kim, H.-J., & Hong, S.-T. (2020). Tumor-specific delivery of a paclitaxel-loading HSA-haemin nanoparticle for cancer treatment. *Nanomedicine: Nanotechnology, Biology and Medicine, 23*, 102089. doi: https://doi.org/10.1016/j.nano.2019.102089

Conti, J., Satterfield, T., & Harthorn, B. H. (2011). Vulnerability and social justice as factors in emergent U.S. nanotechnology risk perceptions. *Risk Anal, 31*(11), 1734-1748. doi: https://doi.org/10.1111/j.1539-6924.2011.01608.x

Coyle, S., & Diamond, D. (2010). Smart nanotextiles: materials and their application.

Cunha, T., & Garrafa, V. (2016). Vulnerability. *Camb Q Healthc Ethics, 25*(2), 197-208. doi: https://doi.org/10.1017/S096318011500050X

Dalton -Brown, S. (2012). Global Ethics and Nanotechnology: A Comparison of the Nanoethics Environments of the EU and China. *NanoEthics, 6*(2), 137-150. doi: https://doi.org/10.1007/s11569-012-0146-2

Danie Kingsley, J., Ranjan, S., Dasgupta, N., & Saha, P. (2013). Nanotechnology for tissue engineering: Need, techniques and applications. *Journal of Pharmacy Research, 7*(2), 200-204. doi:https://doi.org/10.1016/j.jopr.2013.02.021

Delgado -Ramos, G. C. (2014). Nanotechnology in Mexico: Global trends and national implications for policy and regulatory issues. *Technology in Society, 37*, 4-15. doi: https://doi.org/10.1016/j.techsoc.2013.09.005

Devi, K. P., & Chaturvedi, H. (2021). Chapter 9 - An overview of nanotechnology in water treatment applications and combating climate change. In B. Thokchom, P. Qiu, P. Singh, & P. K. Iyer (Eds.), *Water Conservation in the Era of Global Climate Change* (pp. 191-212): Elsevier.

Dinparvar, S., Bagirova, M., Allahverdiyev, A. M., Abamor, E. S., Safarov, T., Aydogdu, M., & Aktas, D. (2020). A nanotechnology-based new approach in the treatment of breast cancer: Biosynthesized silver nanoparticles using Cuminum cyminum L. seed extract. *Journal of Photochemistry and Photobiology B: Biology, 208*, 111902. doi:https://doi.org/10.1016/j.jphotobiol.2020.111902

Dong, Y., Wu, X., Chen, X., Zhou, P., Xu, F., & Liang, W. (2021). Nanotechnology shaping stem cell therapy: Recent advances, application, challenges, and future outlook. *Biomedicine & Pharmacotherapy, 137*, 111236. doi: https://doi.org/10.1016/j.biopha.2021.111236

du Toit, L. C., Kumar, P., Choonara, Y. E., & Pillay, V. (2018). 10 - Use of nanostructured materials in hard tissue engineering A2 - Narayan, Roger. In *Nanobiomaterials* (pp. 257-295): Woodhead Publishing.

Ema, M., Gamo, M., & Honda, K. (2016). A review of toxicity studies of single-walled carbon nanotubes in laboratory animals. *Regulatory Toxicology and Pharmacology, 74*(Supplement C), 42-63. doi: https://doi.org/10.1016/j.yrtph.2015.11.015

Ershova, E. S., Sergeeva, V. A., Chausheva, A. I., Zheglo, D. G., Nikitina, V. A., Smirnova, T. D., . . . Kostyuk, S. V. (2016). Toxic and DNA damaging effects of a functionalized fullerene in human embryonic lung fibroblasts. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis, 805*, 46-57. doi: https://doi.org/10.1016/j.mrgentox.2016.05.004

Escobar López, M. T. (2012). Bioética mas allá del Principialismo. *Rev. latinoam. bioét*, 6-9.

European_Commission. (2021). Internal market, industry, entrepreneurshio and SME. Retrieved from https://ec.europa.eu/growth/sectors/chemicals/reach/nanomaterials_en

Ferrari, A. (2014). Responsability and visions in the new and emerging technologies. In S. Arnaldi, Ferrari, A., Magaudda, P., Marin. F. (Ed.), *Responsability in nanotechnology development*. New York: Springer Science

Feynman, R. (1959). Plenty of Room at the Bottom. Retrieved from https://web.pa.msu.edu/people/yang/RFeynman_plentySpace.pdf

Foladori, G., Bejarano, F., Invernizzi, N. (2013). Nanotecnología: gestión y reglamentación de riesgos para la salud y medio ambiente en América Latina y el Caribe. *Trab. Educ. Saúde, 11*(1), 145-167.

Ghorbani, F., Kokhaei, P., Ghorbani, M., & Eslami, M. (2020). Application of different nanoparticles in the diagnosis of colorectal cancer. *Gene Reports, 21,* 100896. doi: https://doi.org/10.1016/j.genrep.2020.100896

Glenn, J. C. (2006). Nanotechnology: Future military environmental health considerations. *Technological Forecasting and Social Change, 73*(2), 128-137. doi: https://doi.org/10.1016/j.techfore.2005.06.010

Gorbet, M.-J., & Ranjan, A. (2020). Cancer immunotherapy with immunoadjuvants, nanoparticles, and checkpoint inhibitors: Recent progress and challenges in treatment and tracking response to immunotherapy. *Pharmacology & Therapeutics, 207*, 107456. doi:https://doi.org/10.1016/j.pharmthera.2019.107456

Grall, R., Girard, H., Saad, L., Petit, T., Gesset, C., Combis-Schlumberger, M., . . . Chevillard, S. (2015). Impairing the radioresistance of cancer cells by hydrogenated nanodiamonds. *Biomaterials, 61,* 290-298. doi: https://doi.org/10.1016/j.biomaterials.2015.05.034

Groves, C. (2009). Nanotechnology, Contingency and Finitude. *NanoEthics, 3*(1), 1-16. doi: https://doi.org/10.1007/s11569-009-0057-z

Harik, V. M. (2017). Geometry of carbon nanotubes and mechanisms of phagocytosis and toxic effects. *Toxicology Letters, 273*(Supplement C), 69-85. doi: https://doi.org/10.1016/j.toxlet.2017.03.016

Hasan, A., Saliba, J., Pezeshgi Modarres, H., Bakhaty, A., Nasajpour, A., Mofrad, M. R. K., & Sanati-Nezhad, A. (2016). Micro and nanotechnologies in heart valve tissue engineering. *Biomaterials, 103*(Supplement C), 278-292. doi: https://doi.org/10.1016/j.biomaterials.2016.07.001

Have, H. (2007). *Nanotechnology, ethics and politics*. Paris France: UNESCO Publishing.

He, X., Deng, H., & Hwang, H.-m. (2019). The current application of nanotechnology in food and agriculture. *Journal of Food and Drug Analysis, 27*(1), 1-21. doi: https://doi.org/10.1016/j.jfda.2018.12.002

Huang, Z., Qiu, L., Zhang, T., & Tan, W. (2021). Integrating DNA Nanotechnology with Aptamers for Biological and Biomedical Applications. *Matter, 4*(2), 461-489. doi: https://doi.org/10.1016/j.matt.2020.11.002

Hunt, G. (2008). The global ethics of nanotechnology. In G. Hunt, Mehta, M. (Ed.), *Nanotechnology. Risk, ethics and law*. Taylor & Francis Group.

Indoria, S., Singh, V., & Hsieh, M.-F. (2020). Recent advances in theranostic polymeric nanoparticles for cancer treatment: A review. I*nternational Journal of Pharmaceutics, 582*, 119314. doi:https://doi.org/10.1016/j.ijpharm.2020.119314

Joubert, I. A., Geppert, M., Ess, S., Nestelbacher, R., Gadermaier, G., Duschl, A., . . . Himly, M. (2020). Public perception and knowledge on nanotechnology: A study based on a citizen science approach. *NanoImpact, 17,* 100201. doi: https://doi.org/10.1016/j.impact.2019.100201

Jung, H. J., & Lee, J. J. (2014). The impacts of science and technology policy interventions on university research: Evidence from the U.S. National Nanotechnology Initiative. *Research Policy, 43*(1), 74-91. doi: https://doi.org/10.1016/j.respol.2013.07.001

Justo -Hanani, R., & Dayan, T. (2015). European risk governance of nanotechnology: Explaining the emerging regulatory policy. *Research Policy, 44*(8), 1527-1536. doi: https://doi.org/10.1016/j.respol.2015.05.001

Kamarulzaman, N. A., Lee, K. E., Siow, K. S., & Mokhtar, M. (2020). Public benefit and risk perceptions of nanotechnology development: Psychological and sociological aspects. *Technology in Society, 62*, 101329. doi:https://doi.org/10.1016/j.techsoc.2020.101329

Kay, L., & Shapira, P. (2009). Developing nanotechnology in Latin America. *J Nanopart Res, 11*(2), 259-278. doi: https://doi.org/10.1007/s11051-008-9503-z

Khan, A. S. (2014). *Ethics and nanotechnology*. Paper presented at the 2014 IEEE International Symposium on Ethics in Science, Technology and Engineering.

Krishna, V. D., Wu, K., Su, D., Cheeran, M. C. J., Wang, J.-P., & Perez, A. (2018). Nanotechnology: Review of concepts and potential application of sensing platforms in food safety. *Food Microbiology, 75*, 47-54. doi: https://doi.org/10.1016/j.fm.2018.01.025

Kühnel, D., Nickel, C., Hellack, B., van der Zalm, E., Kussatz, C., Herrchen, M., . . . Hund-Rinke, K. (2019). Closing gaps for environmental risk screening of engineered nanomaterials. *NanoImpact, 15*, 100173. doi: https://doi.org/10.1016/j.impact.2019.100173

Kumar Das, P., Prava Das, B., & Dash, P. (2021). Chapter 16 - Application of nanotechnology in the production of bioenergy from algal biomass: opportunities and challenges. In R. P. Kumar & B. Bharathiraja (Eds.), *Nanomaterials* (pp. 355-377): Academic Press.

Kumar, S., & Foroozesh, J. (2021). Chapter 5 - Application of nanotechnology in hydrocarbon reservoir exploration and characterization. In W. Ahmed, M. Booth, & E. Nourafkan (Eds.), *Emerging Nanotechnologies for Renewable Energy* (pp. 115-134): Elsevier.

Larrere, C. (2010). Ethics and nanotechnology: The issue of perfectionism. *HYLE-International Journal for Philosophy of Chemistry, 16*(1), 19-30.

Laudisio, A., Giannotti, C., Chiarella, I., Spitaleri, D., Ballestrero, A., Odetti, P., . . . Monacelli, F. (2020). Social vulnerability is associated with increased mortality in older patients with cancer. *Journal of Geriatric Oncology*. doi: https://doi.org/10.1016/j.jgo.2020.09.018

Lenk, C., & Biller-Andorno, N. (2007). Nanomedicine-emerging or re-emerging ethical issues? A discussion of four ethical themes. *Med Health Care Philos, 10*(2), 173-184. doi: https://doi.org/10.1007/s11019-006-9014-6

León Correa, F. J. (2009). Principios para una bioética social. *Bioethikos, 3*(1), 18-25.

Maagi, M. T., Lupyana, S. D., & Jun, G. (2020). Nanotechnology in the petroleum industry: Focus on the use of nanosilica in oil-well cementing applications - A review. *Journal of Petroleum Science and Engineering, 193*, 107397. doi: https://doi.org/10.1016/j.petrol.2020.107397

Maddu, N. (2021). 9 - Nanoparticle mediated diagnosis of clinical biomarkers of different diseases: a medical application of nanotechnology. In S. C. B. Gopinath & F. Gang (Eds.), *Nanoparticles in Analytical and Medical Devices* (pp. 155-173): Elsevier.

Melchor -Alemán, M.-A., Mesta-Torres, L., & Martel-Estrada, S. A. (2016). Aplicaciones de nanopartículas en textiles para el diseño de interiores. *Espacio I+D: Innovación más Desarrollo, 5*(10). doi: https://doi.org/10.31644/IMASD.10.2016.a07

Michelson, E. S. (2008). Globalization at the nano frontier: The future of nanotechnology policy in the United States, China, and India. *Technology in Society, 30*(3), 405-410. doi: https://doi.org/10.1016/j.techsoc.2008.04.018

Miller, E. M., Samec, T. M., & Alexander-Bryant, A. A. (2021). Nanoparticle delivery systems to combat drug resistance in ovarian cancer. *Nanomedicine: Nanotechnology, Biology and Medicine, 31,* 102309. doi: https://doi.org/10.1016/j.nano.2020.102309

Mohamed, J. M., Alqahtani, A., Ahmad, F., Krishnaraju, V., & Kalpana, K. (2021). Pectin co-functionalized dual layered solid lipid nanoparticle made by soluble curcumin for the targeted potential treatment of colorectal cancer. *Carbohydrate Polymers, 252*, 117180. doi: https://doi.org/10.1016/j.carbpol.2020.117180

Motoyama, Y., Appelbaum, R., & Parker, R. (2011). The National Nanotechnology Initiative: Federal support for science and technology, or hidden industrial policy? *Technology in Society, 33*(1), 109-118. doi: https://doi.org/10.1016/j.techsoc.2011.03.010

Nanosafety_Cluster. (2021). Nanosafety Cluster. Retrieved from https://www.nanosafetycluster.eu/

Nejabat, M., Eisvand, F., Soltani, F., Alibolandi, M., Mohammad Taghdisi, S., Abnous, K., . . . Ramezani, M. (2020). Combination therapy using Smac peptide and doxorubicin-encapsulated MUC 1-targeted polymeric nanoparticles to sensitize cancer cells to chemotherapy: An in vitro and in vivo study. *International Journal of Pharmaceutics, 587*, 119650. doi: https://doi.org/10.1016/j.ijpharm.2020.119650

O'Mathúna, D. (2007). Bioethics and biotechnology. *Cytotechnology, 53*, 113-119.
Pang, Y., Su, L., Fu, Y., Jia, F., Zhang, C., Cao, X., . . . Qin, A. (2021). Inhibition of furin by bone targeting superparamagnetic iron oxide nanoparticles alleviated breast cancer bone metastasis. *Bioactive Materials, 6*(3), 712-720. doi: https://doi.org/10.1016/j.bioactmat.2020.09.006
Pavitra, E., Dariya, B., Srivani, G., Kang, S.-M., Alam, A., Sudhir, P.-R., . . . Huh, Y. S. (2019). Engineered nanoparticles for imaging and drug delivery in colorectal cancer. *Seminars in Cancer Biology*. doi: https://doi.org/10.1016/j.semcancer.2019.06.017
Roco, M. C., & Bainbridge, W. S. (2007). Nanotechnology. *Societal Implications- Individual Perspectives*. Dordrecht: Springer.
Rodríguez -Ramos, R., Santana-Mayor, Á., Socas-Rodríguez, B., & Rodríguez-Delgado, M. Á. (2021). Chapter 19 - Novel applications of nanotechnology in food safety assessment. In W. J. Lau, K. Faungnawakij, K. Piyachomkwan, & U. R. Ruktanonchai (Eds.), *Handbook of Nanotechnology Applications* (pp. 461-505): Elsevier.
Rogotneva, E. N., Melik-Haikazyan, I., & Goncharenko, M. (2015). Bioethics: Negotiation of Fundamental Differences in Russian and US Curricula. *Procedia - Social and Behavioral Sciences, 215*, 26-31. doi: https://doi.org/10.1016/j.sbspro.2015.11.569
Sahani, S., & Sharma, Y. C. (2021). Advancements in applications of nanotechnology in global food industry. *Food Chemistry, 342*, 128318. doi: https://doi.org/10.1016/j.foodchem.2020.128318
Salama, D. M., Abd El-Aziz, M. E., Rizk, F. A., & Abd Elwahed, M. S. A. (2021). Applications of nanotechnology on vegetable crops. *Chemosphere, 266*, 129026. doi: https://doi.org/10.1016/j.chemosphere.2020.129026
Salamanca -Buentello, F., & Daar, A. S. (2021). Nanotechnology, equity and global health. *Nature Nanotechnology, 16*(4), 358-361. doi: https://doi.org/10.1038/s41565-021-00899-z
Saleh, T. A. (2020). Trends in the sample preparation and analysis of nanomaterials as environmental contaminants. *Trends in Environmental Analytical Chemistry, 28*, e00101. doi: https://doi.org/10.1016/j.teac.2020.e00101
Schulte, P. A., & Salamanca-Buentello, F. (2007). Ethical and scientific issues of nanotechnology in the workplace. *Environ Health Perspect, 115*(1), 5-12. doi: https://doi.org/10.1289/ehp.9456
Shajkumar, A. (2015). Chapter 17 - Future of Nanotechnology in Tissue Engineering A2 - Thomas, Sabu. In Y. Grohens & N. Ninan (Eds.), *Nanotechnology Applications for Tissue Engineering* (pp. 289-306). Oxford: William Andrew Publishing.
Shim, M. K., Moon, Y., Yang, S., Kim, J., Cho, H., Lim, S., . . . Kim, K. (2020). Cancer-specific drug-drug nanoparticles of pro-apoptotic and cathepsin B-cleavable peptide-conjugated doxorubicin for drug-

resistant cancer therapy. *Biomaterials, 261*, 120347. doi: https://doi.org/10.1016/j.biomaterials.2020.120347

Shukla, S. K., Anusha, J., Ramaiya, H., Lee, J., & Sadeq, H. A. (2021). Chapter 7 - Application of nanotechnology in membrane-based wastewater treatment: a critical review. In M. P. Shah & S. Rodriguez-Couto (Eds.), *Membrane-Based Hybrid Processes for Wastewater Treatment* (pp. 119-145): Elsevier.

Singha, I., & Kumar Mishrab, P. (2020). Nano-membrane Filtration a Novel Application of Nanotechnology for Waste Water Treatment. *Materials Today: Proceedings, 29*, 327-332. doi: https://doi.org/10.1016/j.matpr.2020.07.284

Siurana Aparisi, J. C. (2010). Los principios de la bioética y el surgimiento de una bioética intercultural. *Veritas*, 121-157. http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-92732010000100006&nrm=iso

Soltani, A. M., & Pouypouy, H. (2019). Chapter 19 - Standardization and Regulations of Nanotechnology and Recent Government Policies Across the World on Nanomaterials. In M. Ghorbanpour & S. H. Wani (Eds.), *Advances in Phytonanotechnology* (pp. 419-446): Academic Press.

Stapleton, A., Cintora, A., De Anda,C., Fitzgibbon, M. (2014). How can Science Produce Unequal Relationships: The Nanotechnology Metaphor. *Proceedings of the 19th World Congress. The International Federation of Automatic Control*, 11431-11436.

ten Have, H. (2015). Respect for Human Vulnerability: The Emergence of a New Principle in Bioethics. *J Bioeth Inq, 12*(3), 395-408. doi: https://doi.org/10.1007/s11673-015-9641-9

Umbrello, S., & Baum, S. D. (2018). Evaluating future nanotechnology: The net societal impacts of atomically precise manufacturing. *Futures, 100*, 63-73. doi: https://doi.org/10.1016/j.futures.2018.04.007

UNESCO. (2005). Declaración universal sobre Bioética y Derechos Humanos. Retrieved from http://portal.unesco.org/es/ev.php-URL_ID=31058&URL_DO=DO_TOPIC&URL_SECTION=201.html

UNESCO. (2012). El día de la justicia social. Retrieved from http://www.unesco.org/new/es/media-services/single-view/news/world_day_of_social_justice/

van de Poel, I. (2008). How Should We Do Nanoethics? A Network Approach for Discerning Ethical Issues in Nanotechnology. *NanoEthics, 2*(1), 25-38. doi: https://doi.org/10.1007/s11569-008-0026-y

Vasantha, V. L., Sharvari, S., Alfia, N. S., & Praveen, N. (2021). Chapter 22 - Application of nanotechnology toward improved production of sustainable bioenergy. In R. P. Kumar & B. Bharathiraja (Eds.), *Nanomaterials* (pp. 445-479): Academic Press.

Wang, D. K., Rahimi, M., & Filgueira, C. S. (2021). Nanotechnology applications for cardiovascular disease treatment: Current and future perspectives. Nanomedicine: *Nanotechnology, Biology and Medicine, 34*, 102387. doi: https://doi.org/10.1016/j.nano.2021.102387

Wetmore, J. M., & Posner, J. D. (2009). Should corporations contribute to nano-regulation? *Nano Today, 4*(3), 217-219. doi: https://doi.org/10.1016/j.nantod.2009.03.002

Wu, D., Shou, X., Zhang, Y., Li, Z., Wu, G., Wu, D., . . . Wang, S. (2020). Cell membrane-encapsulated magnetic nanoparticles for enhancing natural killer cell-mediated Cancer immunotherapy. *Nanomedicine: Nanotechnology, Biology and Medicine*, 102333. doi: https://doi.org/10.1016/j.nano.2020.102333

Xu, X., Li, L., Li, X., Tao, D., Zhang, P., & Gong, J. (2020). Aptamer-protamine-siRNA nanoparticles in targeted therapy of ErbB3 positive breast cancer cells. *International Journal of Pharmaceutics*, 590, 119963. doi: https://doi.org/10.1016/j.ijpharm.2020.119963

Yang, L.-Y., Gao, J.-L., Gao, T., Dong, P., Ma, L., Jiang, F.-L., & Liu, Y. (2016). Toxicity of polyhydroxylated fullerene to mitochondria. *J Hazard Mater, 301*(Supplement C), 119-126. doi: https://doi.org/10.1016/j.jhazmat.2015.08.046

Zhang, T., Cui, H., Fang, C. Y., Cheng, K., Yang, X., Chang, H. C., & Forrest, M. L. (2015). Targeted nanodiamonds as phenotype-specific photoacoustic contrast agents for breast cancer. *Nanomedicine, 10*(4), 573-587. doi: https://doi.org/10.2217/nnm.14.141

Zhao, Y., Pu, M., Wang, Y., Yu, L., Song, X., & He, Z. (2021). Application of nanotechnology in acute kidney injury: From diagnosis to therapeutic implications. *Journal of Controlled Release, 336*, 233-251. doi: https://doi.org/10.1016/j.jconrel.2021.06.026

Zhou, S., Li, D., Lee, C., & Xie, J. (2020). Nanoparticle Phototherapy in the Era of Cancer Immunotherapy. *Trends in Chemistry*. doi: https://doi.org/10.1016/j.trechm.2020.09.008

Zhu, S., Luo, F., Tu, X., Chen, W.-C., Zhu, B., & Wang, G.-X. (2017). Developmental toxicity of oxidized multi-walled carbon nanotubes on Artemia salina cysts and larvae: Uptake, accumulation, excretion and toxic responses. *Environmental Pollution, 229*(Supplement C), 679-687. doi: https://doi.org/10.1016/j.envpol.2017.07.020

Zullo, S. (2014). Features of intergenerational moral responsability in the age of the emerging technologies. In S. Arnaldi, Ferrari, A., Magaudda, P., Marin. F. (Ed.), *Responsability in nanotechnology development*. New York: Springer Science.