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Mega-Sized Concerns from the Nano-Sized World: The Intersection of Nano- and Environmental Ethics

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Abstract As rapid advances in nanotechnology are made, we must set guidelines to balance the interests of both human beneficiaries and the environment by combining nanoethics and environmental ethics. In this paper, I reject Leopoldian holism as a practical environmental ethic with which to gauge nanotechnologies because, as a nonanthropocentric ethic, it does not value the humans who will actually use the ethic. Weak anthropocentrism is suggested as a reasonable alternative to ethics without a substantial human interest, as it treats nonhuman interests as human interests. I also establish the precautionary principle as a useful situational guideline for decisionmakers. Finally, I examine existing and potential applications of nanotechnology, including water purification, agriculture, mining, energy, and pollutant removal, from the perspective of weak anthropocentrism using the precautionary principle.

Keywords Nanotechnology · Environment · Anthropocentrism · Aldo Leopold · Precautionary principle

Introduction

Few developing sciences engage the imagination more than nanotechnology. The United States' National Nanotechnology Initiative (NNI) (2012) goes so far as to claim that nanotechnology is "the Next Industrial Revolution" (Shew 2008, p. 139). As with other developing technologies such as artificial intelligence and biotechnology, the excitement of nanotechnology's potential is tempered by serious alarm. The possible negative effects of nanotechnology on the environment are particularly

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concerning. However, most environmental analyses of nanotechnology are anthropocentric—that is, they study how an environment that was negatively influenced by nanotechnology would affect humans (Powers 2008, p. 109). What seems to be lacking from the literature of both the ethics of nanotechnology, or "nanoethics", and environmental ethics is a consensus as to a realistic merger of the two fields to promote the shared interests of nanotechnologists, the environment, and society as a whole. This fragmentation not only limits the safe deployment of promising nanotechnologies but also poses great risk to both humans and the environment. In this paper, I give an argument for weak anthropocentrism as an appropriate and practical environmental ethic through which to view nanotechnology; I also examine different existing and potential nanotechnologies through the ethical lens of weak anthropocentrism to show how this view would promote the relevant interests mentioned above.

Background: Nanotechnology and Nanoethics

Although regulatory bodies are working to establish a universal definition of nanotechnology (Lövestam et al. 2010), nanotechnology is generally considered to be "science, engineering, and technology conducted at the nanoscale, which is about 1–100 nm" (National Nanotechnology Initiative). Nanotechnology differentiates itself from other technologies in both its unprecedented small scale and the novel properties that nanomaterials exhibit from their bulk properties.

The excitement around nanotechnology stems from both the wide range and deep impact of its potential applications. The likely uses of nanotechnology vary widely, including solar cell units and hydrogen-gas catalysts, water purification systems, devices for human health such as localized drug delivery and organ monitoring, computers with unprecedented processing and communications speeds, materials with high strength and low density, and, importantly in this environmental context, filters and sensors for pollutant elimination and detection (Foresight Nanotech Institute 2005; Peterson and Heller 2007). If successfully developed, many of these applications will greatly surpass older technologies in performance. The United States recognized the far-reaching implications of nanotechnology and, beginning in 2001, invested $18 billion into the National Nanotechnology Initiative, a consortium of multiple federal agencies dedicated to nanotechnology research (National Nanotechnology Initiative). Clearly, nanotechnology has an extraordinary capacity to significantly impact the modern world.

From its start, the incredible potential of nanotechnology has induced reactions ranging from undulating support to harsh criticism. Drexler (1986), an early innovator in nanotechnology, theorized that self-replicating "nanobots" could outcompete natural life forms for Earth's limited resources in what was dubbed the "gray goo" scenario (172). Much of the nanotechnology-related hyperbole in popular opinion and the media today are due to the ideas of two widely respected critical thinkers on the topics of technology and futurism, Joy (2007) and Kurzweil (2007). Joy considers dystopian scenarios of self-replicating nanorobots, totalitarian technology-abusing regimes, and human lives rendered meaningless in the face of superior technologies; he warns of the need to limit science to prevent "the danger that things will move too fast" (32). Kurzweil, on the other hand, preaches the merits of nanotechnology-enabled virtual reality and other futuristic life-enhancing technologies (44–45). Both raise important ethical concerns of technology in general and nanotechnology in particular. However, while the consideration of extreme-case scenarios is important, it can both distort public opinion and distract from less dire but immediate issues in nanotechnology.

More even-tempered discussions on nanotechnology are found in the works of nanoethicists, the number of which proliferated in tandem with the rise of nanotechnology. Allhoff (2008), one of the foremost experts in the field of nanoethics, maintains a sober outlook on his field. He concedes that nanotechnology is not a revolutionary technology, claiming, "[the change brought about by a technology for it to be considered revolutionary] has to be sufficient to warrant a reconception of some basic premises, be they conceptual, normative, or otherwise…there is sufficient doubt as to whether [nanotechnology] satisfies [this criterion]" (26–27). He compares the exponential growth of the number of transistors on a computer chip to the linear increase in tensile strength of nanomaterials; these gains are modest by comparison (23–28). As a result, Allhoff believes nanoethics does not require a revolutionary ethic.

Allhoff's view is promising, because all budding nanotechnologies are improved versions of previous technologies (as opposed to completely new developments). While unparalleled advances in nanotechnology are undoubtedly possible, nanotechnology does not fundamentally constitute a new technology. Unlike artificial intelligence and biotechnology, for example, nanotechnology does not force us to reexamine our definition of life unless coupled with either of these technologies in fanciful scenarios. Nanotechnology is not morally problematic beyond the problems associated with technology in general. This conclusion allows us to broaden our approach to analyzing the effects of nanotechnology on the environment to those of other technologies.

Finding an Appropriate Environmental Ethic

Given the growing reach of nanotechnology, how should we reconcile the interests of nanotechnologists and the environment? I now consider traditional environmental ethics with which nanoethics can be practically extended to include environmental considerations. One reason for emphasizing a "practical" approach is that the probability of nanotechnologists, including consumers, rejecting nanotechnology on environmental grounds is close to zero. The theoretical framework that we choose should be based on its ability to be used by those in a decision-making capacity (i.e., government officials, business executives, and researchers) to reasonably balance the promise of nanotechnology with potential environmental harm, given the overwhelming likelihood that nanotechnologies will continue to find their way into the marketplace.

The study of environmental ethics is centered on a number of theoretical positions, most notably anthropocentrism, consequentialism/deontology, and individualism/holism (Palmer 2003, pp. 18–25). I am primarily interested in anthropocentrism due to its ambiguous conclusions as to technology and the environment. On the other hand, consequentialism and holism clearly have “looser standards” in terms of environmental protection than deontology and individualism. Anthropocentrism alone balances environmental protection and other human interests, since for many humans, a clean environment is an important interest. Deontology and individualism, the two “restrictive” ethical categories, are certainly useful in certain contexts; however, they immediately strike me as limiting, almost Ludditic, to the point of irrelevance for this discussion. I will first investigate a consequentialist, holistic, nonanthropocentric environmental ethic, Aldo Leopold’s “Land Ethic”, for suitability as a pragmatic environmental ethic and then consider an anthropocentric ethic.

Leopold (2003) articulates the “Land Ethic” in his book *A Sand County Almanac*, widely considered to be one of environmental ethics’ seminal works. Leopold stresses that humans should extend their conception of community to not only include other humans but also “the land”—that is, all components of the planet’s natural order, including nonhuman animals; subsequently, we should make decisions that consider the interests of all members of the land community (42–43). Although one might guess that this extended conception is rooted in Bentham’s utilitarianism,[1] it originates from thinking of Earth’s living and nonliving constituents as having developed “modes of cooperation”, or “symbioses” (38). The entire biosphere, including humans, benefits from a healthily functioning whole, which is strongly dependent on humans taking no more than their fair share.

The “Land Ethic” is surely an appealing environmental ethic; the question now becomes whether the perspective of Leopold is a suitable means through which to consider the problems of nanotechnology. Powers (2008) answers this question positively and concludes, “At most, what the environmental holist advocates is that any technology be limited by considerations of the health of the land” (p. 122). However, Palmer notes that “Owing…to the unsystematic nature of Leopold’s writing, there has been some discussion amongst environmental ethicists about how best to interpret Leopold’s ideas” (24). With this in mind, I will reexamine Powers’ belief that Leopold’s holism might be accepting of nanotechnology’s environmental applications.

Powers claims: “If …the only engineered nanoparticles that are released in abundance into the environment are deemed harmless [to the environment], then no objection from the point of view of the holist would be forthcoming” (121). Under a hypothetical scenario in which nanoparticles have an unquestionably insignificant effect on the environment, Leopold might not object. However, a number of passages in “The Land Ethic” indicate Leopold might have had a less open embrace of nanotechnology that, in my opinion, goes beyond rhetoric. Many, including Palmer (24), take the crux of Leopold’s arguments to be his statement that, “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise” (The Land Ethic 46).

[1] Bentham’s famous definition of sentience is found in *An Introduction to the Principles of Morals and Legislation*: “the question is not, Can they *reason*? nor, Can they *talk*? but, Can they *suffer*?”

At the very least, the release of effectively neutral nanoparticles into the environment fails to meet Leopold's standard entropically.[2] The stability of a dilute mixture, such as water and a pollutant, increases with decreasing concentration of the dilute species, meaning that the energy required to extract the pollutant becomes infinite as the pollutant concentration approaches zero. In other words, the mixture can never be fully restored to its original state of purity, no matter the intensity of the effort. This principle is certainly troublesome for conventional pollutants, let alone nanoparticles. Since small particles reach high concentrations easily, the entropic contributions to the energy required for separation are magnified. Even "harmless" nanoparticles violate the integrity of the land in this way, at least in principle.

In general, nonanthropocentric ethical views on technology, by definition, shift the focus of value from solely humans to all forms of life and their various environments. However, most, if not all, technology is *inherently* anthropocentric—the beneficiaries of technology are almost always humans at the expense of nonhuman life and the environment. Technology facilitates human consumption of natural resources above what is required for sustenance, which contravenes nonanthropocentric principles. Nonanthropocentric ethics would either discourage or strictly forbid technologies that promote one species over its fellow community members.

Even "green" technologies enable consumption; although they have a relative positive effect on the environment, they have an actual, absolute negative environmental impact. Hybrid and electric vehicles still produce emissions, solely for the benefit of humans. In fact, green technologies sometimes even have a relative negative effect due to a phenomenon termed the Jevons effect (or the rebound effect). Jevons theorized that as energy efficiency increases, people consume more total energy than before because it costs less (Owen 2010). One economist (Saunders 1992) extended this idea to include secondary rebound effects—that is, more energy use leads to a higher level of general prosperity on the macroeconomic level, which in turn increases total energy consumption. Thus, even green technologies may not be condoned by nonanthropocentric environmental ethics.

The critical point to note, however, is that our planet has entered the anthropocene, or the age of human dominance over Earth (Powers 119). As a result, technology is here to stay. In the anthropocene, "We currently have no choice but to continue to look to technological progress to help ameliorate our most pressing difficulties…We are dependent for our existence on technology" (Jones 2007). I propose that considering nonanthropocentric views of a novel technology after it has been institutionalized is not effective. Environmental holism and other environmental ethics are certainly theoretically sound and useful ethics of personal conduct. However, I contend that they are not practical ethics for examining new

[2] The concept of entropy arises from thermodynamics. Although commonly defined as "disorder", entropy is better understood as nature's tendency towards, or desire to achieve, complete uniformity through the dispersion of energy. The free energy of a system, which is inversely related to its stability, of a dilute mixture is proportional to the logarithm of the concentration of the dilute species; thus the stability increases as this concentration approaches zero.

technologies because the inherent value discrepancy between nanotechnologies and technology almost always prejudices against technology. Technology primarily values humans (at least, in the case of weaponry, values *some* humans), while nonanthropocentrism, by definition, does not.

Anthropocentric ethics, on the other hand, do value humans. One subethic among anthropocentric environmental ethics, weak anthropocentrism, appears to be a reasonable filter to evaluate nanotechnologies. Weak anthropocentrism is rooted in the holistic tradition (Norton 2003, 273). Palmer describes the anthem of weak anthropocentrism as "concern for the protection of the resource base through indefinite time" (18). I believe the maxim of resource management is a reasonable guideline for anthropocentric agents balancing the interests of their human constituents and the environment. For better or for worse, weak anthropocentrism is better aligned with most humans' attitudes on nature (at least in the developed world)—they are interested in preserving nature not for its own sake, but for their own. Weak anthropocentrists still investigate possible sources of environmental harm before condoning a new technology; however, their justification lies in concern for other humans, which is easily defensible from almost every entity able to communicate criticism (other humans). Adapting this ethic stands our best chance at environmental protection while accounting for the unfortunate realities of modern policymaking.

This line of reasoning is perhaps best illustrated with a case study. Consider water purification with silver nanoparticles. This form of silver efficiently eliminates bacteria with little risk of the bacteria developing a tolerance to this treatment (as opposed to many conventional organic antibacterials, which both cannot reduce bacteria populations to the levels achieved by silver nanoparticles and can become tolerated by bacteria). Due to this property, engineers are designing next-generation water filtration systems with silver nanoparticles, which may soon become economically feasible (Barker et al. 2008, pp. 245–250). The relative *over*consumption, as opposed to simple consumption, of water resources by many members of one species conflicts with the concept of Leopoldian community. As nanotechnology drives down filtration prices and enables easier consumption, total human demand for water resources will be exponentially disproportionate to our population and physiological requirements. From my interpretation of Leopold's writing, this application runs entirely opposite to the overarching principles of the "Land Ethic" because excessive human demand on an essential finite resource endangers the stability of the biotic community.

Realistically, however, few humans would refuse access to fresh water for other members of their species, no matter how "green" their constituency. Weak anthropocentrism offers defensible justification for the self-limitation of resources and allows for "reasonable" consumption. While the holistic course of action is certainly a more sustainable solution, the danger of this approach lies in the chance that humans reject holism and disregard environmental concerns entirely. In this event, the well-documented effects of global warming, widespread pollution, strip mining, and other forms of environmental catastrophe will quickly be realized. With weak anthropocentrism, this risk is mitigated.

The Precautionary Principle in Nanotechnology

Now that we have seen that weak anthropocentrism is a relevant environmental perspective for issues of nanotechnology, I want to turn the focus to an ethical guideline commonly applied to nanotechnology: the precautionary principle. The Rio Declaration's Principle 15, a commonly cited definition of the precautionary principle, states that "where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (Commission de l'Éthique de la Science et de la Technologie 2008, p. 80). The precautionary principle is designed as a "principle for action"; it primarily limits in cases of "threats of serious or irrevocable harm" (Commission de l'Éthique de la Science et de la Technologie 80).

Nanoethicists generally consider other common decision-making principles, such as cost-benefit analysis and the life-cycle approach, inappropriate for examining the environmental, health, and safety (EHS) concerns of nanotechnology. Cost-benefit analysis is unsuitable for EHS concerns due to the difficulties in quantifying components of the environment of little economic value and in appropriately accounting for long-term sustainability (Allhoff 2008, pp. 29–30), and the life-cycle approach is neither broadly implementable nor easily enforceable (International Center for Technology Assessment 2007). In contrast, the precautionary principle is widely considered a pragmatic guideline suitable for EHS decisions.

While the Rio Declaration's definition of the precautionary principle accurately captures its essence, I would define the precautionary principle as "the principle of risk optimization". Risk optimization differs subtly but significantly from the profit optimization of cost-benefit analysis in that risk is optimized with cost and benefits as secondary concerns. The idea is to examine a new technology's advantages per "unit risk", meaning a theoretical, difficult-to-quantify unit analogous to the "utils" that measure utility. Of course, the difficulties in applying the precautionary principle on a broad scale arise from the varying levels of risk tolerance of different societal interests, but focusing on risk instead makes this principle necessary for a class of technologies with serious potential for wide-reaching and long-lasting harm.

The precautionary principle is particularly useful in this discussion because it serves as a perfect complement to weak anthropocentrism's long-term resource-maximizing creed. The precautionary principle is both holistic (the commercial rights of corporations are nullified if they negatively impact the community as a whole) and consequentialist (it considers outcomes, not motivations). However, some philosophers reserve sharp criticism for the precautionary principle. Dupuy (2007, pp. 120–122) theorizes that the precautionary principle fails in a big way: it paradoxically fails to account for our inability to predict the properties of new nanotechnologies and thus our inability to caution against negative futuristic scenarios. Although he makes a powerful case, Weckert and Moor (2007) defend the precautionary principle by integrating the notions of positive and negative duties and credible threats to recognize cases where the precautionary principle simply does not apply (131–133). The precautionary principle remains valid when practically applied, despite some theoretical holes.

I now revisit the case study in nanoparticles. Suggested measures resulting from the application of the precautionary principle to nanoparticles would include researching EHS concerns, gauging public risk tolerance for a nanoparticle outbreak, investigating solutions for catastrophe detection, and developing effective policies and regulations (Commission de l'Éthique de la Science et de la Technologie 84). These seemingly sensible recommendations support the use of the precautionary principle for indefinitely maintaining resources as per weak anthropocentrism.

Examples of Nanotechnology and the Environment

The precautionary principle and a weak anthropocentric perspective are now utilized to examine current and potential impacts of nanotechnology on the environment. I will discuss nanoparticles, nanoagriculture, mining practices, pollution removal nanotechnologies, and alternative energies and composite materials.

As previously discussed, the use of nanoparticles is one of nanotechnology's most pressing environmental concerns. In general, nanoscale materials are more reactive than bulk materials due to their high surface area to volume ratio (Lin and Allhoff 2007, pp. 5–6), corresponding to more reaction sites. One result of this effect is the antibacterial nature of silver ions. These nanoparticles are used in personal and medical washing machines (Allhoff 2008, p. 9) and water filtration systems (Barker et al. 2008, pp. 245–250). However, these nanoparticles could reach natural bodies of water and destroy beneficial bacteria upon accidental deployment or via a water treatment plant. An investigation of methods of neutralization is imperative in protecting against this threat.

A related application of nanotechnology can be found in the agricultural sector. Nanotechnology in the agricultural sector holds both promise and risk. Nanotechnology has already been developed for programmable nutrient delivery, increasing crop yields and reducing the costs of food (Barker et al. 2008, p. 253). Additionally, nanotechnology could conceivably be used to create "designer crops" with commercially desirable properties (253–254).

Another concerning effect of the growth of nanotechnology is an increase in mining. The mining of transition metal ores is a rarely mentioned aspect with environmental implications. Many metals, especially precious metals like silver, gold, and platinum, exhibit particularly unique chemistries at the atomic level; expect the majority of chemical nanotechnologies to incorporate these elements. However, current mining practices often expose toxic chemicals to nearby water supplies (Earthworks 2004). The maintenance of water resources is clearly inhibited by these processes.

Of course, not all nanotechnologies pose major problems for the environment. Two areas of nanotechnological solutions that maintain the resource base indefinitely are environmental pollution removal and energy. Nanotechnology could be deployed to absorb or neutralize pollutants, perhaps in the case of an oil spill (Allhoff 2008, p. 12). Additionally, alternative energy sources, such as solar cells and fuel cells, and lightweight composites are being developed with nanotechnology. These technologies decrease "dirty" energy demand by increasing the clean energy supply and decreasing transportation energy demands and serve as a precautionary measure to global warming. From the perspective of weak anthropocentrism, these technologies are undoubtedly beneficial (barring any major unforeseen disasters).

Approaching each of these technologies from the standpoint of weak anthropocentrism promotes common-sense conservation principles and strikes the ideal balance between the interests of the environment and technologists; environmental protection for areas of critical concern is justified without compromising a reasonable and unavoidable pace of technological progress.

Conclusion

Revolutionary or not, the transformative effects of nanotechnology will invariably shape our planet and its inhabitants. A holistic, consequentialist environmental ethic with a base class of solely humans is useful in evaluating decisions involving nanotechnology.

I recommended weak anthropocentrism and the precautionary principle as pragmatic approaches to evaluate the implementation of developing nanotechnologies with the assumption that anthropocentrism is firmly entrenched in industrialized society. However, nonanthropocentrism appears to be breaking ground among leaders in government, businesses, and universities and among ordinary citizens. Bill Joy ends his famous *Wired* cover story by reconsidering the question of human value. He recalls Woody Allen's monologue in *Manhattan* in which he lists things that make life worth living. Joy then writes: "Each of us has our precious things, and as we care for them we locate the essence of our humanity. In the end, it is because of our great capacity for caring that I remain optimistic we will confront the dangerous issues now before us" (36). As society slowly begins caring for the environment—adapting Leopold's "Land Ethic"—we shift the calculus of our "precious things" from technology to the environment. Still, both advanced technologies and a sustainable environment remain immensely desirable to humans. These decisions of relative value remain ours and ours alone.

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