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Nanotechnology

Regulation and Public Discourse

Chapter 2

Ecocentric Evaluation of Nano-Release

Risk, Precaution and Imagination

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1. INTRODUCTION

Nanotechnology is one of the most rapidly emerging new technologies of our time. Applications of nanotechnologies have contributed to the mass production of nanoparticles, which also entails an inevitable release into the natural environment. Neither the effects of nanoparticles in living beings nor the effects of the release of nanoparticles into the abiotic environment can be fully anticipated at present (cf. Filser, chapter 7 in this volume). Critical voices emphasise the incalculable risks of nanotechnologies. Nanoparticles differ significantly from other materials; some authors even speak of a new generation of chemicals (Bensaude-Vincent 2009, 610). Simultaneously, the expectations regarding the positive effects of nano-materials on the environment are high. Nanoparticles can be used to clean up water more effectively than former sewage treatment devices (e.g., Gangadharan et al. 2010; Hillie and Hlophe 2007; Jones 2007); in agriculture nano-materials may serve as highly effective carriers for nutrients and chemicals (e.g., Bradley, Castle, and Chaudhry 2011; Chaudhry and Castle 2011; Chun 2009; Fang and Bhandari 2010; Fathi, Mozafari, and Mohebbi 2012; Miller 2010); and nano-materials have low weight, so that energy for transport—for example, in aviation—might be reduced significantly with the help of less weighty equipment and devices (Bundesamt für Umwelt 2010; Steinfeldt 2010; Greßler and Nentwich 2014).

Even though the release and application of nano-materials in nature has divergent effects, it is not easy to tell whether the positive outweigh the negative outcomes. Instead, nano-ethics draws a far more complex picture. On the one hand, risk assessment is a multifaceted approach to a variety of problems. Moreover, the material qualities of nano-materials cannot be foreseen in detail. As chemicals, nanoparticles behave irregularly—their fate in the environment and their trajectories in natural environments are difficult to describe (Klaine et al. 2012; von der Kammer et al. 2012; Kah, Beulke, Tiede, and Hofmann 2013). On the other hand, the positive effects of nanoparticles cannot easily be assessed either. As always, much of the scenario-based foresight considering new emerging technologies is still a very opaque view into the future (Nordmann 2007; Nordmann and Rip 2009; Grunwald 2010; Lucivero, Swierstra, and Boenink 2011).

In this chapter we elaborate on this particularly complex picture, focussing on the interface between "nano" and "nature." We start with a distinct normative claim: In order to evaluate that interface in a fair and future-oriented way, it is obligatory to engage in what we call an "eco-centric evaluation" of nano-release. "Eco-centrism" is a broad term that covers a range of normative claims regarding the relation between human activities and nature. Its meaning will be outlined by investigating some of its facets. Nature is a web of interrelated living entities, which together build up ecosystems. An eco-centric evaluation makes a judgement about effects on nature that result from human activities (the anthropogenic effects) with respect to effects on the well-being of living beings and the integrity of ecosystems. Whether or not nature is endowed with value, and whether or not the well-being of living beings deserves respect, is part of an ongoing debate in environmental ethics (Jamieson 2001). Whereas many different proposals have been made in order to justify respect to nature, this chapter relies on a rather broad interpretation of these claims. Today, many authors in different camps agree that it is right not to destroy nature's web arbitrarily and intentionally. Instead, nature should be protected from major harm, in particular when materials are released into nature whose effects cannot fully be anticipated.

We proceed in four steps. In section 2 we give a brief review of current research on normative approaches to the effects of nanotechnology on nature. Several research projects have focussed on how nano-materials influence the natural environment and how nano-materials can be used in order to enhance functioning of biological systems and to increase well-being of living beings. Section 3 starts with an assessment of future scenarios. We elaborate on the traditional view that future scenarios need to be evaluated in the context of risk analysis. Also, we examine the so-called precautionary principle (PP), which is one of the most prominent principles in environmental ethics that provides reasons for avoiding risks. Furthermore, we argue that risk assessment is not a comprehensive answer to challenges posed by nanotechnology. In sections 4 and 5 we therefore discuss alternatives. In section 4 we explain a more comprehensive assessment of risk that has been developed in the context of social and environmental risk analysis. It takes the claim seriously that risk assessment needs to pay tribute to democratic procedures. In particular, we investigate how a concept of integrated risk analysis that has been put forward in the context of nuclear materials can be applied to nanotechnologies. In section 5 we attempt an assessment in the context of possible future socio-technological imaginaries—a concept developed by Paul Thompson (2011, 2017, 2018).

2. ETHICS AT THE INTERFACE OF NANO AND NATURE

The development of nanotechnological applications to products has raised questions about ethical issues. The academic and public debate has primarily focussed on questions about the safety, responsibility, and overall desirability of recent developments (Ach 2006; Allhoff and Lin 2008). Recently, authors have claimed that the release of nanoparticles into the environment also needs an ethical investigation and that the application of nanotechnologies for environmental cleaning and for treatment of natural goods needs ethical debate (Hongladarom 2012; Myhr and Myskja 2011; Bruce 2006; Faunce 2012; Kulve et al. 2013). Yet research in these areas has only just started to develop.

So far, three concerns have dominated the debate: issues of safety, societal effects of nanotechnology, and the PP. Concerning safety, questions have been raised about the responsibility of researchers (McGinn 2010) and methods for assessing expectations in the field of nano-development (Lucivero, Swierstra, and Boenink 2011). Nanoparticles behave in unusual ways: toxicity is not positively correlated with mass, but instead more mass might contribute to less toxicity (Reimhult 2017). Due to the specific characteristics of nanoparticles, and due to the challenges resulting from research at the intersection of natural systems and technological options, it is argued that an evaluative assessment of research needs to go beyond classical schemes of evaluating new emerging technologies (e.g. Bruce 2006). It is an academic novelty to discuss whether or not responsibilities in the development of nanotechnologies differ from ethical toolboxes for researchers in comparable fields—for instance in biotechnology (McGinn 2010). Nevertheless, an encompassing nano-specific ethics of safe release has not been elaborated yet. Three ethical issues have been identified so far.

First, for societal effects, research on nanotechnology includes proposals for enhanced safety and proposals for risk assessment (Bachmann 2006, 76–91; Robison 2011). Second, there is a legitimate question of how a fair distribution of gains from nanotechnology can be achieved (Bachmann 2006, 92–101). The term “nano-divide” refers to an unwelcome scenario in which new nanotechnologies intensify the gulf between economically developed countries and countries that cannot invest in new technologies due to poverty and a poor economic performance. Third, the discussion about precautionary measures has distinguished two different approaches of technological development—either "Nano2Bio" or "Bio2Nano." Both investigate an immediate effect of nano-materials on living entities. The former field of research addresses applications of nanotechnology in the life sciences, including approaches that attempt to manipulate biological systems by means of new technologies. The latter approach contributes to applications of nanotechnology in order to enhance certain properties of living beings (Bachmann 2006, 37–42). Even though both research areas raise important questions about possible risks, they focus entirely on organisms. So far, the core concern has been about interrelations of "nano-bio-technology" as a treatment of plants and living beings (Hongladarom 2012). However, among the most pressing issues in terms of environmental conservation is the effect on water and the soil.

In general, the debate on a normative assessment of nano-release is still in its infancy. One reason for this unsatisfactory situation is that evaluation of the effects of the release of nanoparticles into the environment is almost entirely done in a risk assessment framework. Moreover, evaluation usually focusses on societal concerns, disregarding the natural environment and healthy living conditions. In the remainder of this chapter, we wish to challenge this limitation and argue in favour of an eco-centric evaluation of nano-release. We start with an interpretation of eco-centrism as a normative approach and then explore the dimensions of an eco-centric evaluation in more detail.

3. RISK ASSESSMENT

Probably the most relevant aspect of an assessment of nano-release is the actual or potential risk it bears for living beings and future generations, but also for the environment. In this section we focus on three particular aspects of risk assessment of nano-release. First, we focus on the normative implications of risk in general. What sort of action does the instance of a certain risk give a reason for and why? Second, we will briefly outline different accounts of risk management and confront them with criticism. The elucidation of this rather traditional debate in technology assessment will help to clarify some of the pitfalls of reducing ethics of nanotechnology to mere risk assessment. We then turn to an analysis of the concept of PP as a specific sort of ethical principle for risk governance. We will outline the problem of a proper definition before we turn to more pluralist ethical accounts in section 4.

In a highly abstract way, risk can be expressed as expectation value. The probability of a certain negative outcome is multiplied by its disvalue. Thus conceived, a risk is high if the negative consequence occurs with a high probability, or if the disvalue of the negative outcome is exceptionally high. Identified risks of nano-release can be put into three different categories (cf. Gammel 2007, 22):

- scientifically proven hazardous effects
- hypothetical effects
- meta-risk mainly associated with the creation of artificial microorganisms

Two dimensions of risk assessment need to be distinguished (Bachmann 2006, 68). First, there is the empirical task of identifying certain effects and estimating probabilities of certain outcomes in order to define a specific risk (e.g., Organisation for Economic Co-operation and Development [OECD] 2003). An example of this interpretation has already been given. Second, the ascription of "risk" in itself also includes a value statement about the state of affairs when the unwelcome scenario comes true. The evaluation of an outcome justifies normative judgements on how to handle the given risk (cf. Kermish 2012).[1] It is the basis for argumentation about duties and permissions. The ethics of risk of nano-release, as we comprehend it here, are exclusively concerned with this second dimension.

When drawing normative conclusions about risks of nanotechnologies, one needs to keep in mind that possible negative consequences of the development of a new technology and its industrial and commercial application are *not* intended. Developers, designers, companies, or regulators who are presumed to be responsible for a certain risk are only taking some probable negative consequences into account. They do not willingly bring about that state of affairs. Nevertheless, they are responsible for them. When talking about normative implications of risks, we therefore focus almost exclusively on negligence: risks are presumed to be a negative by-product of nano-release and not its intended consequence.

While some authors exclude mere risk evaluation from ethics and locate it in (presumed) neutral technology assessment (Renn and Roco 2006b), we regard it as an ethical issue. However, evaluation of the development and application of nanotechnology products based on a risk assessment can be seen as nano-ethics in a narrower sense. Whereas a wider perspective of ethical issues involves issues such as principles of equity (the problem of "nano-divide"), autonomy (transhumanist scenarios of human enhancement through nanotechnology), and privacy and data protection (see Allhoff 2009), the main concern of risk assessment is with threats to health, security, and the environment.

A risk is generally perceived to be a disvalue—something worthy of being avoided. However, taking a closer look at possible normative implications following from the incidence of risks presents a more intricate ethical picture.

There is a reason to avoid a risk, which is grounded in a principle of non-maleficence (Ebbeson, Andersen, and Besenbacher 2006), which states that in general no harm should be caused and, if possible, harm should be avoided. Many authors in nano-ethics rely on that principle as a basic pillar for the justification of normative evaluation.[2]

This principle justifies a prima facie duty to avoid risk. The term "prima facie" is used to describe obligations that hold as long as there are no contrary reasons outweighing them. Therefore, a duty to avoid risk does not include that it should categorically be avoided. To claim a categorical duty would not be defendable. Individual, social, and political actions inevitably imply certain risks. Thus, an obligation is generally included in the incidence of a risk, but it can be weighed against competing reasons. On the one hand, risk-benefit analysis consists of an assessment of reasons for and against a certain practice and can, therefore, provide overweighing reasons. On the other hand, there may be other values and principles besides the disvalue of the badness of an outcome—for example, basic rights and liberties of action—that may be more fundamental. So, the identification of a certain risk provides a reason for action or regulation. Nevertheless, it is not sufficient for the justification of a duty to avoid it.

The ethical responsibility (besides the legal or political responsibility) to avoid risks of nano-release applies to scientists, designers, developers, and regulators. It is based on a moral duty not to negligently harm people, future generations, living beings, or the environment. In traditional risk management there are three different approaches to derive normative guidance based on the incidence of potential threats (Marchant, Sylvester, and Abbott 2008).

First, the so-called acceptable risk approach defines a threshold beyond which humans, living beings, or the environment should not be exposed to potential harm. Considering nanotechnology, this account not only takes the evaluative stance on certain potential harm to be unacceptable, it also lacks specific evidential basis for determining these thresholds.

Second, if a certain risk is evaluated in the context of potential benefits, risk assessment is equivalent to risk-benefit analysis. Normative statements about proper risk handling on this account are mainly consequentialist—harms can be outweighed by gains. Similar to the acceptable risk approach, this account relies on data that is not available for nanotechnological applications (Marchant, Sylvester, and Abbott 2008, 44).

Third, one account that avoids the problem of evidence is the best available technology account (Shapiro and McGarity 1991; cf. also Sunstein 1991). This account can also be justified on the basis of a strong precautionary principle (see further below). It basically states that for a certain risk, the current best technical means should be applied to avoid that risk. Considering the release of artificial nanoparticles, the account demands that they should be reduced to a minimum in order to avoid toxic interaction with humans, animals, and nature. This pragmatic account on handling threats is in some sense conservative. Without reference to evidence, it pleads for caution about emission of nanoparticles. There is a risk of overregulation. Also, in not providing reasons for the reduction of nano-release, it lacks a justificatory basis (Marchant, Sylvester, and Abbott 2008, 44–45).

Besides their theoretical difficulties, the proposed accounts of traditional risk management all seem to provide normative guidance for an appropriate application and regulation of emerging technologies if there is a recognised threat or a potentially bad future outcome. However, they seem to presuppose sufficient knowledge about future scenarios. One central feature of the ethics of risk that is specific to considerations on emerging technologies is the fact that at an early stage of development, potential harm induced by the production and application of a new technology can only be anticipated.[3]

The lack of knowledge about potentially negative outcomes calls for a moral principle (to avoid risk) that is not exclusively action-based but also includes duties of *ex ante* acquisition of information about possible hazardous outcomes (Weckert and Moor 2006).[4] Usually for a person, a group of people, a company, or an institution to be responsible for their actions implies that they know about possible negative side effects. This implication is called the knowledge condition of responsibility. However, this condition does not seem to hold when it comes to a proper allocation of moral responsibilities in nano-ethics (Robison 2011, 9). We therefore encounter a different sort of responsibility when it comes to new and emerging technologies, especially with nanotechnology. A candidate for an ethical imperative that does not suffer from the shortfalls of risk analysis as portrayed in this section is often seen in PP that traces back to the so-called *Vorsorgeprinzip* in German environmental law (O'Riordan, Jordan, and Cameron 2001, 11). We will briefly examine it and its application to nanotechnology below.

The common basis that calls for precautionary remedies is the assumption of a threat induced by the development of a new technology and the uncertainty about the causal impact (cf., for example, Raffensperger and Tickner 1999, 1; Sandin 1999, 890–91; Gardiner 2006, 36). From this we can infer that a precautionary principle demands mandatory action—either omission of risks or regulation—justified only by the uncertainty about a potential threat. The fact that the threat is to some extent unknown implies that there is a duty to acquire knowledge. Arguably, this principle is very abstract and therefore in need of further refinement and explanation in order to be applicable for regulatory or policy advice (Bodansky 1991, 5). The academic discourse focusses on a proper definition of normative implications of PP. A distinction is commonly drawn between strong versions of PP and weak versions (Soule 2000; Foster, Vecchia, and Repacholi 2000). The former versions are endorsed (e.g., by the ETC Group [2005, 16]), whereas the latter are defended (e.g., by the Royal Society [2004] and SwissRe [2007]).

Strong versions of PP demand that as long as a certain action—the development of a technology, its application, production, and distribution—involves a certain threat to health, security, or environment, it should be omitted or restricted. The burden of proof lies on those who promote the introduction of the technology. If there is a scenario of a bad outcome, it should be given more weight than possible positive effects of the technology. As long as the possibility of that bad outcome cannot be excluded, the technology should not be developed, or its development should be restricted. Weak versions state that an action—the development of a technology, its application, production, and distribution—is permitted as long as it cannot be scientifically proved that it causes a threat. Scenarios of bad outcomes can be assessed in relation to possible positive effects. The burden of proof lies on the shoulders of opponents to the new technology.

One can immediately see that both of these versions of a precautionary principle are deficient. On the one hand, strong versions of PP are overly conservative or even "irrational" (Hourdequin 2007, 344). They seem to attach an unjustifiably high moral weight to a yet unknown bad outcome, while disregarding potentially good outcomes. Also, they set the threshold for the legitimacy of a certain technology too high. Empirically, the nonexistence of an object or an event—the nonexistence of a potential threat—cannot be proven. Thus construed, the principle seems to withhold legitimacy for all technologies. As we have outlined above, the incidence of a risk is not sufficient for inferring a duty to avoid it. This seems all the more true for risks which are unknown or yet unquantifiable. A strong version of the precautionary principle, therefore, cannot be endorsed. On the other hand, the weak versions do not represent an appropriate alternative to derive normative conclusions. Without attaching more weight to the potentially bad outcome of the development of a technology than to potentially good outcomes, the normative conclusions from the principle are congruent to those of risk-benefit assessment. Thus construed, the principle is "empty" (Hourdequin 2007, 344). Beyond mere risk-benefit analysis the principle does not demand any precaution.

A meaningful version of PP, therefore, needs to be conceptualised as a "weaker" type of the strong formulation. Usually, the idea behind the principle can be expressed by the phrase "better safe than sorry." From an ethical perspective this norm certainly has some appeal. The problem is that when it comes to precise formulations in order to derive normative conclusions for scientists, developers, designers, or regulators, PP does not seem to give guidance without further explanation of its meaning. First, it is unclear where to draw the line between justified and unjustified precaution. Second, the conceptual problem remains that the principle itself does not provide justification to "overweigh" unknown threats. However, with regard to the risks of nanotechnology, there needs to be an ethical principle that goes beyond the evaluation of costs and benefits and that states a case for precaution. When there is a possible threat, normative accounts on technology need to account for that, even if it is uncertain.

As for the application to nano-release in the environment, the evaluation of the PP might follow different lines. If we assume the effects of nano-release on natural beings are—even though not fully known—probably particularly harmful, and if we further assume that there is no practical chance to ever recover nano-materials that have been released into the natural environment, the fact that effects are still unknown needs to be weighed against the gravity and the irreversibility of the effects on nature. We know that nanoparticles once released into nature might have negative and disturbing effects that also cannot be healed afterward. An eco-centric interpretation of the PP contributes to the view that "better safe than sorry" makes sense, even though an exclusive application of PP is not possible. In particular, "safe" does not necessarily relate to human health. In an eco-centric framework, the imperative to be safe includes a demand for respect for the safety and health of natural living beings. In order to develop the content of that principle, future scenarios are necessary for outlining what "safety" means. A risk assessment framework may be supplemented by a sort of eco-centric forecasting. We shall further discuss this in section 5.

Nonetheless, it has to be assumed that traditional risk assessment and the PP are insufficient normative guidelines for addressing the ethical challenges of nano-release. Before elaborating an eco-centric framework for an assessment, we will examine an ethical account that attempts to combine a range of different evaluative standards related to moral issues of nanotechnology.

4. AN INTEGRATED NORMATIVE MODEL

Recently, environmental ethicists highlighted the role of fair procedures in making decisions about environmental risk (Thompson 2011). They also considered the social role of risks and the broad variety of the meaning of risks to people living in various places. Even though we think that it is particularly important to get citizens involved in decisions on risky technologies, we also claim that this is only part of a much broader and deeper normative procedure. In particular, coping with risk is only one element, even though it is a particularly important one, in an evaluative practice that should also include a range of normative dimensions. As we have seen in the discussion on a traditional risk assessment framework, the above outlined accounts only have limited meaning with respect to ethical challenges of nanotechnology. One further point of criticism, however, has not been fully established: risk assessment schemes have a tendency for consequentialist evaluation, and they tend to disregard so-called wider ethical aspects.

The principle of non-maleficence that is the basis for normative judgements about handling risks is logically included in the utilitarian claim that overall beneficence should be promoted. Utilitarians consider risk in relation to possible positive effects of an event or action on happiness, well-being, or utility. However, to avoid maleficence does not necessarily include the promotion of overall well-being, utility, or happiness. In contrast to utilitarian theories, deontological theories claim that for some risks, there is a duty to avoid the risk which holds, regardless of positive outcomes which could be achieved by taking it. Furthermore, the disvalue of a risk's potentially bad outcome does not have to entail the derogation of citizens' utility (Kuzma and Besley 2008). It may also include an infringement of citizens' rights or the causation of injustice. Therefore, risk assessment need not always be set in a utilitarian framework. Nevertheless, the principle has a consequentialist orientation. It evaluates actions on the basis of their outcomes.

Deborah Oughton criticises risk assessment's consequentialist foundation as too narrow to be applicable to the specific ethical dimensions in question. As one of only a few scholars in the field of environmental risks, she attempts to establish an encompassing approach to ethical issues of environmental protection (Oughton 2003), of taking appropriate measures to ensure health, safety, and sustainability (Oughton, Bay-Larsen, and Voigt 2009; Oughton 2013), and of restoration of contaminated areas (Oughton et al. 2004), with a focus on radioactive contamination. According to Oughton, a merely consequentialist perspective has some major deficiencies when it comes to a normative assessment on the causal impact of emerging technologies (Oughton 2003, 6).

On the one hand, there is the conceptual problem that values cannot be empirically determined. Furthermore, there is the difficulty of weighing benefits or harms and of making them comparable, which could also be called the "problem of incommensurability" of different harms (Chang 1997): A potentially bad outcome may, for example, consist of a threat to health, or also a threat to social justice. When it comes to comparing these bad outcomes—both undesirable in their own right—it seems to be impossible to put them into a quantifiable relation.

On the other hand, consequentialist risk assessment has what Oughton calls "intrinsic" deficiencies (Oughton 2003). The criticism can be made that assessments of future scenarios are mainly conceptualised on *instrumental* grounds. The question is in what way certain events or actions may negatively affect some predefined values, such as economic well-being, health, safety, etc. Oughton claims that some things are not merely instrumentally valuable (as a means to promote welfare or utility). There are other values that have a significance in their own right and that do not depend on other values. In philosophical jargon these independent values are called intrinsic values. Oughton's account proposes an irreducible set of ethical ideas based on a range of different values.

She identifies four distinct areas of ethical evaluation (Oughton, Bay-Larsen, and Voigt 2009, 439; cf. also Shrader-Frechette and Persson 1997). Relevant ethical issues include:

- equitable distribution of cost and benefits
- consent of affected individuals
- involvement of affected individuals in decision-making
- threats to the environment

Since it helps to differentiate the ethical dimensions at stake with nano-release, we are confident that such an integrated approach is helpful when applied to the ethics of nanotechnology. While, according to Oughton, ethicists may not provide ultimate answers to entrepreneurial, political, or legal questions on what is right or wrong, they may inform about the ethical reasons behind normative convictions in the light of more fundamental principles (Oughton 2003, 9; Oughton et al. 2004, 77–78). The aforementioned ethical dimensions are presumed to represent the candidates for a (nonexclusive) list of the most important moral principles involved.

As becomes evident when considering these ethical dimensions, strong emphasis is put on the attitudes of individuals toward the effects of certain practices or policies. When it comes to regulation of a certain practice, it is relevant how indirectly and directly affected people evaluate different options and outcomes. This concerns not only measures to avoid pollution of the environment but also remedies to cope with environmental pollution. The question is: Do people agree to the proposed political and legal solutions? Of specific importance is the consent of affected parties, which can only be obtained by involving them in the decision-making process. With regard to the resettlement of families living in contaminated areas adjacent to Chernobyl, for example, Oughton et al. (2004) ask whether people, if included in decision-making, would rather have stayed in these areas than leave their homes. An integrated approach accounts for this in promoting a broad inclusion of different parties and democratic ways of finding solutions.

According to Oughton, special emphasis should also be put on intrinsic values of species, plants, animals, or entire biospheres and biodiversity (Oughton 2003, 9). In our common moral understanding, these things seem to have a value in their own right that does not depend on their usefulness for achieving other goals. Both consequentialist and deontological ethical theories provide support for the normative claim that the environment should not be damaged unnecessarily. The reasons for that support, however, differ greatly depending on basic assumptions about values. Whereas anthropocentric accounts plead for protection of the environment solely on an instrumental basis, bio-centric or eco-centric theories reason for protection of the environment based on the assumption of intrinsic values.

For example, Oughton (2003, 9) addresses the question of ethical imperatives to protect the environment from ionising radiation. The duty to avoid contamination and to take remedies to reduce exposure of biotic and abiotic nature to radioactive material is defended on both anthropocentric and eco-centric grounds. She identifies the lowest common denominator of both accounts in the justifiability of obligations to protect certain populations of living organisms (animals and plants) and abiotic nature (soil, groundwater, etc.). In both accounts there are reasons for preservation. Whereas eco-centric approaches identify an intrinsic value in species and natural environments, anthropocentric theories also have legitimate grounds to claim that we should not endanger or destroy them (Oughton 2003, 12). The latter argue that there are essential human interests in preserving biospheres and landscapes. For example, a case for biodiversity can be defended with regard to a human interest to perform research on natural substances to use for economic applications. But most importantly, functioning biological systems in many cases are a precondition for human economic activity.

As Oughton's example shows, an integrated approach attempts to reconcile deviating ethical accounts in common principles. Considering ethical obligations to protect the environment from toxic nanoparticles an integrated approach could provide a promising account for a broad justification. In the following section we will attempt to flesh out this eco-centric dimension of moral judgements on nanotechnological developments. The idea is to frame certain convictions about the value of the environment in a theoretical conception of eco-centric evaluation.

5. ECO-CENTRIC EVALUATION OF FUTURE SCENARIOS

Even though environmental ethics has recently gained momentum, its application to concrete scenarios is still insufficient. In this section we shall present some recently defended accounts that help to evaluate nano-release against the backdrop of environmental concern. Obviously, nanotechnology aims at generating nanoparticles, which in turn are ingredients in materials and products or are used as transport media. As a consequence, the particles are released into the environment. In sunscreen, in cosmetics, as ingredients in food (e.g., in tomato sauce), but also as integrated parts of surfaces and wall paint, nanoparticles are released into the environment. Sometimes nanoparticles are also intentionally used to change the behaviour of certain materials (e.g., they are used as catalysts in water treatment procedures) (Moon et al. 2013; Jiao et al. 2015).

In order to assess the effects of nanoparticles on natural entities, much more would have to be known about their fate and their behaviour in natural surroundings. As already argued in section 3, an assessment of risks is particularly difficult in a situation in which studies exploring the trajectories of nanoparticles in nature are rare. Considering studies in the laboratory, the problem—to really observe the behaviour of particularly tiny materials—cannot be overstated. In addition, nano-materials might also be particularly helpful in supporting processes of environmental cleaning.

Despite this two-sided picture, one lesson of environmental ethics needs to be taken seriously. Some authors now defend the view that a new era has begun. We live in times in which the "Anthropocene" is reality (Crutzen 2002). In other words, planet earth is in the midst of deep modification, including change of its basic geophysical mechanisms and systems. And according to widespread conviction, this process is irreversible. Therefore, humankind needs to react to it in a constructive manner in order to prevent really dreadful scenarios, perhaps even climate catastrophes and water shortages. We do not want to paint a particularly dark picture here. But it needs to be emphasised that eco-centrism is no longer a luxury of some environmental philosophers. It is a timely approach whose lesson needs to be learned. Instead of providing theoretical advice that focuses on "planet–people–profit," it is time to develop a new order, changing the sequence to "planet–people–prospect."

As for the assessment of nano-release, this speaks in favour of strengthening precautions. It also speaks in favour of research on technologies that support environmental cleaning (e.g., exploring nano-materials as catalysts in sewing factories) and that work in favour of eco-efficiency, such as providing smart and lightweight materials. Yet the eco-centric assessment will not only apply to nano-release, but also to nanotechnologies as important technologies in the transformation of plant life and in the agricultural sector.

One proposal to evaluate technologies at an early stage of development has been elaborated by Paul Thompson (Thompson 2018). His proposal is particularly helpful for the assessment of technologies in agriculture. In particular, he departs from a unilateral focus on risk. Instead, he regards emerging technologies (e.g., the genetic modification of organisms) as a form of progress that produces harm as well as benefits (Thompson 2011, 137–177). In addition, he discusses alternatives to the technologies—for instance so-called organic breading (Thompson 2011, 178–198). Besides this fair balance, what really is new and of particular interest for an ethical assessment are his insights into the underlying normative assumptions behind choosing one specific technology instead of another. Overall, he rejects what he calls "naïve economic utilitarianism" (Thompson 2017, 5) as a normative framework for assessing benefits and harms accordingly. In contrast, he argues that real decisions about the choice of technologies are not the outcome of a rational calculus. According to his account, choices are guided by normative assumptions and what he calls an "ethos" of the groups of people who favour one technology over another (Thompson 2017, 4–5). This ethos provides the backdrop of the evaluation of technologies by groups of practitioners.

In order to give a systematic overview of the choices that can be made in evaluating an emerging technology, Thompson correlates the deep embeddedness of the assessment of technologies in the ethos of practitioners with theoretical insights of philosophers of technology. In particular, he argues with Sheila Jasanoff about whether the future development of technologies can be crystallised along lines of "imaginaries" (Jasanoff and Kim 2015). In contrast to dreams about possible future lines of development, socio-technical imaginaries are shaped by material and institutional conditions. An imaginary is a way to characterise how innovators and developers "envision the transformation of existing realities into a future shaped by the realisation of mere possibilities" (Thompson 2018, 187). For agricultural development, he offers four socio-technical imaginaries as competing visions (Thompson 2018, 187). Even though he focusses on agro-technologies, these four imaginaries can serve as paradigms for the imagination of future developments of technologies; in particular, they can provide a baseline for understanding the dreams and expectations of technicians that in the end guide collective decisions.

The first socio-technical imaginary is named "technological modernisation" (Thompson 2018, 188). It envisions the future of a technology that is still in its infancy through processes of industrialisation that open the door to a consumer-oriented industry. Becoming a sector of the existing economy is a goal of modernisation. The second imaginary is termed "sustainable intensification" (Thompson 2018, 188–189). It is driven by one overarching value commitment concerning the agricultural sector: the commitment to "feed the world" and thus to increase production by means of efficient techniques of land use. Thompson argues that intensification is not possible without additional use of technologies such as genetic engineering. Yet the objective is to ameliorate the current procedures and not to replace agriculture as it is practised today. The third imaginary is called "extensification" (Thompson 2018, 189–190). This imaginary envisions alternative social institutions. In the food market, for example, institutions could be built and sustained that support food sovereignty. The fourth imaginary is "urban agriculture" (Thompson

2018, 190). It places emphasis on the social relations surrounding a technology. In particular, it also relates to initiatives that wish to realise not only technological change, but also social change.

At first glance, the proposal to adopt the technique of "socio-technological imaginaries" for the evaluation of nano-materials in an eco-centric framework might look far-fetched. However, a second look reveals some interesting possibilities for application. The assessment of new technologies is usually based on the notions of risk, precaution, and perhaps also shared values that are either supported by or put at risk through the invention and application of new technologies. Also, the calculation of costs and benefits might follow simple economic principles. However, this is only one aspect of the deliberative process and choices that people make. As for the agriculture sector, these choices include the opposition between a "productionist paradigm" (Thompson 2017, 66–92) and the opposite, which is the ideal of the "good farmer" in terms of "agricultural stewardship" (Thompson 2017, 93–112). Both relate to completely different visions not only of possible future developments, but also of goals that are worth pursuing. Whereas the productionist paradigm is basically oriented toward an ever more efficient economic performance, the ideal of stewardship takes responsibility not only for the urgent needs of human beings, but also for goals of sustainability. Certainly, to assess new technologies by scrutinising the underlying imaginaries and ethical commitments is not a particularly hard technique compared to the calculation of risks. It allows one to derive a bottom line, which is needed for real evaluation not only of benefit and harm, but also of the possible gains from a technology that should ultimately serve goals that are more important than goals of risk prevention or profit-seeking behaviour. In particular, this is also a technique that can be used to become aware of the underlying wishes and values that guide the further development of technologies.

6. CONCLUSION

In this chapter, we have chosen a rarely discussed, yet ever more pressing perspective on nanotechnologies. We have highlighted several options to assess the effects of nano-materials in the context of natural environments. Even though it is obviously the first goal of regulators and a major function of public discourse to emphasise the dangers for human health, it is equally important to get a clear picture of the immediate and long-term effects of nano-materials on the natural environment.

Some of the established techniques of risk assessment in the context of the ethics of risk can be applied to this specific concern. In section 3 we described ways to get a clearer picture of the existing risk management account for nano-materials. Risk assessment is difficult yet possible, but it includes theoretical assumptions about normative dimensions of the incidence of risks. We have argued that risk assessment rests on ethical decisions that need to be taken seriously. They not only include an estimation of the value of outcomes in scenarios with uncertainty, but also include a duty to be as well informed as possible. This proves not only important for regulators, but also for policy makers. In particular, the funding for research is one of the ways to live up to the duty to get informed.

We have further argued that the limits of this approach must be considered. It is not helpful to put too much weight on an ethical procedure that has only limited applicability in a specific scenario. As a supplement to risk assessment, we have discussed one of the most important principles in environmental law, at least in Europe, which is the PP. Its normative demands include a severe shift of the burdens of proof: The principle favours a "better safe" perspective. Furthermore, it also needs to be complemented by a clear-cut assessment of the boundaries and meanings of safety. In particular, it needs to relate to an interpretation of goods in nature that can be argued to be eminently worthy for the human population.

Before discussing this facet of eco-centrism, we provided an introductory interpretation of a model of "integrated value management," as proposed by Oughton. Even though Oughton's focus lies much more on dangerous nuclear materials, we think that lessons from her approach can also be learned regarding nano-release. She argues, among other things, that the final assessment of risks needs to be performed by persons who suffer from risks or from harmful incidents. Risk assessment has a subjective and a cultural side. And sometimes people are willing to take risks, even though it might seem irrational from an external perspective. In particular, a normative framework needs to integrate elements that have been described in theories of democracy.

Our final section was dedicated to an evaluation of future scenarios in the context of an eco-centric assessment. Even though nobody is in a position to foresee the future, the framing of possible trajectories of developments by choosing and analysing various socio-technological imaginaries is helpful. In particular, this account suggests that the shaping of our institutional and material surroundings is not a matter of necessity, nor is it just something that happens. Instead, groups of people and decision makers choose future developments by means of shared value commitments. It is helpful to be aware of these commitments. Thompson's proposals to distinguish various paradigmatic imaginaries is just a beginning for an evaluative enterprise that is also needed for nanotechnologies. In times of ecological crisis, the future of our planet is at stake. Even though nobody knows what impact nanotechnologies will finally have in supporting environmental cleaning and enhancing eco-efficiency, highlighting these goals in an imaginary of guardianship is the first important step.

Overall, in this chapter we have pursued two major objectives. First, we wish to highlight the need for an eco-centric debate when it comes to ethical principles concerning the application of new emerging technologies. "Nature first" is a normative demand to be taken seriously in this context. Second, we think that regulators as well as public discourse need to be informed by ethics. In particular, ethics need to apply a rich diversity of practices of evaluation to concrete scenarios in order to support regulators in developing fair and helpful normative guidelines.

NOTES

1. The distinction between the empirical side of risk assessment and the normative conclusions that derive from it are often described as the division between "risk assessment" and "risk management" (cf. Jahnel 2015a; 2015b).
2. Scholars in the field of nano-ethics sometimes refer to parallels in the ethics of biotechnology and the crucial ethical framework provided by Beauchamp and Childress (2001) and Kemp and Rendtorff (2000) (e.g., Ebbesen et al. 2006, 453).
3. The problem of knowledge about potentially bad outcomes becomes more apparent given the so-called Collingridge dilemma: The later the stage of development of a new technology, the more knowledge that exists about potentially negative impacts. Also, however, the later the stage of development, the fewer the measures that can be taken to alter production procedures or designs in order to avoid negative impacts (Collingridge 1980).
4. For simplicity, by "lack of knowledge" we refer to both the "ignorance" of possible outcomes and the "uncertainty" about the probability that certain outcomes will occur (cf. European Environment Agency 2001, 170).