Radiological Protection and Intergenerational Justice

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Abstract *: In this chapter, we first present three families of theories of intergenerational justice. We then use this approach to address three sets of issues. How should we deal with radioactive waste, both on the physical disposal side and on the funding side ? Does intergenerational justice have anything to say about restricting our focus of analysis to two generations when it comes to assess the hereditary effects of radioactivity ? What should we think about adjusting general standards of radiological protection to those required for children ? Answers are provided on each of these three questions, from the perspective of intergenerational justice.*

Keywords : generations, ethics, radioactive waste, reversibility, children

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"Peoples of the world, together
Join to serve the common cause!
So it feeds us all for ever
See to it that it's now yours.

Forward, without forgetting
Where our strength can be seen now to be!
When starving or when eating
Forward, not forgetting
Radioactivity"[2]

Do we need theories of justice ?

The death toll of the 1986 Chernobyl accident is very uncertain, and likely to remain so. Estimates range from 4000 up to… 1 787 000 deaths! A few tens of thousand deaths may be a plausible figure.3 Regardless of such uncertainties, Chernobyl keeps reminding us that going for nuclear energy should not be decided lightly. Moreover, protecting people against radioactivity clearly raises important issues of justice. Yet, too often do we assume that when it comes to identifying what should be regarded as an acceptable degree of risk imposed on people, only two steps would be required. First, scientists should state as honestly as possible what the state of the art tells us about the costs of minimizing exposure, the technical possibility of doing it or the nature of biological effects of radioactivity on people's health. And once this clarified, we should jump straight to the citizens – second step - and ask them to decide democratically on the matter. In short, we should inform them about the science, and then let them decide, preferably after some deliberation. To put it differently: whatever would not belong to the sphere of expertise of natural sciences would simply fall into the "political sphere".

This approach is insufficient. For it ignores the possibility of coming up with theories of justice, and of showing that some of them are more valid than other ones. Admittedly, philosophers do not dispose of the equivalent of experimentation to test the validity of their theories. They share however with experimental scientists the requirement of consistency, of coherence. For a theory to be acceptable, it needs to be coherent.

[2] Inspired from B. Brecht and heard in a German anti-nuclear demonstration : Wildt (1999 : 215).

[3] On these figures : Peplow (2006), Dupuy (2006 : 51ff.). Highest estimate: Bertell (2006 : 247).

And such a requirement is sufficient to discard some potential candidates in a political discussion focusing on what we should do.

My claim is that when dealing with issues such as radiological protection, it is not enough just to tell people what we know about facts and their causes. We should also tell them which are the available normative views, which ones are more likely to be consistent, and what implications the choice of one or the other may have on the issue at stake. A public debate without proper input from theories of justice on the normative dimensions of an issue should not be considered well-informed, as it is the case with a debate in which scientists would not have had any input on modelling or representation of facts. Complexity is present at both factual and normative levels and requires a clear analysis, ensure that citizens understand the full implications of their decisions. In addition, majority vote is a justifiable and important rule in a democratic society. It may certainly be a necessary test to consider an outcome as fair. It is however not a sufficient one. For it makes sense to say that there are many cases in which a majority takes unfair decisions, notwithstanding the fact that all parties have been heard. This means that the outcome of a deliberation can be independently assessed, through the prism of substantive theories of justice.

Moreover, in the same way as a reference to mere "common sense" would seem out of place when it comes to assessing the genetic effects of radioactivity, such a reference is equally out of place when it comes to addressing complex normative questions regarding whether this or that person *should* be burdened with radioactive risks. The attractiveness to some of appeals to *common sense* may originate from different sources. An anti-theoretical move first. Yet, it is not necessarily very consistent to accept the explanatory power of scientific theories while denying any justificatory power to normative philosophical theories. Second, there may be the idea that the gap between what we should do and what most of us are in fact willing to do is huge. This is often not true. And even when it is, the existence of such a gap should not necessarily be seen as a sign of inadequacy of our theories. Very often, it is our behaviour, rather than our theories, that is inadequate.

Finally, let us clear up one further possible source of misunderstanding. Scientists may believe that the reason why ethical issues are especially significant in the realm of radiological protection would be due to the fact that risks and uncertainties are especially important here, more than in other areas. "Ethics" would then play the role of a default set of rules whenever what should be done becomes especially blurred due to factual uncertainties. It is true that issues of risk and uncertainty (i.e. risks when probabilities cannot be calculated) render our decisions especially complex. However, two points are in order here. First, ethical issues are as important in domains where the risk or uncertainty dimension is not especially present. Second, in most cases, the existence of risk and uncertainty on the factual side does not modify in any deep sense the nature of the problems of justice that we ought to address. Risk and uncertainty often constitute red herrings when it comes to identify issues of radiological protection that are really challenging from the perspective of theories of justice.

This paper will be divided into two sections. In the first one, I will present three families of theories of justice. I will then unfold their implications in the intergenerational domain . And I will say a few words about the articulation of risk and uncertainty issues with the idea of justice. In the second section, I shall address in turn

three set of issues that have to do with radiological protection, asking each time whether theories of justice have anything special to tell us on each of these issues.

Theories of intergenerational justice

Three notions of justice: Aggregative, distributive and commutative[4]

Justice is in part about protecting basic freedoms. It is also about allocating burdens and benefits. Radiological protection focuses on burdens of a certain type, on their prevention, their "optimization" once justified and their allocation. In order to understand how theories of justice can deal with this, let us start with a simple case involving a regulator having to allocate a given consumption good (e.g. a banana) among two people: a rich person having contributed more to the social product, and a poor one whose poverty is due to no fault of her own. Let us focus on three intuitions. The first one will recommend to allocate this banana in such a way as to generate as much additional well being as possible. The aim here is to maximize the aggregate amount of well-being. The second intuition is that the banana should be allocated to the person who is the most disadvantaged, in order to reduce inequalities as much as possible or to ensure that the situation of the least well off ends up being the best possible. The third intuition is that the banana should be granted to the one who most contributed to the social product. We should thus make sure that larger inputs get larger rewards. The first intuition is an aggregative one, the second a distributive one and the third a cooperative one (or a commutative one, when it comes to bilateral relationships). Let us unfold these three intuitions.

According to the aggregative intuition, what matters is whether an action or a rule ultimately promotes the largest possible aggregate well-being in society. Utilitarianism is the standard version of an *aggregative* theory using *well-being* as a currency. Notice that distributive or cooperative justice can also rely on welfare ("utilitas" in Latin) as a metrics. Moreover, we could imagine other currencies (e.g. "opportunities for welfare") the aggregate of which we have to be maximized. In short, aggregative views are not the only ones to care about welfare and they are not always welfarist either. Moreover, "utilitarianism" is often mistakenly read as "instrumentalism". "Utilitas" does not have to do with transforming people into mere means, into mere instruments. It has to do with what we care about when we are concerned with how people fare, i.e. their welfare.

According to the distributive intuition, what matters is not the total size of the cake of well-being, but the distribution of this well-being within society. Again, a distributive theory can focus on other metrics than welfare, such as opportunity for welfare, primary goods, capabilities (basic or not), etc. What matters is the focus on the relative size of the endowments that each person benefits from. In short, it concentrates on the inequalities among people, rather than in the total size of the relevant good in such a society. In most cases, the metrics, the currency will be defined in such a way that inequality reduction only applies to a more or less limited sphere, such as the resources required to cover people's basic needs (in which case we will talk about an egalitarian form of *sufficientarianism*) or the compensation of disadvantages resulting from circumstances only (as opposed to

[4] For two introductions to the theories of justice : Kymlicka (1990), Arnsperger & Van Parijs (2000).

choice).[5] The latter view is referred to as luck egalitarianism and will typically treat differently disadvantages resulting from knowingly taking risks by practising dangerous sports, from disadvantages resulting from a congenital handicap for example.

Three remarks are in order at this stage. *First*, aggregative theories do not primarily care about distribution. However, if slicing the cake of social income in a certain way were to have an impact on the total level of well-being, an utilitarian would certainly not be insensitive to income inequalities.[6] *Second*, there is one intermediary theory, referred to as *aggregativo-distributive* that neither focuses primarily on the total size of the social cake of well being, nor is concerned about inequalities as such, but rather on improving the absolute situation of the least well-off members of society. Such a *prioritarianism* (or "maximin egalitarianism") focuses on improving the situation of the least well off, either as much as possible (standard prioritarianism) or up to a certain level of sufficiency (sufficientarianism, here in its prioritarian form). In general, an egalitarian approach (focusing on the reduction of inequalities) and a prioritarian one (focusing on the improvement of the situation of the least well off) will lead to advocating exactly the same policies. However, it won't always be the case, as the famous "argument from incentives" in fiscal policy illustrates. *Third*, according to several distributivist views, what we owe each other is at least in part independent from each of us' input in society, which is not the case for a cooperativist view. Take the case of a heavily and congenitally handicapped person. She may be contributing less to society than fully active people. Yet, she may be deserving *more* than the latter in terms of social benefits, under a distributive view.

This brings us to the third intuition, the cooperativist (or commutative) one.[7] The idea here is that what we benefit from as a result of social cooperation should be at least as large as our input in the social product and/or proportional to that input. In a bilateral contractual relationship, the input of each party should be comparable. Otherwise, the output should be distributed proportionally to the input of each party. In no way is such a view able to justify benefits to people with no input at all, or an allocation of burdens and benefits merely aiming at maximizing social welfare. For distributivists, the problem of such a cooperativist (or commutative) view is generally that it does not correct at all the initial inequalities that constitute the starting point of each of the potential cooperators. And for a strict cooperativist, people should not be expected as a matter of justice to make net positive transfers to the benefit of others, as compared to what they would have in the absence of cooperation.

Intergenerational justice

Intergenerational justice is only *one* dimension of justice that radioprotectionists should look at. Yet, it is the one on which we shall focus on here. Let us very briefly present the intergenerational version of each of our

[5] See e.g. Dworkin (2000)

[6] See e.g. Arnsperger & Van Parijs (2000 : 24-25) on the relevance of diminishing marginal utility.

[7] See e.g. Gauthier (1986)

three families of theories, focusing especially on the distributive one.[8] We begin with the commutative view, consisting in this case in an "indirect reciprocity" view. What does it tell us? First, why do we have obligations towards future generations? Not to make sure that they do not end up being more disadvantaged than we are. The reason is rather that we received something from the previous generation, which generates a debt that should be paid back. The subtlety is that we are supposed to pay it off to the next rather than to the previous generation. This is what makes it an *indirect*, rather than a direct reciprocity view. For the set of persons to whom we owe something back is not the same as the one constituted by our initial benefactors. Second, the theory of indirect reciprocity also tells us *what* we owe to the next generation: at least as much as what we inherited from our ancestors.[9]

What about the aggregativist view? One feature of the world plays a key role here: capital, if properly invested, can be productive. Aggregativists thus focus on back-loaded goods of a certain type: those involving early burdens that will generate larger benefits in the future.[10] Take a simple example. You produce seeds. Instead of consuming just enough to sow the same amount of crops next year, you consume a bit less and keep them. These remaining seeds will give you many more seeds the year after. Suppose that for most types of investments, the return will be higher in the future than the corresponding consumption today. If this is so, early generations should tighten their belts to allow later generations to transfer them much larger benefits than the self-imposed burdens falling on early generations. In other words, rather than defending a prohibition on transferring less to the next generation, and an authorization to transfer more, utilitarians will generally advocate an obligation to consume less than what we inherited in order to end up transferring to the next generations a productive capital *larger* than the one we inherited. This is supposed to bring about an intergenerational world in which intergenerational well being, i.e. the aggregation of each generation's welfare, would be maximized. Utilitarianism thus tends to advocate the sacrifice of early generations to the benefit of later ones, in the name of maximizing the total happiness of the whole set of generations (early and late ones).

As to the distributive view, it generally involves a (hopefully short) accumulation phase, followed by a steady state stage. To limit ourselves to the latter, an author like Rawls advocates the idea of a prohibition on transferring to the next generation *less* than what we inherited from the previous one, and an authorization to transfer more.[11] Egalitarianism at steady state would thus advocate the same principle as the indirect reciprocity view. In fact, I have defended elsewhere the egalitarian view that there should be a *prohibition* not only on transferring less, but also transferring *more* to the next generation than what we inherited.[12] This may be surprising. For what could possibly be wrong for a generation being especially generous towards the next one? Here is the answer. If one generation has a surplus compared to what she inherited from the previous generation, she should allocate it to the least well off members of its own generation, rather than to the next generation as a

[8] For an introduction to intergenerational theories of justice : Gosseries (2005)

[9] For a systematic treatment of intergenerational reciprocity : Gosseries (2006)

[10] On the front-loaded/back-loaded distinction : Gardiner (2006) and below <pp. x–y>.

[11] Rawls (1999 : § 44, pp. 251-258)

[12] See Gosseries (2001) (2004 : chap. 4), Gaspart & Gosseries (2007)

whole. Hence, transferring more to the next generation is unfair to the least well off members of our own generation. Notice that this claim proceeds from an *intergenerational* concern, not from any preference towards the members of one's own generation. The idea is simply that if we are concerned with adopting an intergenerational path such that the least well off, whichever generation they are members of, be as well off as possible, the rule prohibiting both transferring more (savings) and transferring less (dis-savings) would best help taking such a path.

Of course, there is a set of assumptions underlying this principle of prohibition on both generational savings and dis-savings.[13] And there are exceptions to the rule as well. In some cases, for example, if future exogenous disadvantages are to be expected (e.g. major degradations of our future environment due to natural phenomena), we would then have the obligation to transfer *more* than what we inherited from the previous to the next ones, to make sure that they don't end up being more disadvantaged than we are. Utilitarianism may to some extent – through the idea of diminishing marginal utility – be able to integrate this dimension. But a reciprocity-based view would certainly be totally unable to justify an obligation to transfer *more* than what we inherited.

Moreover, it is important to link this with Brundtland's view. If we give it a sufficientarian reading, Brundtland's view consists in saying that we could transfer to the next generation *less* than what we inherited, provided that they are able to cover their basic needs. And we are also allowed to transfer *more* to the next generation, provided that we don't jeopardize the ability of the members of our own generation to take care of their basic needs. This is still another theory, which can be seen as a form of egalitarianism or prioritarianism. Still, this reading of Brundtland definitely advocates a very different intergenerational principle from the Rawlsian one, or from the one I would defend as the most plausibly egalitarian view.[14]

Justice, risk and uncertainty

Before proceeding with the examination of a few of the radiological protection issues, let me say a few more words about risk and uncertainty. Why is it central? Probably for several reasons. *First*, when we deal with the very long term, time increases or decreases risks, depending on their nature. For example, as we increase the time frame, the number of generations also increases. And the more the latter increases, the more we increase the risk that members of one of them would e.g. mismanage radioactive wastes. On the other hand, as the radioactivity level of wastes slowly decreases with time, the physical risk decreases accordingly. In short, time affects risk in both directions. *Second*, our knowledge of the effects of radioactivity is not yet as good as our knowledge of the effects of e.g. fridges or vaccines. Here, what matters is both the relatively recent character of our interest in radioactivity (not longer than for fridges) and the intrinsic complexity of its effects (higher than

[13] For a full account of this argument: Gosseries (2004 : chap. 4), Gaspart & Gosseries (2007)

[14] See Gosseries (2004)

for fridges). And one of the recurrent questions in this respect has to do with whether threshold effects are present or not, which is of course crucial when dealing with low level exposure to radiations.[15]

Risk as well as uncertainty (when probabilistic assessment is unavailable) are ever present in the debate. Do they raise any specific difficulties for theories of justice? The latter have long been concerned with issues of risk, as the following three points illustrate. First, neo-contractarians have tried to bridge hypothetical insurance with justice. The paradigmatic device in this respect is Rawls's *veil of ignorance*.[16] By asking us to imagine a world in which some of our characteristics are hypothetically ignored, we are trying to find out what a self-interested (or "mutually disinterested") agent would choose as a theory of justice, given his level of risk aversion. And the idea of *maximin* promoted by Rawls can certainly be read both on the risk side (avoiding the worst case scenario) and on the justice side (avoiding the institutional setting such that the least well off will be worse off than in alternative institutional settings).

Another aspect of the risk issue is the treatment offered by luck egalitarians of risk-taking behaviours. To put things very briefly, luck egalitarians will tend to endorse two key principles. On the one hand, disadvantages resulting for me from my circumstances should be fully compensated by society. On the other hand, disadvantages resulting for me from my choices should not be compensated for by society. As mentioned earlier, an example of the former is a congenital handicap leading to a series of disadvantages. As to the latter, it is best illustrated by people practising risky sports. Bad luck will be referred to as bad brute luck in the former case and as bad option luck in the latter case. Of course, this distinction raises a series of questions. For example, does the availability of insurance transform any bad brute luck into bad option luck? And how should we treat altruistic risk-taking that would lead to disadvantages to the risk taker? Yet, this offers us a second illustration of the connection between theories of justice and risk/uncertainty issues.

The third point is the most important one. There have been attempts at connecting risk-aversion with the idea of justice. And we also saw that luck egalitarians attach specific consequences to risk-taking behaviours. Here is a third issue: is imposing risks on others fundamentally different from actually harming them? Is it fundamentally different to hit a person or to set up a device that is likely to harm her through a small explosion involving exactly the same degree of harm? I don't think so. The difference between imposing a harm and imposing a mere risk of harm becomes especially small when we look at risks involving large probabilities of occurrence or large populations of potential victims (which is the case with a succession of large generations).[17]

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[15] See the current debate on the impact of radiations on cataract

[16] See Rawls (1999 : §§ 24 – 26)

[17] For a concurring view : Shue (1986: 194). See as well : Thomson (1985), Nozick (1974 : 75). Note that imposing a harm (rather than a mere risk of harm) may differ significantly in the eyes of the potential victim. The two may differ analogously to the way in which pointing your finger at someone to send her to war would differ from slecting her through a lottery. (Thanks to G. Ponthière for this point).

Let me add three remarks with regard to this focus on risk. *First*, we often tend to focus on *levels* of risks. And we forget that the *distribution* of such risks among potential victims or the compensation mechanisms to be set up to compensate those few (and sometimes many) who end up being the unlucky victims of these risks are equally important. No doubt, the distribution of such risks may on some occasions follow an intergenerational axis. And sometimes, society will automatically ask the risk taker alone – for various reasons - to compensate for the harm – as in no fault liability regimes. *Second*, we often forget that taking small risks today could sometimes *preserve* us from much higher risks in the future, which is also relevant to issues of intergenerational justice.[18] *Third*, perhaps for some of the nuclear issues (most notably waste management), focusing on risk is often a way of focusing on the burden side only, because the benefits associated with such burdens are seen as distributed quite uniformly within society.

To conclude very briefly before actually exploring the implications of these developments for radiological protection, there are two points worth insisting upon once again. First, we presented three key intuitions of justice as well as their general implications for a theory of intergenerational justice - which is the only dimension along which we will analyse the issues below. Each of these three intuitions lead to quite distinct views when it comes to intergenerational justice. Second, we insisted upon the need to distance ourselves from an exclusive fascination for risk and uncertainty to also address the standard justice issues that radiological protection invites us to look into.

Nuclear issues

With this toolbox at hand, let us address some of the issues of *intergenerational* justice raised by the use of radioactive substances. We shall be selective. For example, the fact that uranium is a non-renewable resource raises similar intergenerational issues as those raised by the use of fossil fuels. The exact contribution of nuclear energy to climate change, the connections between civilian and military uses of radioactive materials, as well as whether we should continue relying on nuclear energy at all are also set aside. What will matter here is the *nature* of *some* of the intergenerational problems at stake, independently of the assessment of their quantitative importance.

Nuclear wastes

Front-loaded goods

Nuclear wastes are emblematic of what can be referred to as "front-loaded" goods, i.e. practices whose temporal distribution of costs and benefits spreads across several generations and is of a "benefits first, costs later" type. This is especially so since the degradation rate of electricity is very high, the one of radioactive

[18] I am indebted to V. Beloin on this

wastes is very low[19] and the life of nuclear power plants only spans over a few decades. In contrast, investment in blue sky research or renewable energy is paradigmatic of *back*-loaded good, with costs coming first and benefits arising later. As Gardiner pointed out, one may expect "each generation to oversupply front-loaded goods and undersupply back-loaded goods".[20]

The notion of "front-loaded" goods offers a good first approximation of the problems at work here. Yet, its use requires two qualifications. *First*, whereas in the case of back-loaded goods, the temporal distribution of benefits and costs can be roughly defined, it is less so for front-loaded goods since it is rarely true that there will be no "spill-over" benefits to later generations resulting from earlier energy consumption. "Descending benefits" (i.e. benefits accruing to later generations through the efforts of earlier ones) may of course not be easy to trace precisely. Yet, they are very likely to obtain, taking the form of durable material goods (e.g. large dams), or of immaterial ones (e.g. technology). Still, it may remain plausible to claim that nuclear wastes constitute a case in which earlier generations will enjoy *net* benefits, whereas later generations could incur *net* costs as a result of it.

S*econd*, for some types of radioactive wastes, the temporal distribution of costs and benefits might actually be such that they are "middle-loaded" rather than "front-loaded". Of course, they will *always* be "middle-loaded" if we take a very long term perspective since the degradation rate of radioactive wastes is positive. But they may be "middle-loaded" even from a more "short-term" perspective. In fact, taking high-level radioactive wastes resulting from the operation of power plants as an example, and leaving the development phase (± 50 years for PWR) as well as financial provisions aside, four phases can be identified: (i) licensing and construction phase (± 10 years, net burden), (ii) beginning of the operation phase (30 to 60 years, net benefit if there is no accident), (iii) phase-out and decommissioning of the plant (± 30 years) and management of the spent fuel until it cools down (± **200 years** <check>, significant net burden), (iv) waste management (through geological disposal) after the waste cooled down (**thousands <check>** of years, small net burden).[21]

A rule of thumb

Having characterized the general nature of the problem, what about potential principles of intergenerational justice with respect to radioactive waste management? Take the following candidate: "radioactive waste shall be managed in such a way that will not impose *undue burdens* on future generations" (the "undue burdens" principle).[22] Such a principle certainly implies that future generations matter. Yet, the too vague notion of "undue burden" requires the help of a theory of justice for its definition.

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[19] And yet, it is positive, which is not the case of other dangerous types of waste such as asbestos, thallium, etc. Thanks to A. Debauche for this point.

[20] Gardiner (2006 :149)

[21] Jackson (2006: 8).

[22] International Atomic Energy Authority (1995: 17, principle 5, our italics). See as well: Nuclear Energy Agency (OECD) (1995, p. 7)

What about the idea that "the generations that receive the benefits of a practice should bear the responsibility to manage the resulting waste"?[23] This principle may be taken as an appropriate rule of thumb, bearing in mind that it is potentially both not demanding enough and too demanding. It would *not be demanding enough* if, once the fact that benefits may also accrue to later generations is acknowledged, the first generation would not have to bear the full responsibility for setting up the scheme. Here, two things should be separated. Of course, if later generations also benefit, it can make sense for them to contribute to the costs. However, there is a special responsibility of the first generation that sets up the power plants, *even if* benefits also accrue to later generations. This extra responsibility of the first generation consists in anticipating as well as possible the temporal distribution of costs and benefits before launching the project. This could be included in the term "managing" above, and should not be seen as dependent on the degree to which the first generation benefits or not from the technology. As a matter of fact, the very first generation that develops the technology and sets up the plants may have no net benefits at all given the time it takes.

The "undue burden" principle *may be too demanding* as well, for two reasons. The *first* one is that a generation may well transfer burdens with regard to nuclear waste management, while transferring to the next generation much more than what it inherited in other respects (e.g. renewable energy technology, enhanced political institutions, etc). Limiting us to the benefits of a given practice and asking for the absence of net costs being imposed with respect to that very same practice presupposes that negative intergenerational transfers in one sector (e.g. nuclear energy) cannot be compensated by positive ones in another sector (e.g. more powerful peace enforcing institutions). In other words, adopting such a closed principle at a *practice-specific* level denies any *substitutability* of gains at one level to losses at other levels. Yet, a public debt unproblematic if it is used to fund the construction of schools for example, the latter benefiting mostly to coming generations. The *second* reason why this principle might demand too much (and sometimes too little as well) is that a generation could be less lucky overall than another, through no fault of her own (e.g. adverse natural conditions concentrating especially on one generation). In that case, a distributive theory of intergenerational justice of a luck egalitarian type (see above) would certainly allow that such natural "exogenous" disadvantages be compensated by allowing an earlier generation, if exogenously disadvantaged, to violate our principle above, and imposing larger waste related costs to the next generations.[24]

In short, if our rule of thumb can be regarded as a good general principle, we should be aware of its limitations, the latter varying according to the general theory of intergenerational justice we use to assess this rule of thumb. For example, a commutative approach may agree on the substitutability dimension, while not seeing the "exogenous disadvantage" idea as relevant. Let us now look more closely at two central issues that have to do with radioactive wastes and check whether our rule of thumb has anything to say.

[23] International Atomic Energy Authority (1995: 17, principle 5).

[24] On this exogeneous disadvantage hypothesis: Gosseries (2001)

Storage or geological disposal for highly radioactive waste?[25]

92 % of a sample of 24 708 European citizens interviewed in 2005 agreed that "a solution for highly radioactive waste should be developed now and not left for future generations".[26] At the same time, the data from a 2000 French consultation on nuclear waste storage/disposal conclude to a massive opposition of the public to geological disposal.[27] In fact, at all levels of radioactivity, the storage/disposal of radioactive wastes raises an issue of intergenerational justice, i.e. which policy should we adopt *today* in view of the need to be intergenerationally fair. We need to balance a set of risks, the nature, level and distribution of which will vary. Let us focus on C type wastes (high-radioactivity vitrified wastes). Such waste will remain very warm for 150 to 200 years. Leaving reprocessing aside, let us compare two options: interim storage during 100 years (possibly followed by geological disposal),[28] or disposal in deep geological structures within the 40 years of the waste production.

What are the risks involved in geological disposal? There is some degree of irreversibility insofar as geological disposal is concerned, at least once the disposal site has been fully filled in.[29] Such an irreversibility – despite not being total – raises two difficulties.[30] One may want in the future to retrieve the waste either because of serious risks of leakage that would not have been anticipated or because of newly discovered uses of such radioactive wastes, e.g. due to the discovery of new reprocessing techniques. As to interim storage at the surface, risks of leakage can more easily be dealt with in principle. However, if not dealt with (which is also a risk),[31] their consequences might be worse than in the case of geological disposal. Moreover, while the opportunity cost involved in deep disposal has to do with a loss of energy resource, storage on the surface may also have an opportunity cost in terms of loss of space – admittedly very limited for C wastes. Finally, geological disposal offers seismical conditions safer than in case of mere storage.[32] And the risk of intentional proliferation (e.g. terrorism) is clearly larger in the case of storage at the surface. The present day situation may bias us as to the importance of the latter risk.[33] But the history of the last century or so as well as the mere observation of the international situation clearly indicates that even in the absence of international terrorism, political stability itself is always hard to secure. This constitutes a serious reason against retrievability. This is worth emphasizing because irreversibility is often seen as unacceptable because it would amount to "imposing our choice on future

[25] On this issue : Shrader-Frechette (1993), Bouttes & Shapira (2005)

[26] European Commission (2005: 70).

[27] Boisson, Huet & Mingasson (2000 : 43)

[28] A solution proposed e.g. by Shrader-Frechette (1993 : 195)

[29] Boisson, Huet & Mingasson, (2000 : 49)

[30] Bouttes & Shapira (2005 : 4)

[31] For a recent Belgian example: Crivellaro (2003), Crivellaro (2003a), Schoune (2003) (more than 400 defective barrels in 2003 (and 55.000 similar ones thrown at sea)

[32] Boisson, Huet & Mingasson (2000 : 50)

[33] Shrader-Frechette in 1993 was already discussing this argument though (1993 : 188).

generations".[34] We often forget two things in this respect. First, in most cases, any alternative will necessarily lead to irreversible consequences. Moreover, reversibility may be associated with risks that may themselves, if they end up leading to harm, threaten to reduce future generation's opportunity set irreversibly. This is true with the risk of proliferation. But take as well the total eradication of a virus that used to kill thousands of people every year. This would be irreversible. But would that necessarily be a bad thing for future generations? Most probably not, even if it deprives experimental biologist of a possible research object.

Provided that proper studies are made (which is the case in several western countries), deep geological disposal in the next 30 years looks like the most defensible option and the fairest one for both current and future generations. If risks of leakages are compared, storage at the surface runs both risks of intentional leakages (of potentially major impact for both current and future generations if not take care of) and of accidental ones (of potentially large impact on both current and future generations as well). Leakages are also a risk in the case of geological disposal, but their impact is likely to remain local.[35] And they will be less serious due to both the ability of the geological structure (clay, granite, salt) to act as extra barriers and the fact that the leakages occurring in the future will occur at a time when the level of radioactivity of the wastes will have become much lower. Given the development of renewable resources, the loss of a potentially re-usable resource does not seem to weigh much once compared to the risks of both accidental and intentional leakage involved in storage at the surface.

Let us now adopt another perspective on this storage/disposal by leaning on the 1995 OECD NEA report on the matter. Their standpoint is sensible and goes as follows:

"our responsibilities to future generations are better discharged by a strategy of final disposal than by reliance on stores which require surveillance, bequeath long-term responsibilities of care, and may in due course be neglected by future societies whose structural stability should not be presumed".[36]

This illustrates the *sequential* nature of intergenerational issues. There will be hundreds of "intermediary" generations between the one setting up a nuclear power plant and the last one to be potentially affected by radioactivity. Each of them will have to pass the bucket on to the next one. Whether the current generation will end up having managed to transfer what she should to the final generation potentially affected will depend on each of these intermediary generations. And this sequential nature can be taken into account in at least three ways here. *First*, through insisting on the fact that the structural stability of future societies should not be presumed,[37] the NEA makes clear that to avoid problems such as significant proliferation, a minimal political stability of each and every of these "intermediary" generations is needed. Geological disposal relies on

[34] Boisson, Huet & Mingasson (2005 : 43) (our translation). For other explicit references to future generations in relation to irreversibility: Ecoiffier (2000), CNE (1998 : IV).

[35] Bouttes & Shapira (2005 : 5)

[36] Nuclear Energy Agency (OECD) (1995 : 5).

[37] *Ibid*. (1995 : 5)

geological stability (when it comes to seismic risks) while not taking for granted the political stability of future societies. *Second*, in insisting on "bequeathing a passively safe situation which places no reliance on active institutional controls"[38] may imply at the same time that we should not rely on the coming generations to *care for* our wastes until they cease being significantly radioactive, regardless here of the risks of political instability. *Third*, there is the idea of not relying on the technical knowledge of future generations regarding radioactivity, as "we cannot be sure that future society will maintain the knowledge (…) necessary for the protection of humans and the environment from hazards inherent in a strategy of supervised storage".[39] At the same time, the knowledge of intermediary generations could be relied upon to address the "out of sight – out of mind" phenomenon.[40] The latter concern is mentioned in the NEA report. [41] Considering all this, it is hard to follow Shrader-Frechette when she claims that "it is clear that permanent disposal places the greatest health and safety risks on members of future generations".[42]

Do our theories of justice help to choose among the envisaged scenarios? Our rule of thumb is not of much help since we have to decide about various possible interpretations. And as we stressed earlier, as soon as we don't adopt a problem-specific version of these theories, there is certainly room for leaving debts to the future in the nuclear realm as long as we compensate in other respects. Suppose now that we don't know anything about the other intergenerational transfers likely to take place and that we focus on our two scenarios only (*ceteris paribus* approach). A utilitarian theory will privilege intergenerational savings. Investing in reducing future risks (especially risks for the near future) at a comparable implementation price will clearly amount to a form of savings. Similarly, a luck egalitarian theory will certainly expect a generation not to transfer to the next one a stock of productive potential lower than the one it inherited (per capita). Risks of adverse effects of various types (including malevolent leakage) clearly have to be discounted from such a stock. If the aggregate risks to the next generations are less serious (both in terms of likelihood and of size of potential harm) under the geological disposal option, and if there are no reasons to believe that the temporal distribution of implementation costs of each formula need to differ, the case for geological disposal is clear. If we believe on top of it that there is a tendency to underestimate future disposal costs (as suggested by the British experience),[43] this case for geological disposal becomes even stronger. The same holds for the commutative view of intergenerational justice.

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[38] *Ibid*. (1995 : 8)

[39] *Ibid*. (1995 :10)

[40] Note that as the precise list of disposal sites may have to be kept confidential for security reasons, keeping in mind the existence of such wastes may turn out being especially difficult. See Crivellaro (2003b).

[41] Nuclear Energy Agency (1995 : 9).

[42] Shrader-Frechette (1993 : 183)

[43] See Jackson (2006 : 24-28) (labour costs time bomb), Cour des comptes (2005 : 205).

The funding issue[44]

If the intergenerational structure of the of nuclear energy production problem is one of a front-loaded good, this can be countered by appropriate funding aiming at making sure that the money will be available in the near future to decommission power plants (and deal with spent fuel, a related issue left aside here) in order to reduce as much as possible the potential impact of radioactivity on the future. Suppose that power plants are owned and run by states (rather than private firms). Abiding by our rule of thumb to deal with the issue of funding, the main net beneficiaries of power generation through nuclear power plants should provide for the funds necessary for decommissioning.

There are three main funding options regarding decommissioning. In all three cases, we need an initial (and possibly revisable) estimate of total future decommissioning costs, possibly based on a pessimistic scenario. Once this is done – it can be reassessed all along – we can have a *prepayment* system through which a lump sum is set aside from the very beginning, covering the estimated full costs of decommissioning, such that with the annual interests estimated at 5% (from which we substract an inflation of 2%) we will end up at the end of the plant's estimated lifetime with the amount needed to cover the full decommissioning costs.[45] This initial sum would thus correspond to the value of the future sum necessary for decommissioning. It should deal better than the next option with hypothesis of early closure.[46] The second option consists in the *progressive build up* of the appropriate fund (sinking fund), which means that if a plant has to be dismantled before its normal exploitation time, there might not be enough money put aside. A lesser burden will thus be put on early generations than under the prepayment option. The risk of underfunding in case of early closure is larger. The third option – that could also operate as a complement to the two other ones - is one of *insurance* (comparable to a life insurance). A premium is paid each year and the insurance company has to be ready to make the money available (possibly through a lump sum) whenever the termination of operations has to be decided.[47]

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[44] For an explicit reference to intergenerational justice: Cour des comptes (1998 : chap. V – 18). For a general overview of the existing funding experiences : Tchapga (2005). For an overview of the Belgian situation : Degros (2004)

[45] See e.g. Belgian Act of April 11, 2003 (Loi sur les provisions constituées pour le démantèlement des centrales nucléaires et pour la gestion des matières fissiles irradiées dans ces centrales), Art 11, §3, http://www.ejustice.just.fgov.be/cgi/api2.pl?lg=fr&pd=2003-07-15&numac=2003011326. Note that one equivalent of this would consist in including in the initial price of the plant the decommissionning costs, as B. Tinel suggested to me.

[46] See e.g. DGEMP/DIREM/SD2/2A, 10 may 2006, "Présentation à la Commission européenne du dispositif de sécurisation du financement du démantèlement des installations nucléaires et de la gestion des déchets nucléaires", p. 2.

[47] On these three options : US Nuclear Regulatory Commissions Regulations, § 50.75 (e) (http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0075.html), Cour des comptes (2005 : 203) (constitution immédiate v. constitution progressive).

Assessing which one of these three options is more likely to satisfy the requirements of intergenerational justice is difficult. In fact, a preliminary reminder is in order. As is also true in the pay-as-you-go v. funded pension schemes debate,[48] whichever of our three options we end up promoting on grounds of intergenerational justice, it will always and necessarily burden future generations at a very fundamental level. This is stressed upon by the French Minister of Planning and the Environment in a reply to the 1998 Cour des Comptes annual report:

« (…) there will unavoidably be a transfer of burdens to future generations, that the Cour des comptes would like to avoid but that is intrinsic to the nuclear activity. For whatever the mechanism one may imagine to guarantee the availability of the necessary sums of money at the time they are needed, such sums will only have a real value if they have a counterpart in the economic activity at the time when they will have to be made, the necessary spending being subject to later challenge through a strong degradation of the economic situation. Such burdens are thus clearly a burden on future generations.»[49]

Setting aside money is not like setting aside non-degradable goods for future use. Financial capital will only have value in the future if there is a corresponding economic activity going on. With this point in mind, let us now first consider the case of the *early closure* of a power plant's operation. Who pays? In the *prepayment* case, each of the generations from the beginning of the operation onwards will pay. Later generations are less likely to have to pay directly. In the *progressive build up* case, if there is underfunding, it will be the generation present at the time of termination that will have to pay for the rest, and possibly later ones in case this is managed through imposing a debt on later generations. In case of *insurance*, the intergenerational impact will depend on the extent to which insurers are able to mutualise the risk through time, i.e. make future insurees, possibly insured for other kinds of risks, pay for such decommissioning costs. This will depend among other things on the degree of competition on the insurance market. It is thus likely that the prepayment option will concentrate the effort on early generations more than the two other options.

Let us then add an extra source of complexity. So far, we assumed that power plants were owned by the state and that the relevant funds were managed by the State and raised through taxing citizens. As a matter of fact, power plants are increasingly run by the private sector. And when it is the case, one should contemplate the possibility of *bankruptcy*, e.g. just before the planned termination of the plant's operation. This is not implausible, not only because of the room firms may have for strategic behaviour, but also because the nuclear energy sector is unlikely to grow much in the future,[50] at least in western countries. In case of bankruptcy, how

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[48] See e.g. Gosseries (2005a : 302). One difference with the pensions issue is that decommissionning is limited in time. Thanks to B. Tinel for attracting my attention on this.

[49] http://www.ccomptes.fr/Cour-des-Comptes/publications/rapports/rp1998/rp1998_42.htm (our translation)

[50] Cour des comptes (2005 : 205) (on how bankruptcy of British Energy was avoided) ; Jackson (2006 : 21-24) (On the fact that nuclear decommissionning companies look like « a bad long-term investment prospect on the stock market »).

do our three funding options behave? *Prepayment* into a legally protected/ruled fund, provided that the estimation of the necessary funds was correct, is quite robust in such a bankruptcy case. The financial burden will be mostly carried by early generations of stakeholders (especially clients, workers and shareholders) of the firm, rather than by citizens at large. *Progressive funding* is more vulnerable and is likely to shift part of the financial burden from pre-bankruptcy stakeholders to post-bankruptcy citizens at large, even if the State is granted the status of a privileged creditor. *Insurance* will be able to cover decommissioning costs if the bankruptcy is not incorporated as a clause of exclusion. But it will still shift the burden on future insurees, rather than on future taxpayers in the previous option. And the risk of bankruptcy of the insurance company itself should be envisaged as well, even if there is a state guarantee protecting insurees.

Many more issues could be discussed here. But what matters is to emphasize the difficulties involved in providing a plausible generational assessment of the costs distribution of each of the three options in a relevant number of hypothesis. This difficulty originates from various sources. One problem is that if the early generation puts money aside while not being ready to reduce its consumption accordingly, it will simply reduce other intergenerational financial transfers accordingly (substitution effect), be they channelled through state budgets or intra-family transfers. At the end, disposing of proper funding set aside by the early generations may end up not making any difference in terms of what each generation will inherit *as a whole* from the previous one. Another issue is whether it makes any difference from the intergenerational point of view that the financial burden would be imposed on taxpayers at large rather than merely on the stakeholders of large private electric utilities. Admittedly, these groups do not fully overlap. And burdening one rather than the other might have significant efficiency as well as *intra*generational justice effects. For example, it is crucial for states in this respect not to let firms leave them with the responsibility for the costs while fleeing with the benefits. It is also of key importance that the amounts needed be properly estimated,[51] and that the money set aside be invested in a manner that is not too risky, in order to ensure that we will indeed end up with the appropriate amount of money.[52] Finally, defining who should run the fund is also of crucial importance, as a fund run by a (set of) private firms (typically electric utilities), even supervised by state authorities, does not necessarily offer the same guarantees as a fund run by the state itself.[53] My (informed) guess is that contrary to the storage/disposal issue, the funding dimension raises important issues of justice. Yet, that are not primarily of an *inter*generational nature.

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[51] On the underfunding hypothesis: 2003 Belgian Act, Art. 11, § 3; Cour des comptes (2005: 206).

[52] See EU Commission Recommendation of 24 October 2006 on the management of financial resources for the decommissioning of nuclear installations, spent fuel and radioactive waste (OJ, L 330, 11.28, 2006), § 21, available at http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_330/l_33020061128en00310035.pdf; US Nuclear Regulatory Commission Regulations, § 50.75 (c). A recent and interesting issue was raised as well when the Belgian government decided to devote part of the money set aside to lend money to projects aimed at increasing energy efficiency (especially on the demand side). Should that be seen as a legitimate use of the money?

[53] For a Belgian illustration: Condijts (2006)

Long-term hereditary effects and the two extra generations restriction

In its 2005 Draft Recommendations, the ICRP proposes a new framework to estimate hereditary risks induced by exposure to radioactivity:

"(…) New genetic risk coefficients recommended by ICRP consider exposure and genetic risk for *two generations only* – the equilibrium value used in ICRP60 is judged to be of questionable scientific validity because of the unsupported assumptions necessary on selection coefficients, mutation component and population changes over hundreds of years"[54]

A scientific controversy exists as to whether it is true that no or merely negligible genetic effects may occur beyond the second generation.[55] Yet, there is no theoretical reason to believe that a genetic mutation could not be transmitted beyond the second generation. Suppose that there were indeed some *significant* effects of radioactivity *beyond the second generation*. It would then be problematic not to take them into consideration in the moral assessment of a present action. This being said, there are two specific dimensions of the problem should be considered in turn.

First, there is the so-called "non-identity" problem.[56] In many cases involving claims of alleged (future) harms to future people, taking measures today to avoid such future harm will often mean that *other* individuals will be born. For example, modifying our energy policies is likely to affect the organization of our time, the amount of time we spend in commuting, etc. And since this means that we will have sexual intercourse at *different* moments, the children who will be born will not be the same ones since they are very likely to result from the meeting of possibly the same egg with a different spermatozoa. This apparently anecdotic fact raises an unexpectedly serious and quite intractable challenge for moral philosophy. For we end up with a situation in which avoiding harm for a given future person will in fact mean that she is likely never to exist. To put things differently, if an allegedly harmful action also turns out as a matter of fact to be a necessary (or very likely) condition for the victim's very existence, a concept of harm cannot be used. For a standard concept of harm always requires a comparison between the actual state of a person and the counterfactual state of that very same person, i.e. the state in which she would have found herself in, had the allegedly harmful action not taken place. If we agree that no obligations can obtain unless a violation of such obligations can lead to some harm, this is of course of great significance.

This argument is complex and has been defended and challenged in various ways. It holds for nuclear energy as well. Suppose – quite plausibly - that changing energy policy would reduce radioactivity, while

[54] ICPR (2005 :Annex A, section A17, my emphasis). See as well : (2005 : §108).

[55] See ICPR (2005 : § 109), UNSCEAR (2001).

[56] *Locus classicus* : Parfit (1984 : chap. 16)

simultaneously changing not only the genetic background – which only modifies the qualitative identity of a person -, but also the "numerical identity" of future people (i.e. neither how *many* people will be born, nor how they will *look like*, but *who* will be born), through various channels (necessary changes in energy use, leading to significant changes in daily life timing, but also irradiation of some of the spermatozoa, leaving space to only those that would survive, etc.).[57] As I argued elsewhere, one way out of the non-identity argument is available at generational overlap. But how do we deal with cases in which a person carries a disease as a result of radioactive exposure, but does not develop it (radioactivity-induced recessive mutations). In case of such a recessive genetic mutation, we may have to wait for a few extra generations before one person actually develops the disease and becomes effectively ill because of it. This is a *time bomb* (or sleeper effect) kind of situation.[58] Why is this relevant? Because if the solution to the non-identity problem requires generational overlap, and if no physical harm actually occurs within generational overlap between the allegedly harming generation and the next one(s), then we would be stuck again with the non-identity problem. However, there is a sense in which a person carrying the mutation without actually being ill can be said to be harmed. She is not physically harmed. But knowing about the risk that one of the next descendants may actually develop the disease, she will have to transfer her more resources as a matter of justice, to make sure that her descendants do not end up in a worse situation than her (compulsory generational savings). At least this obligation will obtain for an egalitarian theory of justice, perhaps not for a standard version of the indirect reciprocity view. And this is how time bombs can also be said to harm in a way the *intermediary* generations in the face of which such bombs don't explode. This approach will seem far fetched to all those who are not familiar to the non-identity-problem. Yet, this is a problem that has to be addressed with the seriousness it requires, regardless of how anecdotic it may seem at first sight.

In short, even if we take the non-identity problem seriously and the possible "time bomb nature" of *some* of the hereditary effects of radioactivity, there is no philosophical justification – at least for an egalitarian - , if scientific data were to confirm that there can be significant effects beyond the second generation, not to take such effects into consideration at all.[59]

Adjusting adult standards to children levels

The last issue I wish to briefly look at supposes that we take generations not as "birth cohorts" but rather as "age-groups". The question is: should we adapt our general standards to the level of radioactivity acceptable for children rather than for adults. There are three general approaches to such type of problem, when dealing with "minorities" that are especially affected by a given policy. Either we simply impose it without compensation,

[57] See e.g. Gosseries (2004 : Chap. 1)

[58] On time bombs and intergenerational justice : Gosseries (2004 : 97-98 & 232-234).

[59] Admittedly, a certain degree of discount rate could be justified (e.g. referring to the uncertainty as to the existence and number of future people). But not a degree such that future generations would be fully disregarded.

arguing that whatever policy we adopt will always have an adverse impact on *some* categories that are especially vulnerable. For example, if we go for an affirmative action policy, some members of the group over-represented up to now will of course suffer from it. But at the same time, if we don't enact such an affirmative policy, it is members of the under-represented group that will suffer even more from such an inaction. Alternatively, we may claim that minorities will indeed suffer from imposing inappropriate standards, but that this is unavoidable and that the best thing to do is to compensate such victims *in cash*. Car traffic kills many people every day on the planet. In the best cases, we will compensate the family of such victims (not the victims themselves since we are dealing with deadly accidents). Aggregativists will typically adopt such a policy up to the level where a marginal gain from increasing traffic becomes more expensive than the costs involved in compensating victims. But distributivists may be unhappy with such a view, belonging then to a third possible approach. We may want to argue that people should be protected from some types of potential harm, and that mere financial compensation is not enough. The intuition behind this can be of various types, including libertarian views on people's right to physical integrity or assumptions as to the impossibility of fully compensating some kinds of harms. As suggested above, someone who gets killed by the traffic will and could never be compensated for that. Of course, this third view is often difficult to implement whenever we are dealing with pollutants that are widely dispersed.

Let us now more to the case of children and radioactivity. If child-specific standards were ineffective, should we fix our general radiological protection standards at the levels of what would be required for children not to be harmed? Answering this question requires an answer to two sub-questions. The first one is of a scientific nature. Are there factors that make children more vulnerable towards radioactivity than adults? The answer is positive. Among those factors, let us mention two.[60] *First*, children are smaller than adults. This means that their organs are smaller and their cells less numerous. There is then less backup tissue. Moreover, bystander effects, i.e. effects on the cells surrounding a damaged cell are likely to have a proportionally larger effect. *Second*, besides this size effect, the replication rate of cells in the case of children is much higher than for adults. This makes the acquisition of the set of genetic mutations required for the development of cancer much more likely.

Children are thus biologically more vulnerable to radioactivity. Our second sub-question belongs to the sphere of theories of justice. Should we care more specifically about children, *even if* they were not more biologically vulnerable than adults? The answer is positive and twofold. *First*, children were not even able to participate in the democratic process. How can a state then impose on them rules or absence of rules the adoption of which they did not take part in, and that are harmful for them?[61] *Second*, it is clear that in case of non-fatal diseases, even if they were not more biologically vulnerable, children would be more affected for two reasons: either their quality of life would be affected for longer if their additional life expectancy remains unchanged. Or, in case of fatal diseases, their life expectancy at birth would be lower than the one of people impacted at adulthood. If, in

[60] Thanks to C. Busby on this. See as well Voisin (1999).

[61] One may add that children are less well informed (Shue, 1986: 198-199) (discussing the case of saccharin as a food additive) and hence are unable to form express consent if exposure is avoidable (cognitive vulnerability). This is relevant to justifying children-specific standards (e.g. for medical uses) as well as here.

the latter case, it makes sense, *ceteris paribus*, to aim at equalizing life expectancies (or improving the life expectancy of the least well off), it is clear that children deserve special attention here, as a matter of mere justice. This holds at least insofar as we focus on a situation in which the level of radioactivity surrounding us is not constant and uniform. If the location of radioactivity can be controlled and kept away from children to some extent, children-specific standards will do, without the need to adjust the standards of the whole population accordingly. And if radioactivity is constant through time, then each generation will be equally affected, including at childhood, which will not generate inequalities in life-expectancy for example. The hypothesis of constancy is not realistic, though. This is clear when considering accidental radioactivity (e.g. Chernobyl) as well as the fact that there has necessarily been a *first period* affected by non-natural radioactivity. In that period, young and old coexisted, which entails that two cohorts were differentially affected, including in terms of average life-expectancy. First periods are likely to occur whenever new sources of radioactivity are developed.

Conclusion

Let me conclude very briefly in two steps. For all issues involving an intergenerational dimension, it is crucial to refer to existing theories of intergenerational justice. Expecting that democratic debate as such is enough to bridge the factual dimensions of the issues with their normative implications is not enough. If citizens need a minimal grasp of scientific theories to understand the basics of natural phenomena, they also need to get minimally acquainted with theories of justice to be able to find their way into the normative implications of our practices. This is so even if it turns out for *some* of these issues that selecting one theory rather than another will not make much difference. For whether it makes a difference or not can only be ascertained once we checked the relevant policies against these theories. To take an analogy, it would be erroneous to conclude from the fact that an experiment would confirm that a given chemical is not toxic for any living being that we did not need experimental science in the first place.

As to our three specific areas of focus, what should we conclude? *First*, regarding radioactive waste, on the issue of disposal/storage, there is an intergenerational case for "early" geological disposals, especially when we consider the seriousness of risks of malevolent uses. As to the funding issue, it is not clear that the intergenerational constraint imposes strict constraints. However, for other reasons of justice, there might be a case for picking one of the three options. And it would certainly be worth considering with more care the insurance option. *Second*, regarding radioactivity-induced hereditary diseases, serious doubts can be raised about the "two extra generations" restriction. *Third*, there are serious reasons of justice to consider seriously adjusting our radiological protection standards to those that would be required to adequately protect children. This is so at least when children-specific standards alone will be ineffective to protect children (e.g. because of impossibilities of restricting some forms of radioactivity to a sphere in which they would only affect adults).

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