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Commentary

Precaution and Cholera: A Response to Tickner and Gouveia-Vigeant

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1. INTRODUCTION

The precautionary principle is said to promote prevention, rather than cure, especially in relation to potential risks from modernity. The hopes are that the precautionary principle will generate a new environmental law system that will protect the present and future generations against the environmental and health risks associated with our contemporary production methods and consumption patterns, which have become highly technological. Precaution therefore is regarded as the lodestar on the road to sustainability. As the European Commission puts it:[1]

> The dimension of the precautionary principle goes beyond the problems associated with a short- or medium-term approach to risks. It also concerns the longer run and the well-being of future generations.

Many arguments have been put forward in favor and against the principle and many articles and books have been produced either in defense of, or highly critical of, the precautionary principle. However, the discussion seems to us rather polarized: proponents and critics tend to add to the discourse in no uncertain terms. This does not make it easy to review the discourse on precaution.

Tickner and Gouveia-Vigeant add to the discussion by addressing a frequently used example in the precaution discourse that purportedly shows the failure of precaution, namely, the cholera epidemic in Peru. The argument goes that as a result of the application of the precautionary principle, decisionmakers stopped chlorination of the water supply due to the risks of disinfection byproducts (DBPs), resulting in the epidemic.

Tickner and Gouveia-Vigeant emphatically argue, with the aid of diverse material, that such is not the case. Multiple interconnected factors contributed to the 1991 cholera epidemic, and even full chlorination of drinking water in Peru probably would not have prevented the epidemic, although, they state, that more insistent preepidemic disinfection would have reduced the magnitude of the outbreak. They further state that the Peruvian case distracts from the numerous examples of failures to apply precaution and the well-documented implications for health, the environment, and the economy. Their closing remark that despite the fact that every decision tool, precaution included, will likely result in some failures (they mention the issue of tradeoff risks), in their view, the cholera example failed to adequately demonstrate the failure of the precautionary principle.

In this response we contend that the arguments put forward by Tickner and Gouveia-Vigeant in favor of the precautionary principle unwittingly demonstrate the inescapable failure of the principle. One of the main problems with it, as we will discuss below, is the confusing role and function of science. It is not *per se* the case that precaution engenders an attitude of anti-science in decisionmakers, as Tickner and Gouveia-Vigeant correctly ascertain. It is worse than that. Our contention is that the precautionary outlook provokes unjustifiable scientific restrictedness supportive of the application of the precautionary principle, as a result of which the ideological vulnerability of the scientific community is critically augmented.

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[1] Communication from the Commission on the Precautionary Principle. (2000). Commission of the European Communities, Brussels.

Precaution of necessity has a lopsided perspective on science: choices of research topics, the development and justification of hypotheses, and the application of scientific results are permeated by the precautionary worldview held by its proponents. Scientific research therefore is carried out in line with those worldviews, generating by default a precautionary-biased outcome in terms of preferred hypotheses and selected underpinning data. Implementation of the principle, consequently, is self-evident. The DBPs issue in the Peruvian case can only be a focus of scientific and regulatory discussion because of precautionary environmental and public health concerns, among other things, set off by the cultural ecological critique,[2] and cannot be regarded as a serious and noteworthy trade-off risk in relation to water treatment with chlorine and its concomitant reduction of the risk of microbiological contamination.[3]

Below, we will briefly discuss the framework of science in relation to worldviews. We will show that the precautionary principle is part and parcel of a specific worldview with overarching influences on all parts of the framework of science, whereby *a priori* selection of science and its results will be produced. This generates a confusing role for science in the environmental debate. In conclusion, we will comment on the Peruvian case as an irrelevant falsification of the failure of the precautionary principle.

1.1. The Framework of Science in Relation to Worldviews

The status and application of scientific knowledge in relation to environmental issues have become increasingly important, as it impacts on the precautionary perspective. How scientific knowledge is understood and actually used impinges on the ways in which environmental issues are viewed. We therefore need first to establish a framework in which the scientific enterprise can be positioned, and see whether or not worldviews and ideologies shape and influence the process of scientific inquiry.

Before we do that we need to distinguish between *actual* science and *good* science, and the way worldviews in reality, or in theory, do (should) or do not (should not) impact on the development of theories and explanations, and the way experimentation is set up.[4] The Lysenko affair was a prime historical example of the (in this case catastrophic) influence of worldviews on science.[5] However, from this historical example (and there are others to give) that actual science is not always good science, it does not inevitably follow that good science *should* be wholly identical with actual science. The refutation of the existence of worldview-neutral science—as so often stated with reference to the work of Kuhn[6]—does not result from one or even multiple examples.

If good science should be worldview neutral—that is to say that it is not aligned to, or does not support, a particular ideology, religion, or worldview over another—then the activity of science needs to be specified more precisely. Weber, for instance, asserts that results from scientific work are value free *if* they do not contain any judgment of personal, cultural, moral, or political value.[7] In this particular sense, science is worldview neutral. However, values cannot, Weber emphasises, be eliminated when it comes to what scientists choose to investigate. In this particular sense science is *not* worldview neutral. Therefore, in order to refine the issues of (partial) worldview influences and elucidate the actual locations of these influences, it is helpful to distinguish four different stages of the scientific *modus operandi*:[8]

1. The problem-stating phase of science (science$_1$)
2. The development phase of science (science$_2$)
3. The justification phase of science (science$_3$)
4. The application phase of science (science$_4$)

2 Hanekamp, J. C., Verstegen, S. W., & Vera-Navas, G. (2005). The historical roots of precautionary thinking. *Journal of Risk Research*, *8*(4), 295–310.

3 The hormetic dose-response discussion raises serious issues with the linear non-threshold (LNT) dose-response extrapolation traditionally held in this field.

See, e.g., Calabrese, E. J. (2005). Historical blunders: How toxicology got the dose-response relationship half right. *Cellular and Molecular Biology*, *51*, 643–654.

4 Stenmark, M. (2004). *How to Relate Science and Religion. A Multidimensional Model*. Cambridge: Wm. B. Eerdmans Publishing Co. (Religion, here, is in the wider context referred to as worldviews.)

5 Jovarsky, D. (1970). *The Lysenko Affair*. Chicago: University of Chicago Press.

6 Kuhn, T. S. (1970). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

See for initial work on the sociology of knowledge: Fleck, L. (1935). *Entstehung und Entwicklung einer wissen-schaftlichen Tatsache: Einführung in die Lehre vom Denkstil und Denkkollektiv.* Basel: Benno Schwabe & C. This rather unknown book has been given attention by Kuhn, who himself became famous for his work on the philosophy of science. Fleck's work is translated: Fleck, L. (1979). *Genesis and Development of a Scientific Fact*. Chicago: University of Chicago Press.

7 Weber, M. (1949). *On the Methodology of the Social Sciences*. New York: Free Press.

8 Derived from Stenmark, note 4.

In relation to $science_1$, scientists must first decide what is worth studying, what they want to spend their time, energy, and their own, or other people's, money on. This might seem a trivial matter, yet Imre Lakatos expressed his trepidations on this matter already some decades ago quite clearly (italics in the original):[9]

> *In my view, science as such, has no social responsibility.* In my view it is society that has a responsibility—that of maintaining the apolitical, detached scientific tradition and allowing science to search for truth in the way determined purely by its inner life. Of course, scientists, as citizens, have responsibility, like all other citizens, to see that science is *applied* to the right social and political ends. This is a different, independent question.

Lakatos's concern was that $science_1$—the problem-stating phase of science—is threatened by political (ideological) intrusions. Obviously, in the contemporary scientific enterprise, this political influence has materialized more extensively than Lakatos could have anticipated. Research efforts usually require large sums of money, which results in the mandatory involvement of governments and economic parties who can actually supply the necessary and usually large funding. Consequently, people in power often decide the kind of research that "should" be initiated, and the kind that "should" be neglected. $Science_1$—in short—has become heavily politicized and commercialized. Climate research—as an environmental example—is a primary illustration in which "big money" is a prerequisite for its advancement. Its results are subsequently, and not surprisingly, appraised within the political context of the suppliers of that money, namely, governments.

After scientists have chosen their research arena, and have defined the problems to be solved, they subsequently try to devise methodologies suitable for solving these problems, and try to develop hypotheses that would provide adequate explanations of phenomena under scrutiny and test them against what they consider to be evidence. If evidence is lacking or insufficient to corroborate the hypotheses, scientists try to find better and more conclusive evidence. This—in Stenmark's terminology—is the development phase of science; $science_2$.[10] This phase of the scientific enterprise is not without its problems in relation to worldview influences. One particular issue has to do with the fact that if a certain group of scientists with a particular worldview dominates a certain scientific area, then their intrinsic political commitment could well hinder development of certain hypotheses that might better explain empirical data than actually are developed by this group of people.

The application phase of science—$science_4$—is the most obvious candidate for worldview influence. Scientific knowledge—construction or theory—formation is now generated to a major extent with a perspective specifically on application. Here, the societal and political expectations of science's ability to provide clearcut and useful answers to an escalating range of issues and problems surface most poignantly. What "useful" means depends of course on the particular worldview one holds and one's position toward government, industry, NGOs, etc.

The concepts and empirical data produced are discussed at conferences, published in peer-reviewed scientific journals, and the like and might even make it into the public media. In the justification phase of science—$science_3$—scientists try to convince the rest of the scientific community of the adequacy of the explanations they have put forward through the different scientific platforms of communication in order to have their theories accepted as a part of the *corpus* of scientific knowledge. Although the other parts of the scientific endeavor are in fact, and sometimes problematically, influenced by worldviews of different sorts, worldview influences on $science_3$ are the most challenging and, as is our contention, counterproductive. Worldview influences at the justification phase of science ($science_3$) fundamentally distort the process of science.

Our line of reasoning is simple: theories should be accepted by the scientific community only in the light of considerations that involve transparent and reproducible empirical data, other (accepted) theories, and cognitive values such as consistency, simplicity, integrity, and explicatory power. Worldview (political and ideological) considerations, but also appeals to authority, consequences, force, and popularity—to name some of the argumentation fallacies—clearly are illegitimate ways of deciding between theories.[11] These undermine the integrity and

9 Lakatos, I. (1978). *Mathematics, Science and Epistemology: Philosophical Papers*. Volume 2. J. Worall & G. Currie (Eds.) (p. 258). Cambridge: Cambridge University Press.

10 See note 4.

11 Appeal to authority: a proposition is held to be true because it is held by persons regarded to be authoritative in a specific field.

Appeal to consequences: the author points to the disagreeable consequences of holding a particular belief in order to show that this belief is false.

Appeal to force: the reader is told that unpleasant consequences will follow if he or she does not agree with the author.

Appeal to popularity: a proposition is held to be true because it

Table I. Science and Worldviews

	Worldview-Neutral Science	Worldview-Partisan Science
Problem-stating phase		+
Development phase		+
Justification phase	+	
Application phase		+

transcend the boundaries of science.[12] Our basic tenet is that one does not have to agree as to what constitutes a good human life, a good society, what a righteous societal order is, etc. In Table I, Stenmark portrays the scientific enterprise—science$_1$ to science$_4$—in relation to worldview influences with which we concur.[13]

Obviously, the extent to which worldviews shape the scientific process is not encapsulated in this scheme. Nonetheless, we are convinced that few scientists today seem to be conscious of the effects of various worldviews on the scientific questions asked, the generation of empirical data, and on the formulation and assessment of theories.

For science to operate sustainably and trustworthily, the justification phase of science needs to be driven by interscientific standards alone, as discussed above. Worldview influences on science$_3$ are fatal for the scrutinized theories in question if indeed these influences generate a bias toward the "politically correct" theory, that is to say that a theory that is politically (or ideologically) helpful for the main group of researchers in question in terms of (research) money, power, authority, or otherwise is favored. Thereby extra-scientific deliberations—other than reproducible and consistent empirical data, consistency, explanatory power, simplicity, and so on—are taken on board in order to decide discriminatorily between available theories, explanations, and empirical data.

1.2. Science and the Precautionary Principle

Environmental issues have gained central prominence in the world and within the global scientific community. This is not an *a priori* qualification of the potential importance of environmental issues as such, yet has much to do with historical processes. Bramwell, in her study on the ecological movement in the 20th century, firmly positions the rise of environmental thinking to political power in the early 1970s of the 20th century when the cultural ecological critique merged with the scientific economic concept of nonrenewable resources.[14] The conservative moral and cultural ecological critique combined with a recognizable scientific basis has rendered "green thinking" the powerful political force it is today. Bourke remarks, on a similar note, the rise of a public and scientific interest in environmental issues in relation to public and private fears. She observes:[15]

> The fear of crime was not the most potent dogging late-twentieth-century societies. There was another category of danger that frightened many Britons and Americans as the century staggered to its conclusion: ecological degradation.

Here, we use "ecology" and "ecological" in the normative political sense. It encompasses the belief that a man-induced drastic change within the environment is wrong and should be prevented or amended.[16] Ecology is therefore associated with conservation, sustainability, and precaution. Green thinking on the one hand postulates "wrongness" about Western industrialized society in, for instance, its use of finite resources and its pollution potential and on the other hand sees part of the solution in a reorganized society in which these resources could be used more efficiently, whereby environmental contamination could be curbed.

Western culture over time incorporated the notion that natural resources and the environment enforced strict limits on world population and economic growth and therefore on science and technology. Precautionary thinking should mainly be seen as a reaction: it is an answer to the self-confidence mainstream society had in the "progress" of postwar civilization. It is an antithesis that materialized when, especially Western, civilization was stirred by stories and facts

is widely held to be true or is held to be true by some sector of the population (e.g., upper class).

12 See further Weinberg, A. M. (1972). Science and trans-science. *Minerva*, *10*, 209–222.

13 See note 4.

14 Bramwell, A. (1989). *Ecology in the 20th Century. A History*. London: Yale University Press.
Bramwell, A. (1994). *The Fading of the Greens. The Decline of Environmental Politics in the West*. London: Yale University Press.
See note 2.

15 Bourke, J. (2005). *Fear. A Cultural History*. UK: Virago Press. See also Furedi, F. (2002). *Culture of Fear. Risk-Taking and the Morality of Low Expectations*. UK: Continuum.

16 Veldman, M. (1994). *Fantasy, the Bomb and the Greening of Britain. Romantic Protest, 1945–1980*. Cambridge: Cambridge University Press.

about pollution and the degradation of nature.[17] The precautionary principle, in other words, is an essential part of the cultural ecological critique, which was brought center-stage in the early 1970s.

Grübler points out that science and technology itself delivered the data to underscore this line of thought: the first space missions rendered pictures of Earth as a small blue planet engulfed by the dark hostility of space.[18] Science and technology as originators of the perceived predicament of humanity has proven to be indispensable to highlight and measure the very same predicament.[19] Here, (part of) science merged with the environmental (green) worldview, and is thereby implicitly and explicitly employed to explicate issues thought to be important within this worldview. Science_1 (the problem-stating phase), science_2 (the development phase), and science_4 (the application phase) within different scientific fields are thus to a considerable extent directed by "green thinking."

1.3. Science in Defence of the Precautionary Principle: Undermining Science_3

Tickner and Gouveia-Vigeant apply the scientific method to elucidate risks that might or actually threaten human and environmental health.[20] Their scientific treatment of the Peruvian case as a presumed erroneous example to demonstrate the failure of precautionary principle bears witness to that obligation. They make the case that the tradeoff between DBPs, as a result of chlorination of drinking water, and cholera when chlorination is precautionarily abandoned is an overtly simplistic dichotomy not supported by evidence. Nevertheless, they mention that DBP trepidations may have simply provided a convenient rationale for the complex set of factors that limited expanded chlorination.

Furthermore, they state that research over the past 20 years has indicated that DBPs pose "uncertain, though real risks" to human health. However, what are "uncertain, though real risks"? Notwithstanding this mystifying risk characterization of DMP risks, in their view concerns over DBPs cannot be considered a false positive. Tickner and Gouveia-Vigeant therefore uphold a risk tradeoff between DBPs and chlorination, which is not resolved in the article within the precautionary context. A mere risk tradeoff is presented—clearly in favor of chlorination, as they state that "increased chlorination would have significantly reduced, but not have prevented or stopped the cholera epidemic"—in which precaution has no role to play. What is more, the article of Tickner and Gouveia-Vigeant does not address or show the usefulness of precaution as such. From a logical point of view the alleged efficacy of the precautionary principle is not corroborated by a refutation of a failure of precaution.

The analysis put forward by Tickner and Gouveia-Vigeant divulges what is clearly amiss with scientific research in the realm of the precautionary principle. On the one hand, both authors vigorously engage in the scientific method to make an effort to disprove an ostensible example falsifying the merits of the precautionary principle. In contrast, the scientific method is barely deemed constructive in cases where precaution, in their view, should operate. Indeed, "evidence indicating that there is a potential for harm" in their view suffices in the implementation of the precautionary principle. However, "evidence" of "potential" is not evidence at all; it is speculation.[21] The precautionary principle introduces asymmetry in the elucidation of risk by means of the infusion of the precautionary worldview in the justification phase of science (science_3). Indeed, as the Rio definition shows:

> Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The lack of robustness of scientific justification bearing out certain risks in relation to processes and products is a common theme when the principle is implemented. The antibiotic growth promoter issue is exemplary thereof.[22] The European Commission

17 See note 2.

18 Grübler, A. (1998). *Technology and Global Change*. Cambridge: Cambridge University Press.

19 See note 2.

20 The scientific method employed by most scientists comprises, put succinctly and oversimplified, the formation of a hypothesis followed by verification. Three evaluative criteria can subsequently be put forward: (i) any hypothesis must include all available data (integrity); (ii) the scope of the hypothesis must be no more complex than the coherent inclusion of all data requires (simplicity); (iii) the hypothesis must make sense of the available data and outperform competing hypotheses (explicatory power).

21 See, e.g., Gori, G. B. (1996). Science, imaginable risks, and public policy: Anatomy of a mirage. *Regulatory Pharmacology and Toxicology*, *23*, 304–311.

Gori, G. B. (2001). The costly illusion of regulating unknowable risks. *Regulatory Pharmacology and Toxicology*, *34*, 205–212.

22 Bezoen, A., Van Haren, & W., Hanekamp, J. C. (1999). *Emergence of a Debate: AGPs and Public Health. Human Health and Antibiotic Growth Promoters: Reassessing the Risk*. Amsterdam: HAN.

Phillips, I., Casewell, M., Cox, T., De Groot, B., Friis, C., Jones, R., Nightingale, C., Preston, R., & Waddell, J. (2004). Does the banned several antibiotic growth promoters as a precaution, disregarding the advice of the European Union's own Scientific Committee on Animal Nutrition (SCAN). SCAN's unambiguous scientific statement was that data to support a ban was deficient.[23] Lack of evidence of risks associated with resistance transfer from animals to humans was translated into the meaningless truism, "[a]bsence of evidence of harm is not evidence of absence of harm,"[24] in order to defend the use of the precautionary principle. As there is a distinct bias in favor of negative information about possible health dangers,[25] and because it is easier to prove that a particular risk exists than to prove that any and all possible risks are absent, the precautionary principle is prone to generate a *probatio diabolica* (the proof of a negative), which is impossible and thereby unlawful. Tradeoffs of the ban—most importantly the increase in usage of therapeutic antibiotics in food animals of direct importance in human medicine—were wholly ignored.[26]

Another example concerns the precautionary ban of phthalates.[27] DINP—a presently banned phthalate generally used in toys—recently underwent an EU Scientific Risk Assessment, which clearly showed that children are not at risk from the use of DINP in toys, including from those that can be put in the mouth.[28] Implementation of the precautionary ban thereby ignored the scientific method and its results.[29]

The justification phase of science (science$_3$) is seriously undermined when scientific research is concerned with the precautionary principle. The phthalates and antibiotics cases show that in expounding a certain scientific position, the precautionary stance *a priori* permeates this justification process by selecting scientific knowledge (hypotheses and data) in line with the envisioned precautionary measure. Accordingly, the breadth and depth of *available* scientific knowledge (scientific integrity)[30] is edited to precautionary needs; both examples mentioned above are proof positive thereof.

In the Peruvian case, Tickner and Gouveia-Vigeant state that DBPs pose risks to human health, whereby a tradeoff between DBPs and cholera is induced. However, within the precautionary framework they do not resolve this risk tradeoff. They simply state that "increased chlorination would have significantly reduced, but not have prevented or stopped the cholera epidemic." The fact that the risks of DBPs in relation to cholera and drinking water chlorination are raised at all is typical of green thinking. The current regulatory witch hunt of chemicals to which humans are exposed to at low levels[31] simply amounts to superstition disguised as risk predictions

use of antibiotics in food animals pose a risk to human health? A critical review of published data. *Journal of Antimicrobial Chemotherapy*, *53*, 28–52.

Cox Jr., L. A., & Popken, D. A. (2004). Quantifying human health risks from virginiamycin used in chickens. *Risk Analysis*, *24*(1), 271–288.

Forrester, I., & Hanekamp, J. C. (2005). Precaution, science and jurisprudence: A test case. *Journal of Risk Research*, accepted for publication.

23 SCAN. (1996). *Report of the Scientific Committee for Animal Nutrition (SCAN) on the Possible Risk for Humans of the Use of Avoparcin as a Feed Additive, 21 May 1996*. Luxembourg: Office for EC Publications.

SCAN. (1998). *Opinion of the Scientific Committee for Animal Nutrition (SCAN) on the Immediate and Longer-Term Risk to the Value of Streptogramins in Human Medicine Posed by the Use of Virginiamycin as an Animal Growth Promoter, 10 July 1998*. Luxembourg: Office for EC Publications.

24 Christoforou, T. (2004). The regulation of genetically modified organisms in the European Union: The interplay of science, law and politics. *Common Market Law Review*, *41*, 637–709.

25 Siegrist, M., & Cvetkovich, G. (2001). Better negative than positive? Evidence of a bias for negative information about possible health dangers. *Risk Analysis*, *21*(1), 199–206.

See for an explanation of negative bias: Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin*, *110*(1), 67–85.

26 Casewell, M., Friis, C., Marco, E., McMullin, P., & Phillips, I. (2003). The European ban on growth-promoting antibiotics and emerging consequences for human and animal health. *Journal of Antimicrobial Chemotherapy*, *52*, 159–161.

27 Durodié, B. (2003). The true cost of precautionary chemicals regulation. *Risk Analysis*, *23*(2), 389–398.

Bergkamp, L., & Hanekamp, J. C. (2003). The draft REACH regime: Costs and benefits of precautionary chemical regulation. *Environmental Liability*, *5*, 167–180.

28 Babich, M. A., Chen, S.-B., Greene, M. A., Kiss, C. T., Porter, W. K., Smith, T. P., Wind, M. L., & Zamula, W. W. (2004). Risk assessment of oral exposure to diisononyl phthalate from children's products. *Regulatory Toxicology and Pharmacology*, *40*, 151–167.

29 European Commission—Joint Research Centre Institute for Health and Consumer Protection European Chemicals Bureau (ECB). (2003). *European Union Risk Assessment Report 1,2-Benzenedicarboxylic Acid, di-C8-10-Branched Alkyl Esters, C9-Rich and di-"Isononyl" Phthalate (DINP)*. Brussels: Publications Office.

30 Barnard, R. C. (1994). Scientific method and risk assessment. *Regulatory Toxicology and Pharmacology*, *19*, 211–218.

31 Hanekamp, J. C., Frapporti, G., & Olieman, K. (2003). Chloramphenicol, food safety and precautionary thinking in Europe. *Environmental Liability*, *6*, 209–221.

Hanekamp, J. C., & Kwakman, J. (2004). Beyond zero-tolerance: A novel and global outlook on foodsafety and residues of pharmacological active substances in foodstuffs of animal origin. *Environmental Liability*, *1*, 33–39.

of formalistically correct mathematical formulas lacking biological meaning,[32] typical of the implementation realm of the precautionary principle.[33]

The article of Tickner and Gouveia-Vigeant, therefore, exemplifies the distinct asymmetry in relation to the usefulness of science in defending the precautionary principle. Reflecting a deep ambiguity toward the scientific method, the goal of precaution is "to foresee and forestall:"[34]

> Scientific uncertainty about harm is the fulcrum of this principle. Modern-day problems that cover vast expanses of time and space are difficult to assess with existing scientific tools. Accordingly we can never know with certainty whether a particular activity will cause harm. But we can rely on observation and good sense to foresee and forestall damage.

At first sight, it seems to stress that even when we have to be critical about what science has to offer—Tickner and Gouveia-Vigeant mention limitations in scientists' and policymakers' abilities to characterize and prevent complex and uncertain risks—we still can be optimistic since we have alternatives at our disposal to fall back on. However, when considering the alternatives—observation and good sense—we find that these are the basic tenets of the investigative attitudes that led to the development of science and the ideal of objective knowledge in the first place.[35] Inadvertently, with the precautionary principle we return to the very same thing that is discarded in the first place. So with the precautionary principle, a very high level of scepticism with regard to what science cannot do, goes hand in hand with a very high level of confidence regarding what science (observation and good sense) is supposed to deliver.

The irony of the article of Tickner and Gouveia-Vigeant—as a final point—is encapsulated in their complaint about the misuse of cases to discredit precautionary and preventive policies and their plea to be more sceptical before accepting such cases as true. Indeed, we need to have a "holistic understanding of complex sets of events rather than simple sound bites that present only part of the story." It seems clear to us that the proponents of the precautionary principle are in large part responsible for this situation. Cases where the principle is implemented are more often not based on fiction and sound bites that portray only part of reality. The whole of this reality can, within the scientific context and its boundaries,[36] only be elucidated by a scientific community perceptive of their worldview-neutral responsibilities, particularly and especially within the justification phase of science.

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32 See Calabrese, E. J., & Baldwin, L. A. (2003). Toxicology rethinks its central belief. Hormesis demands a reappraisal of the way risks are assessed. *Nature*, *421*, 691–692.

Calabrese, E. J. (2004). Hormesis—basic, generalizable, central to toxicology and a method to improve the risk-assessment process. *International Journal of Occupational and Environmental Health*, *10*, 466–467.

33 Rozman, K. K., & Doul, J. (2003). Scientific foundations of hormesis. Part 2. Maturation, strengths, limitations, and possible applications in toxicology, pharmacology, and epidemiology. *Critical Reviews in Toxicology*, *33* (3 & 4), 451–462.

34 Raffensperger, C., & Tickner, J. (Eds.). (1999). *Protecting Public Health and the Environment: Implementing the Precautionary Principle*. Washington DC: Island Press.

35 Latour, B. (1993). *We Have Never Been Modern* (p. 1). Cambridge: Harvard University Press.

36 Hence, there should be no room for scepticism, nor should there be any room for scientism. Scientism is the view that science alone is capable of resolving genuine human problems, whereby all areas of human life can be reduced to science. See Stenmark, M. (2001). *Scientism. Science, Ethics and Religion*. Burlington: Ashgate Publishing Limited.

See also Haack, S. (2003). *Defending Science Within Reason. Between Scientism and Cynicism*. New York: Prometheus Books.