24. Bodanksy D. The precautionary principle in US environmental law. In: O'Riordan T, Cameron J, eds. *Interpreting the Precautionary Principle.* London, England: Earthscan; 1994:203–228.

25. Graham J. Perspectives on the precautionary principle. *Human and Ecological Risk Assessment.* 2000;6:383–385.

26. Tickner J, Raffensperger C, Myers N. *The Precautionary Principle in Action: A Handbook.* Windsor, ND: Science and Environmental Health Network; 1999.

27. Tickner J, Raffensperger C. The American view on the precautionary principle. In: O'Riordan T, Cameron J , Jordan A, eds. *Reinterpreting the Precautionary Principle.* London, England: Cameron & May; 2001.

The Precautionary Principle and Electric and Magnetic Fields

Dale Jamieson, PhD, and Daniel Wartenberg, PhD

Current environmental regulation represents a paternalistic policy, more concerned to avoid false positives than false negatives, limiting opportunities for individuals to make choices between risk-avoidance and risk-taking alternatives. For example, many exposures to magnetic fields could be reduced at little or no cost but are not considered seriously, owing to the uncertainty of risk and the concern to avoid false positives.

Even though precautionary approaches that focus on avoiding false negatives often do not lead to adverse economic consequences or irrational choices, such approaches usually are not taken. The value of autonomy and the proper role of governmental paternalism with respect to environmental policy need to be considered more carefully in environmental decision making.

A clear distinction should be made between what is not found by science and what is found to be non-existent by science. What science finds to be non-existent, we must accept as non-existent; but what science merely does not find is a completely different matter. . . . It is quite clear that there are many, many mysterious things.

His Holiness the Dalai Lama[1]

THE PRECAUTIONARY principle came to prominence in Europe in the 1970s, and over the last 2 decades it has increasingly figured in international law and policy.[2] It is best thought of as a family of principles rather than a single principle. Some versions would appear to virtually banish technology (e.g., "where potential adverse effects are not fully understood, the activities should not proceed"[3]), while other versions border on the trivial (e.g., lack of "full scientific certainty shall not be used as a reason for postponing cost-effective measures"[4]). At its core, the precautionary principle is related to the familiar adages "An ounce of prevention is worth a pound of cure" and "It is better to be safe than sorry."

The precautionary principle can be contrasted with the "polluter pays" principle. The "polluter pays" principle, which is based on a long and respected tradition in Anglo-American jurisprudence, holds that those who cause harm to others through their polluting activities should pay for setting things right. For this principle to be applicable, (1) it must be possible to identify the polluter, (2) the effects of the pollution must be reversible, and (3) it must be politically and socially feasible to compel the polluter to reverse the effects of the pollution.

Clearly, in many cases of pollution, conditions 1 and 2 are, at best, difficult to satisfy. In many cases it is difficult to identify the polluter, or the sources of pollution are so widespread that it is difficult to identify particular agents as polluters. Also in many cases, such as those that cause death or the loss of irreplaceable ecologic goods, the effects of pollution are not reversible, at least on human timescales. Although some economists argue that the loss of any good can be compensated in monetary terms, this argument is not widely accepted in society.

Another alternative to the precautionary principle is a cost–benefit approach. However, in cases in which the precautionary principle comes into play, markets play only a small role and good cost–benefit information is not available (although people often will perform cost–benefit calculations anyway). Even when costs and benefits can be reliably computed, there may still be questions about the distributions of benefits and costs.

In any case, it is when conditions 1 and 2 are difficult to satisfy that discussion of the precautionary principle comes into play. For a wide range of cases, it seems reasonable to institute the precautionary principle. When it is difficult to identify specific causes and to link them conclusively to specific individual deleterious effects, it may be plausible to regulate substances that may have such effects even if the relationship has not been proven.

However, for the precautionary principle to be applicable, some link must be established between an exposure and some possible harm, although it is not easy to say what threshold of confidence should be required. Will a single complaint suffice, a single case, a single animal study, a single human study, some combination, or more? Should the regulatory cost, both in dollars and to society, be part of the decision-making process? In addition, if one chooses to go for-

ward, one must identify specifically what to regulate in light of the scientific uncertainty.

AN EXAMPLE: ELECTRIC AND MAGNETIC FIELDS

A case in which the precautionary principle has loomed large is the possible risk of childhood leukemia from residential exposure to electric and magnetic fields (EMFs). In 1979, Wertheimer and Leeper published the first modern study of the health effects from exposure to EMFs.[5] That study showed that children born in Denver, Colo, who died of leukemia were more likely to have lived in homes that had high EMFs (as characterized by a wire coding scheme) than in homes that had low EMFs. The conclusions of that study ran counter to current scientific knowledge, as there is no generally accepted toxicologic or physical mechanism by which nonionizing radiation, such as that produced by EMFs, causes cancer.

Several similar studies of EMF exposure were conducted in the United States and elsewhere, including a replication in Denver. In general, they produced similar but weaker results, lending some credence to the suggested association. The most recent reviews and expert panels have judged that although the results were not "consistent and conclusive," there is an association between exposure to EMFs and the occurrence of childhood leukemia[6–10] and EMFs are a possible human carcinogen.[7] Nonetheless, the plausibility and existence of the association continue to be debated in the scientific community.[11] The questions these studies raise in the context of the precautionary principle are what, if anything, should be done to limit or prevent exposure and possibly disease, and what data would be sufficient to warrant such actions.

As soon as the early EMF studies began to accrue, activists called for changes in the electrical systems in the United States to limit exposure. Their goal was to prevent possibly dangerous exposures even at the cost of preventing exposure to a nonhazardous situation. In the spirit of the precautionary principle, they were more concerned with avoiding false negatives than false positives.

Those who were more skeptical believed that the data were not sufficient to force the overhaul of the electric power delivery system. They sought to prevent costly exposure reductions, even if that resulted in putting some people at unnecessary risk. They sought to avoid false positives rather than false negatives. In part, this position was a response to the fact that we all depend so heavily on electrical devices day in and day out—exposure is ubiquitous, and discontinuing electrical use is not feasible. Modifications to appliances, residential wiring systems, and electrical power delivery systems are all possible, but potentially costly.

In the face of these considerations, 3 strategies were proposed: (1) do nothing unless the health effects data become more consistent; (2) allow individuals to make personal choices to limit exposure ("prudent avoidance"[12,13]); or (3) regulate power lines and appliances. These strategies differ markedly in terms of cost and exposure reduction[14] as well as in terms of whether they can be accomplished by individuals or must be implemented by manufacturers or utilities.

Further research has shown that technology offers a wide range of choices both in terms of cost and in terms of exposure reduction. The simplest solution to reducing residential exposure is to increase the minimum distance of the power line from the residence, reducing exposure exponentially as this distance increases. The cost is for the land and its maintenance only, but it can be high in more densely populated areas.

> *"Despite the diversity of precautionary approaches, the public policy debate . . . has focused on regulatory extremes: do nothing until the data are conclusive, or restructure major portions of the electric power delivery system."*

An alternative solution is to configure the wires on the poles in ways that reduce exposure. This option is less effective but also less costly. For new lines being constructed, the additional costs are minor. For existing lines, the cost is mainly that of rehanging the wires. For multiple-circuit lines (those with 6 or more wires), specific phasing of the electric current can markedly reduce exposure, again at little cost other than the initial setup of the wires, although certain technical issues about power delivery also must be addressed. For subtransmission and distribution lines (lower voltages), the lines can be placed underground, eliminating virtually all residential exposure. This option has the interesting trade-off of greater cost at installation and greater cost of repair but markedly less likelihood of accidental or weather-induced line breakage than occurs with lines on poles (i.e., greater reliability); it also has aesthetic benefits.

For appliances, redesign has offered some approaches to exposure reduction. Some manufacturers have reconfigured the internal wiring in electric blankets to reduce exposure (in a manner similar to rephasing of power lines), letting the marketplace guide personal choice and exposure reduction.

Despite the diversity of precautionary approaches, the public policy debate over the possible effects of exposure to EMFs has focused on regulatory extremes: do nothing until the data are conclusive, or restructure major portions of the electric power delivery system. Regulations to limit the rate at which exposure is increasing by restricting construction of new power lines to the lower-exposure configurations met with fierce opposition in some locations from people who do not believe that the association between EMFs and cancer has been proven and thus contend that no action should be taken.

Since the scientific uncertainty is unlikely to be resolved in the foreseeable future, policy decisions must be based on the possibility of risk and the cost and technology of reducing exposure. Whether such decisions should be dictated by personal choice in the marketplace (what to buy, which appliances to use) or gov-

ernmental regulation (where to build or whether to modify the electric power delivery system) depends in part on how one views the precautionary principle and its implications.

PATERNALISM AND THE PRECAUTIONARY PRINCIPLE

No regulatory principle will be error-free. Most will produce false positives and false negatives, but each principle will have a bias about what proportions of false positives and false negatives are tolerated. The precautionary principle is biased in favor of preventing false negatives. In contrast, many of our current regulatory policies are biased in favor of preventing false positives. For example, most air and water emissions from commercial activities are permitted unless they are specifically regulated.

The reason for avoiding false positives is to avoid panic, anxiety, and negative social and economic impacts. Some individuals have become extremely concerned over high exposures to EMFs and have paid to have their homes moved farther from power lines; some have paid to have power lines near a school reconfigured and buried underground to avoid what may be a nonexistent risk.

False negatives should be avoided to prevent unnecessary disease and potentially harmful exposures. It is estimated that if the association between exposure to EMFs and childhood leukemia is real, EMFs may be responsible for between 3% and 11% (depending on assumptions and models) of all childhood leukemias in the United States, or between 50 and 250 cases each year.[8,10]

In our personal lives, most of us favor precaution except when we voluntarily consent to greater risk. We prefer that our doctors seek to avoid false negatives rather than false positives. I can handle (or not) the anxiety and panic of false positives. If I am informed of the superset of risks, then I can decide which risks I want to take and which to avoid. If I am informed only of a subset of risks, then I will be subjected to risks to which I have not in any way consented. This suggests that we favor precautionary approaches because they respect our autonomy and enable us to choose which risks we are willing to bear. On the other hand, the bias in favor of avoiding false positives is paternalistic—it seeks to protect us from panic and anxiety, rather than providing us with knowledge that we can respond to as we wish.

> *"Even if we suppose that adopting the precautionary principle would lead consumers to react irrationally, this is an argument for educating consumers, not for depriving them of control over their own lives."*

It is surprising that so much of our environmental and public health regulation is paternalistic in this way, given that our society is generally moving away from paternalistic policies. This trend is especially striking in medical practice,[15] but it can also be seen in various other social policy innovations, such as proposals to privatize all or part of Social Security.

One reason why the precautionary principle has had little effect in the United States may be the difficulties, previously noted, in framing a fully adequate version of the principle. Another reason may be a concern about the economic consequences of adopting a precautionary approach. In a nutshell, the worry may be that if we give every individual the information he or she would need in order to act autonomously, this would lead to bad economic consequences for everyone, since people react irrationally to risk. Here are 3 responses to this concern.

First, it is not clear that precautionary approaches lead to bad economic consequences for everyone. Consider, for example, the resistance to labeling genetically modified foods. Even if it were true that consumers would actively avoid genetically modified foods, this would not be bad for everyone. It would be bad for those farmers and businesses that rely on producing genetically modified foods, but it would be an advantage to those farmers and businesses involved in producing non–genetically modified foods. And insofar as there are free markets involved in agriculture, we would expect farmers and businesses to move in the direction of satisfying consumer preferences. Indeed, the idea that consumer preferences are sovereign and unchallengeable is at the heart of free-market economics. Similarly, many precautionary measures could be taken to reduce EMF exposure at little or no cost and with no adverse consequences.

Second, even if we suppose that adopting the precautionary principle would lead consumers to react irrationally, this is an argument for educating consumers, not for depriving them of control over their own lives. Educating consumers about risk involves at least making clear the ubiquity of the risk (we are all exposed to EMFs, at home, at work, and elsewhere) and also making clear that trade-offs among risks are unavoidable (few if any of us would consider living without the convenience and safety offered by electricity, even though some exposures cannot be avoided easily). For example, there is a great deal of room for improvement in how statistical information is represented.[16]

Finally, even if precautionary approaches would lead to bad collective outcomes and people were uneducable, there still would be some reason for favoring precautionary approaches. In American society, we generally suppose that people should be free to make irrational choices, even ones that damage the public good, so long as these choices do not involve acts of violence. For example, we allow people to drive sport utility vehicles despite the fact that they are major contributors to climate change, and we allow people to teach their children that evolution is false. Limiting one's EMF exposure, even if unnecessary, is easy to accomplish and can be done at little cost to the individual or society.

CONCLUSION

Here we have used EMF policy as an example of failure to implement the precautionary principle even though it could be done relatively easily and

cheaply. We have not argued for any particular EMF policy, nor have we tried to define and characterize the full array of precautionary approaches. Instead, we relate the discussion of the precautionary principle and EMFs to larger questions about human agency and public authority. Reluctance to regulate on the grounds of avoiding false positives that may scare and upset people is paternalistic. In our view, concerns about the proper role of government paternalism are at the heart of questions about regulating environmental and health risks and therefore should be as central to the discussion as economic and epidemiologic data. ■

About the Authors

At the time this editorial was written, Dale Jamieson was with the University Center for Human Values, Princeton University, Princeton, NJ. Daniel Wartenberg is with the Department of Environmental and Community Medicine, Robert Wood Johnson Medical School, University of Medicine and Dentistry of New Jersey, Piscataway.

Requests for reprints should be sent to Dale Jamieson, PhD, Environmental and Technology Studies, Carleton College, 1 North College St, Northfield, MN 55057 (e-mail: djamieso@carleton.edu).

This editorial was accepted June 5, 2001.

References

1. His Holiness the Dalai Lama. *The Path to Tranquility: Daily Wisdom.* New York, NY: Viking Arkana; 1999:9.

2. Foster KR, Vecchia P, Repacholi MH. Risk management. Science and the precautionary principle. *Science.* 2000; 288:979–981.

3. *World Charter for Nature.* New York, NY: United Nations; 1982. UN General Assembly Resolution 37/7.

4. *Rio Declaration on Environment and Development.* Nairobi, Kenya: United Nations Environment Programme; 1992. Publication E.73.II.A.14. Also available at: http://www.unep.org/Documents. Accessed June 28, 2001.

5. Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. *Am J Epidemiol.* 1979;109: 273–284.

6. National Research Council. *Possible Health Effects of Exposure to Residential Electric and Magnetic Fields.* Washington, DC: National Academy Press; 1997.

7. Portier C, Wolfe M, eds. NIEHS Working Group. *Assessment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields.* Research Triangle Park, NC: National Institute of Environmental Health Sciences; 1998. NIH publication 98-3981.

8. Greenland S, Sheppard AR, Kaune WT, Poole C, Kelsh MA. A pooled analysis of magnetic fields, wire codes and childhood leukemia. *Epidemiology.* 2000;11:624–634.

9. Ahlbom A, Day N, Feychting M, et al. A pooled analysis of magnetic fields and childhood leukemia. *Br J Cancer.* 2000;83:692–698.

10. Wartenberg D. Residential EMF exposure and childhood leukemia: meta-analysis and population attributable risk. *Bioelectromagnetics.* 2001 (suppl 5):S86–S104.

11. Foster K, Erdreich L, Moulder J. Weak electromagnetic fields and cancer in the context of risk assessment. *IEEE Proc.* 1997;85:733–746.

12. Morgan M, Florig H, Nair I, Hester G. Power-frequency fields: the regulatory dilemma. *Issues in Science and Technology.* 1987;3:81–91.

13. Morgan M. Electric and magnetic fields from 60 Hz electric power: possible health risks? *Chance: New Directions for Statistics and Computing.* 1989;2(4): 12–20, 37.

14. Florig HK. Safe, fair, affordable, practical and predictable: multiple objectives in EMF policy. Paper presented at: Annual Meeting of the National Council on Radiation Protection and Measurement; April 6–7, 1994; Arlington, Va.

15. Faden A, Beauchamp T. *A History and Theory of Informed Consent.* New York, NY: Oxford University Press; 1986.

16. Hoffrage U, Lindsey S, Hertwig R, Gigerenzer G. Communicating statistical information. *Science.* 2000;290: 2261–2262.

The Precautionary Principle Also Applies to Public Health Actions

The precautionary principle asserts that the burden of proof for potentially harmful actions by industry or government rests on the assurance of safety and that when there are threats of serious damage, scientific uncertainty must be resolved in favor of prevention. Yet we in public health are sometimes guilty of not adhering to this principle.

Examples of actions with unintended negative consequences include the addition of methyl tert-butyl ether to gasoline in the United States to decrease air pollution, the drilling of tube wells in Bangladesh to avoid surface water microbial contamination, and villagewide parenteral antischistosomiasis therapy in Egypt. Each of these actions had unintended negative consequences. Lessons include the importance of multidisciplinary approaches to public health and the value of risk–benefit analysis, of public health surveillance, and of a functioning tort system—all of which contribute to effective precautionary approaches.

Bernard D. Goldstein, MD

PUBLIC HEALTH ADVOCATES around the world have increasingly invoked the precautionary principle as a basis for preventive actions.[1–9] This has been particularly true for environmental and food safety issues, in which the precautionary principle has moved from being a rallying cry for environmental advocates to a legal principle embodied in international treaties.[2,6,8–11] Definitional issues have become more important as the term has made the transition from a noble goal to a component of legal requirements. For the purposes of this commentary, a useful definition is one that is contained in the 1989 Rio Declaration[12]: "Nations shall use the precautionary approach to protect the environment. Where there are threats of serious or irreversible damage, scientific uncertainty shall not be used to postpone cost-effective measures to prevent environmental degradation."

The upsurge in use of the term "precautionary principle" has been relatively sudden. For example, changes in the approach to hazardous air pollutants in the 1990 US Clean Air Act Amendments embody the precautionary principle. Until then, control of individual air pollutants in this category depended on a risk-based approach in which the burden of proof was on the US Environmental Protec-