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Commentary

Title: Seven deadly sins of environmental epidemiology
and the virtues of precaution

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ABSTRACT

The potentials for error in planning, conducting, reporting and utilizing epidemiologic results can be considered in terms of the traditional seven deadly sins. To counter these sins, epidemiologic virtues should be inspired by the precautionary principle. The remedies emphasize acknowledgment and exploration of the impact of uncertainties, weight-of-the-evidence assessments that consider what could be known given the opportunities for research, and epidemiologic strategies that facilitate the use of tentative, though innovative studies in decision-making.

What an individual is capable of may be measured by how far his understanding is from his willing. What a person can understand he must also be able to make himself will. Between understanding and willing lie the excuses and evasions.

Kierkegaard¹

The quality of environmental epidemiology research can be considered from two perspectives, one representing methodologic issues, the other dealing with the usefulness of the work. These two views are connected, because a study of superior quality is likely to be of greater validity and therefore more useful. Still, an imperfect study can be of great relevance, and epidemiologists must therefore tackle the challenging balance between being an advocate for particular policies and being skeptical ivory-tower scientists²⁻⁴ Methodology and application should not be separated – or, using Kierkegaard’s wording,¹ both the understanding and the willing are essential in environmental epidemiology.

The Precautionary Principle offers a new perspective on the quality of epidemiology. The Precautionary Principle is the principle of reducing a potential hazard even before there is strong proof of harm, i.e., despite the uncertainties that are prevalent in epidemiology.⁵ As a counterweight to the deficiencies or vices of epidemiological research, the Precautionary Principle inspires some virtues that could increase the value of epidemiologic research.

What are the vices of epidemiology that the Precautionary Principle can help overcome? In classical terms, there are seven deadly sins; the capital or cardinal sins from which all sinful behavior originates. I propose here 7 deadly sins of epidemiology. While interrelated, some sins may appear more fundamental and serious than others, and their sequence is a matter of choice. In Dante's Mount Purgatory, the lowest level was here pride must be conquered and sloth was at the last and highest level (Fig. 1).⁶ To achieve the goal of epidemiology in furthering public health, researchers must climb their own Mount Purgatory, surmounting their own sins. This commentary explores the manner in which these sins affect epidemiologic research and it seeks to identify the precautionary virtues that could guide us as we aim at reaching the summit.

Pride

Pride is a form of self-delusion, where grandiose illusions are substituted for the reality of who we are. Imperfection in our own studies is ignored, while the work of colleagues is subjected to the highest standards. Such exaggerated criticisms can be a tool for dismissing unwanted results. An international call for guidelines on 'Good Epidemiological Practice' backfired when strict interpretation of epidemiologic rules was applied to disregard epidemiological findings that for other reasons were regarded as unwelcome.⁷ Scientific rigor was misunderstood as an unrealistic requirement for controlled studies that could furnish virtual certainty. In parallel, inconclusive studies were labeled "negative" and were claimed to represent "no risk", instead of "no information".⁸

The proud epidemiologist, who overzealously highlights methodologic difficulties, or failures to reach statistical significance, also ignores the innate tendencies of bias toward the null hypothesis.⁵ Although frequently overlooked, a noisy study is more likely to miss a true causal link than to create spurious associations.^{9,10} The literature is nonetheless replete with inferences that misclassification of exposure is an explanation for a positive finding.¹⁰

Perhaps the most pervasive symptom of Pride in epidemiology is the condescending attitude toward epidemiology studies from other countries or cultures, most often reflected as an emphasis on major epidemiology journals and English-language literature. Auto-citation is a related phenomenon, where the epidemiologist prefers to cite his or her own work rather than acknowledge the contributions of colleagues.

Envy and Wrath

Dante grouped Envy and Wrath with Pride as the sins of "Perverted Love."⁶ Envy leads to ingratitude and failure to recognize other colleagues' achievements, whether in terms of primacy, first authorship, or lower *p* values. Related to Pride, Envy is the feeling of pain that an epidemiologist experiences when he sees that a colleague has discovered a new method or possesses some unique material that he himself does not, thus creating a threat to his self-esteem.

The envious epidemiologist will exaggerate perceived errors committed by a particularly successful colleague and misapply methodologic criteria to discount her findings. Typically, this invites abuse of the aspects of causality originally presented by

Bradford Hill.¹¹ Misapplication of these causal “criteria” occurred in evaluating the research on endocrine disrupting chemicals.^{12,13} Oftentimes, expert committees advising national and international bodies are tempted to express unreasonable critiques of epidemiologic research and to stress the preponderance of uncertainties. For example, an important study may be disregarded by erroneously referring to the need for a Bonferroni adjustment.¹⁴ More seriously, vested interests may spur envious behavior in sowing doubt about health risks.¹⁵ Unwanted results are then criticized as junk science, and uncertainties in this evidence are interpreted as an indication that exposures were safe.

Wrath (or anger) is aroused when an epidemiologist suffers a real or perceived injury, and the pain is transformed into the pleasure of vengeance. Our culture paves the way for Wrath in espousing pride, standing up for one’s rights, being competitive, and seeking prestige. Narrow-minded inflexibility, sometimes coupled with self-righteousness or despondency, leads to anger, where we concentrate on the object of our anger and forget everything else.

Risk assessment is at times an angry battle ground, with harsh condemnation of evidence and its interpretation,¹⁶ and accusations that environmental epidemiology research is paparazzi science leading to chemophobia.¹⁷ Perhaps worse, there has been suppression of information, withholding of evidence, lambasting of whistle-blowers, and releasing of half-truths or untruths.¹⁸ Researchers who publish results at odds with certain vested interests have become targets of unreasonable criticism and intimidation with the aim of suppressing or throwing suspicion on unwelcome information about health risks.^{19,20}

Lust, Greed, and Gluttony

The licentious epidemiologist becomes obsessed with seeking pleasure through attention and recognition, including the highest academic titles and prizes. Colleagues become ways of satisfying the lustful epidemiologist's needs by drafting manuscripts and otherwise delivering pleasure. Lust also affects the choice of study topics toward those that are linked to short-term rewards.²¹ When results are published, a sponsor's interests can color the conclusions drawn by the lustful epidemiologist. Studies supported by the pharmaceutical industry are more likely to conclude that a drug is efficacious than studies conducted without such support^{22,23}; similar tendencies are also observed in other fields.²⁴⁻²⁸

Gluttony is the related desire for an excess of anything, in our case often an inordinate appetite for publications. Gluttony involves preoccupation with producing and publishing to excess, which can lead to social apathy. In conjunction with the demand for replication in science (which creates inertia and constipation), Gluttony is propagated when students are taught to replicate and extend their mentor's own research. Thus, the majority of published papers in environmental health journals deals with a limited, rather stable list of pollutants, such as lead, while other pollutants with complicated names have been barely studied at all. The Glutton also reports his findings sequentially in Least Publishable Units, in the hope that his productivity will make him an epidemiology celebrity.

Greed (or avarice) is the craving for material possessions and prestige. The prestige and the academic honors from a burgeoning Curriculum Vitae become the means to achieve, wield and display personal power (and in this sense the greedy one

distinguishes himself from the Glutton). The greedy epidemiologist tries to intimidate or control others, thereby reinforcing his own illusions and feeling of success. Her vanity publications often appear in trade journals or in publications disguised as scientific journals.²⁹ When Greed leads him to compromise himself by entanglements in undeclared vested interests,³⁰ public trust is abused by the deceit. The purposes of epidemiology in seeking the truth are betrayed.

Sloth

Sloth in epidemiology is the indifference to public health and to the welfare of others. The lazy epidemiologist does not make it a priority to consider the implications of his work for public health, and he may appear as callous and uncaring. Eventually, sloth results in alienation of the epidemiologist, who in neglecting the utility of his work, loses his sense of purpose.

When early epidemiology warnings about environmental health hazards did not lead to appropriate prevention,³¹ sloth closed people's eyes to the danger signs. Sloth and "taking the easy way" may even restrict the design of a study (such as the anecdotal drunk, who looks for his lost keys only under the lamp post), so that the proper public health issue is not addressed. This misleading type of study is sometimes referred to as committing a type III error.³² The blindness to social injustice and other serious problems can be coupled with an uncritical focus on epidemiologic methodology. In economics, similar concerns have led to accusations of autistic preoccupation with technical detail.³³ The context of justification therefore needs to be balanced with the context of application.

The Precautionary Principle

The precautionary principle was included in the first convention on the protection of the North Sea in 1984, later to be followed by many other international agreements including the EU treaty.⁵ The key element of the Precautionary Principle is the justification for appropriate public health action in response to limited (but plausible and credible) evidence of likely and substantial harm. The Precautionary Principle is thereby aimed at avoiding possible future harm associated with suspected, but not conclusive, environmental risks. In placing importance on imperfect evidence, the Precautionary Principle has implications for quality judgments of epidemiology.

In contrast to the scientific traditions of epidemiology, where replication is held as key, the Precautionary Principle does not inspire repetitive verification. Further, the Precautionary Principle does not demand testing of a null hypothesis that an exposure may be without a discernible effect. Rather, information is requested on whether an exposure might be a serious endangerment to health, and whether such a hazard can be prevented. Although the Precautionary Principle has not been universally welcomed,³⁴ the common sense inherent in the Precautionary Principle may inspire more virtuous ways of planning, conducting, reporting, and utilizing research in environmental epidemiology.

To counterbalance our deadly sins, particular virtues have been recommended in the past.⁶ Table 1 provides some Precautionary Principle suggestions of virtues inspired by the Precautionary Principle. For clarity these are discussed under three separate headings.

Acknowledging uncertainty

Given the absence of final proof, uncertainty should be looked upon as a normal condition that needs to be explored and addressed rather than minimized.³⁵ Assessment of imprecision and its implications is crucial because standard statistical methods assume that an exposure is measured without imprecision. Efforts are sometimes made to exaggerate or manufacture uncertainties with the aim of explaining away a statistically significant association.³⁶ Exposure imprecision may be erroneously thought to cause exaggerated associations, while most often the opposite is true.^{9,10,37}

Attention therefore should be paid to the impact of uncertainties on the possible extent or risk of adverse effects. Whether the confidence limits include the possibility of no effect is not the only interest, and one or more worst-case scenarios deserve just as careful scrutiny: How serious could the effects be, and how large an effect can be reasonably ruled out? Thus, in acknowledging uncertainty, we need to stress how large a problem we can likely rule out, rather than the likelihood that our findings could be due to chance.

Weighing the evidence

The epidemiologic evidence must be considered in light of both strengths and weaknesses,³⁸ while also taking into account information from other disciplines. A methodologic failure may of course weaken the support for a particular association, but the mere occurrence of some scientific weakness does not prove the absence of a risk. Unfortunate and erroneous rejection of early warning signals has occurred in the past because of presumed confounding or other biases, and uncertainties.³⁴ The burden of

proof needs to shift its focus to the extent of the purported safety, rather than to the mere presence of a risk.

While acknowledging the limitations of epidemiologic evidence, there must be consideration to the question of how much could possibly be known, given the type of evidence available. Noisy studies (e.g., with imprecise estimates of the causative exposure and insensitive and nonspecific outcome measures) are unlikely to detect anything but the most serious risks. These studies will not support safety claims. The fact that the null hypothesis could not be rejected with confidence is irrelevant.

At the same time, all conclusions must be accepted as being provisional and temporary. Frequently cited conclusions published in major journals are often found to be wrong.³⁹ While accepting that a tentative conclusion based on preliminary evidence may later turn out to be wrong, public health responsibility may still demand that a serious threat be taken seriously, despite the lack of strong proof. Any actions would need to be adjusted, as more definite documentation emerges, perhaps from intervention studies.

Research strategies

As indicated by Bailar,⁴⁰ sinful behavior may affect the full research process, from the framing of the research question to the interpretation and reporting of results. In order to limit uncertainty, epidemiology often focuses on narrowly-defined issues, thereby resulting in reductionism, potentials for type III errors, and incomplete information on only proximate hazards. Vision and courage are needed in the choice of research topics and research methods. Some balanced extent of replication can often be justified, but the

lack of attention by environmental epidemiologists to scores of potentially serious health hazards is inexcusable.

The absence of epidemiologic data complicates decision-making. Even preliminary data can facilitate decision-making based on the precautionary principle. Although such data may not stand alone, they can later be included in meta-analyses or provide a starting point for follow-up studies. In this regard, prospective studies must be favored over multiple, less informative, cross-sectional studies. Precautionary action can also pave the way for intervention studies, of which there are too few in environmental epidemiology. Such action may be the result of stakeholder involvement, thereby making transparency a new and important asset in epidemiology.

Conclusions

Environmental epidemiology is crucial for decision-making on public policy, but research practices reveal traits that might be characterized as sinful. The classical seven deadly sins seem to have infected our field, and all of us are probably guilty in one way or another. The precautionary principle provides a perspective that may be helpful for expunging sinful epidemiology. The specific precautionary remedies for the ailing of environmental epidemiology emphasize acknowledgment and exploration of uncertainties in regard to adverse outcomes, weight-of-the-evidence assessments that focus on what could be known with limited data, and research strategies that provide preliminary but innovative epidemiologic information that is relevant to decision-making based on the precautionary principle.

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PHILIPPE GRANDJEAN is Professor and Chair of Environmental Medicine at the University of Southern Denmark and Adjunct Professor of Environmental Health at Harvard School of Public Health. As an environmental epidemiologist, he has explored the impact of imprecision on research findings. On behalf of the Collegium Ramazzini, in 2002 he organized an international conference on the precautionary principle and its implications for research and prevention.

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Table 1. Common vices in environmental epidemiology and the virtues suggested by the Precautionary principle.

Vice		Precautionary virtue	
Pride	Preoccupation with methodology	Humility	Exploration of uncertainty
Envy	Failure to recognize achievements by others	Fairness	What could be known, given the evidence?
Wrath	Self-righteous intimidation of competitors	Empathy	Weighing in all relevant evidence
Lust	Desire for academic honors	Restraint	Balanced choice of research methods/topics
Gluttony	Excessive craving for publications	Innovation	Limiting attempts of replication
Greed	Benefit from vested interests	Transparency	Involvement of all stakeholders
Sloth	Callousness to injustice	Compassion	Public health responsibility

Legend to figure

Fig. 1. Mount Purgatory for sinful epidemiologists, who must heed the precautionary virtues to reach Paradise, (substantially) revised from Dante.

