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Seven deadly sins of environmental epidemiology and the virtues of precaution*

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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.

Kierkegaard

The quality of environmental epidemiology research can be considered from two perspectives, one representing methodological 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 a skeptical ivory-tower scientist.¹⁻³ Methodology and application should not be discussed in separation, or, using Kierkegaard's wording,⁴ both the understanding and the willing are essential in environmental epidemiology.

The Precautionary Principle (PP) offers a new perspective on the quality of epidemiology. The purpose of the PP is to facilitate decision-making when there is a need to act so as to reduce a potential hazard even before there is strong proof of harm, i.e., despite the uncertainties that are prevalent in epidemiology.⁵ Thus, to counter the deficiencies or vices of epidemiological research, the PP inspires some virtues that could increase the value of epidemiologic research. Vices have a long history in religion, literature, and psychology, often referred to as the seven deadly sins; from these capital or cardinal sins, all sinful behavior originates.

While interrelated, some sins may appear more fundamental and serious than others, and their sequence is a matter of choice, e.g., in Dante's Mount Purgatory (Fig. 1).⁶ To achieve the goal of epidemiology in furthering public health, the researcher must climb Mount Purgatory. This Commentary explores the manner in which these sins affect epidemiologic research and it seeks

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to identify the precautionary virtues that could counteract the vices as we aim at reaching the summit.

Pride

Pride is a form of self-delusion, where the reality of who we are is substituted by grandiose illusions. Any imperfection on our own behalf is ignored, while exaggerated attention and pious respect is paid to high methodological standards when judging the work of colleagues. An international call for guidelines on 'Good Epidemiological Practice' backfired when strict interpretation of epidemiological rules was applied to disregard epidemiological findings that for other reasons were regarded as unwelcome.⁷ Scientific rigor was misunderstood as the unrealistic requirement for controlled studies that could furnish virtual statistical 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 methodological difficulties, or failure to reach statistical significance, at the same time also ignores the innate tendencies of bias toward the null hypothesis.⁵ Although frequently overlooked, a noisy study is more likely to fail in revealing a true causal link rather than creating spurious associations,^{9,10} but 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 own work, rather than acknowledging the contribution by colleagues.

Envy and Wrath

Dante grouped Envy and Wrath along with Pride as the sins of "Perverved 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 specific threat to his self-esteem.

The envious epidemiologist will exaggerate perceived errors committed by a particularly successful colleague and misapply methodological criteria to discount his 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 critique of epidemiologic research and 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 were then criticized as junk science, and uncertainties in this evidence were 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 in science. Narrow-minded inflexibility, sometimes coupled with self-righteousness or despondency, leads to anger, where we concentrate on the object of it and forget everything else.

Risk assessment is at times an angry battling ground, with harsh condemnation of evidence and its interpretation,¹⁶ and accusations of environmental epidemiology research being paparazzi science leading to chemophobia.¹⁷ Perhaps worse, suppression of information has occurred, as have withholding of evidence, lambasting of whistle-blowers, and releasing of half-truths or untruths.¹⁸ Researchers publishing 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 by seeking satisfaction and seeks frequent and limitless 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 well known to be much more likely to conclude that a drug is efficacious than studies conducted without such support,^{22,23} but similar tendencies have been observed in other fields.²⁴⁻²⁸

Gluttony is the related desire for an excess of anything, in our case mostly an inordinate appetite for credentials and publications. It involves preoccupation with producing and publishing to excess, thereby leading to social apathy. In conjunction with the demand for replication in science, which creates inertia and constipation, Gluttony is further propagated when students are taught to replicate and extend the tutor'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 as 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, the academic honors, and the burgeoning CV become means to achieve, wield and display personal power (and in this sense he distinguishes himself from the Glutton). The greedy epidemiologist tries to intimidate or control others, thereby reinforcing his own illusions and feeling of success. His vanity publications often appear in trade journals or in publications disguised as scientific journals.²⁹ When Greed traps him into vested interests, often undeclared,³⁰ public trust is abused by the deceit, and the purposes of epidemiology in seeking the truth are betrayed.

Sloth

Sloth (or acedia) in epidemiology is the indifference to public health and to the welfare of others. Epidemiologists are generally busy researchers, but a compressed calendar may also function as an excuse for lack of devotion. The lazy epidemiologist does not make it a priority to serve public health and appears as callous and lacking caring. Eventually, sloth results in alienation of the epidemiologist, who does not bother about other opinions and so never questions whether he is right or wrong.

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 convenience may also overrule the scientific needs in designing a study (like the anecdotal drunk, who looks for his lost keys only under the lamp post), so that the proper public health issue is not addressed, thereby making the study misleading, sometimes referred to as type III error.³² The blindness to social injustice and other serious problems is sometimes 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 (PP) 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 PP is the justification for appropriate public health action in response to limited, but plausible and credible evidence of likely and substantial harm. The PP is thereby aimed at avoiding possible future harm associated with suspected, but not conclusive, environmental risks. In placing importance on imperfect evidence, the PP has implications for quality judgments of epidemiology.

In contrast to the scientific traditions of epidemiology, where replication is held as a key to supporting conclusions on causation, the PP does not inspire repetitive verification. Further, the PP does not demand testing of a null hypothesis that an exposure may be without a discernible effect. Rather, information is requested whether an exposure could potentially be seriously endangering health, and whether such a hazard can be prevented. Although the PP has not been universally welcomed as an ideal process,³⁴ the common sense inherent in the PP 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 and Table 1 provides some PP-inspired suggestions, which, for clarity, are discussed below 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 for the purpose of carrying out research.³⁵ Assessment of the imprecision and its implications is crucial, because standard statistical methods assume that an exposure is measured without imprecision. Sometimes efforts are made to exaggerate or manufacture uncertainties with the aim of explaining away a statistically significant association.³⁶ Likewise, 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 as careful a 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 epidemiological evidence must be considered in light of both strengths and weaknesses,³⁸ while also taking into account information from other disciplines. A methodological 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 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 the mere presence of a risk.

While acknowledging the limitations to epidemiologic evidence, the point of view needs to be considered, what 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 and 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. For example, a study of often-cited publications in major journals found that many of the conclusions were subsequently 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, even though strong proof is not at hand. Any actions would then need to be adjusted later on, as more definite documentation emerges, perhaps from intervention studies.

Research strategies

As indicated by Bailer,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 is 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.

Absence of epidemiological data complicates decision-making, and provision even of preliminary data can facilitate PP-based decision-making. Although such data cannot stand alone, they can later be included in potential 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 can be properly characterized as sinful. All of 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 ailing 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 at this point, and research strategies that facilitate the use of preliminary, but innovative epidemiological information in PP-based decision-making.

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Biography

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

Table 1

Common vices in environmental epidemiology and the virtues suggested by the Precautionary principle, with examples.

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