Dec 20, 2005

Name: ______________________ Pledge (sign): ______________________

Env Studies 201 Test #3

Point Total: 100 pts possible

5 pts 1. What are *confounding factors* in epidemiological studies?

Epidemiology is the study of the correlation between the dose of one or more pollutants and the health of humans or ecosystems exposed to that pollutant. Confounding factors are variables other than pollution level that could also have affected human/ecosystem health in a particular epidemiological study. Examples of confounding factors could be climate, socioeconomic status, or lifestyle choices.

5 pts 2. Both RCRA and CERCLA regulate hazardous waste. What is the distinction between them? Be brief (1–2 sentences).

RCRA—the Resource Conservation and Recovery Act—regulates the normal disposal and/or treatment of hazardous waste by its generators. CERCLA, the Comprehensive Environmental Response, Compensation, and Liability Act (sometimes called the Superfund act), regulates the cleanup of areas when hazardous waste is released into the environment in an unsafe manner; such releases do not conform to RCRA standards and may even predate that law.

5 pts 3. What is 'free riding' in environmental treaties?

International environmental agreements (IEAs) are attempts to address transnational environmental problems. Such problems are characterized by a degradation of the global 'commons' (eg air or water quality) that affects multiple countries. The degradation is usually caused by the actions of multiple countries as well. A prime example of this is global climate change due to greenhouse gas emissions.

IEAs crafted to improve the situation frequently demand sacrifices (at least in the short-term) from the parties to the agreement. The problem is that improving environmental conditions may well provide benefit for everyone, *whether they honor the IEA or not*. Thus there is a temptation to 'free ride:' to benefit from the actions of others while doing nothing to alleviate the problem addressed in the IEA. This is an aspect of Hardin's tragedy of the commons. Effective IEAs must counter this tendency by (i) inducing countries to sign a treaty that will significantly improve matters and (ii) getting them to behave as agreed in the IEA.

5 pts 4. Briefly describe the 'harvesting' effect of severe pollution episodes.

Severe pollution episodes can result in a significant short-term increase in mortality. In some cases, the effects of such episodes are much greater among the elderly who have pre-existing health problems—many of which would shortly be fatal in any event. The concept of 'harvesting' describes the notion that many who die in severe pollution episodes would have died soon anyway (in a matter of days or months). Some thus argue that the 'harvesting' effect distorts the actual effect of such pollution episodes.

The existence of a more susceptible sub-population (eg, children, the elderly, or those already sick) can result in a 'hockey-stick' dose-response curve that exhibits a plateau at higher pollutant concentrations. At these higher concentrations, those who are most susceptible to the pollutant's effects have already succumbed (ie, died). Presumably at still higher concentrations, eventually even healthy people will be affected as well.

5 pts 5. In pollution regulation, what is 'technology forcing?'

Technology forcing is when pollution regulation mandates the use of a particular pollution-reduction technology, such as the use of catalytic converters to reduce auto emissions. The technology is chosen based on its cost and feasibility. The advantage of this approach is that it is relatively easy to implement, and compliance is easily monitored. The disadvantage is that there is not guarantee that the technology chosen will reduce risk to an acceptable level (where 'acceptable' can be defined by a variety of criteria).

5 pts 6. What is the distinction, made by the EPA and other organizations, between risk *assessment* and risk *management*. In your answer, be sure to state the goal of each process.

Ideally, risk assessment is a purely scientific process: it is the evaluation—preferably expressed quantitatively—of the risk to human or ecosystem health by the discharge of a pollutant to the environment. The quantitative risk will be determined by the route, duration and intensity of the exposure, as well as the dose-response relationship for the organisms at risk. Ecosystem risk will also need to consider the various interdependencies in biological community, since organisms who are not directly harmed by the pollutant may still be affected due to changes in the populations of other organisms. The risk assessment process produces a final quantitative statement of risk (risk characterization), ideally including an estimate of the uncertainties in the assessment process.

Scientific risk assessment is then combined with other factors—such as economic, social, political and technological factors—in determining a policy response to control the risk. So the goal of risk assessment is a quantitative statement of the level of risk posed by a pollutant, while the goal of risk management is to reduce that risk to an acceptable level, for example by regulating the activities that discharge the pollutant into the environment.

8 pts 7. In a little detail, describe the SO_2-trading provisions (Title IV) of the 1990 Clean Air Act amendments.

Title IV of the 1990 CAA amendments is a cap-and-trade program for SO_2. In Phase I (1995–1999), 110 power plants were included in the plan. Each plant was given a certain number of emission 'allowances,' each one equal to one ton of emitted SO_2. These allowances were tradeable. Each plant faced a decision of whether to use all its allowances; any unused allowances could be sold to other Phase I plants who needed them. This provides a financial incentive to reduce SO_2 emissions. However, for some plants it may well be more economical to buy allowances from other plants rather than reduce their own emissions. Theoretically this results in greater economic efficiency: plants who can more easily reduce their emissions do so and sell their allowances to plants for whom reduction would be considerably more expensive.

Besides economic efficiency, environmental improvement results because future overall emissions reduction could be achieved by buying and retiring a specified number of allowances; under Phase I the total reduction was about 3.5 million tons per year. Phase II, which started in 2000, expanded the program to include virtually all fossil-fuel power plants.

Power plants that participate in the program were required to install monitoring systems to track emissions and assure compliance. Plants could only emit SO_2 according to the number of allowances they possess; exceeding the allowances resulted in fines ($2000 per ton of excess emission) and the excess emissions were offset by using allowances from the following year.

8 pts 8. What is photochemical smog, and how is it formed? In your answer, be sure to identify smog's precursor pollutants, as well as the human activities that generate these pollutants.

Photochemical smog is a complicated mixture consisting primarily of ozone (O_3), nitrogen oxides (NO and NO_2), nitric acid (HNO_3), partially-oxidized organic compounds (such as alcohols, organic acids, and organic nitrates such as PAN), organic PM, nitrate PM, other substances. The PM and brown NO_2 give photochemical smog its brown and hazy appearance. Photochemical smog is produced when reactive organic gases—primarily hydrocarbons—undergo atmospheric oxidation in the presence of NO. This oxidation process produces NO_2, which absorbs light to produce atomic oxygen, which in turn reacts with O_2 to produce ozone.

The precursor pollutants are thus reactive organic gases (reactive VOCs), primarily hydrocarbons, and NO_x. The major sources of these precursors are motor vehicles and fossil fuel-based power plants.

9. Nutrient pollution is one of the main problems for water bodies in industrialized countries.

6 pts (a) What are these pollutants, and how are they released into the environment? Be complete.

Nutrient pollutants are inorganic forms of nitrogen (usually as ammonium and nitrate) and phosphorus (usually as phosphate). They are released by a variety of activities, including:

- application of synthetic fertilizer in agriculture and in residential lawns (surface runoff contains N and P; nitrate also migrates to the groundwater);
- discharges of treated and untreated sewage into surface waters;
- livestock farms release animal waste (runoff) and ammonia gas (some of which deposits as PM); and
- fossil fuel combustion releases NO_x gases (some of which deposits as PM).

6 pts (b) How does nutrient pollution degrade water quality? Answer in a little detail.

Nutrient pollution causes *cultural eutrophication*, which is an accelerated increase in the rate of primary productivity (ie, photosynthesis) in aquatic ecosystems. The increased plant (algae) biomass leads to oxygen depletion and increased incidences of algae blooms. In extreme cases, the blooms can be toxic or the oxygen depletion can be so severe that so-called *dead zones* develop, such as in the Gulf of Mexico.

Besides oxygen depletion, the increased productivity reduces the clarity of the water, which makes it less visually appealing and also adversely affects submerged aquatic vegetation. The increased rate of sedimentation due to can also smother/bury some organisms or eggs on the bottom. Highly eutrophic water bodies are also more noxious, due to both oxygen depletion and the particular algae that thrive under these conditions. Finally, treatment of drinking water reservoirs that have become eutrophic is more problematic.

10. In Article 3 of the UNFCCC agreement, the parties agree to be guided by the precautionary principle with respect to policies to mitigate activities that cause climate change. Briefly:

4 pts (a) What is the UNFCCC?

The UNFCCC is the United Nations Framework Convention on Climate Change, created at the Rio Earth Summit in 1992. It is a coalition of countries—the so-called *climate regime*—who have agreed to address jointly the effects human activities on global climate.

4 pts (b) What is the precautionary principle? How does it apply here?

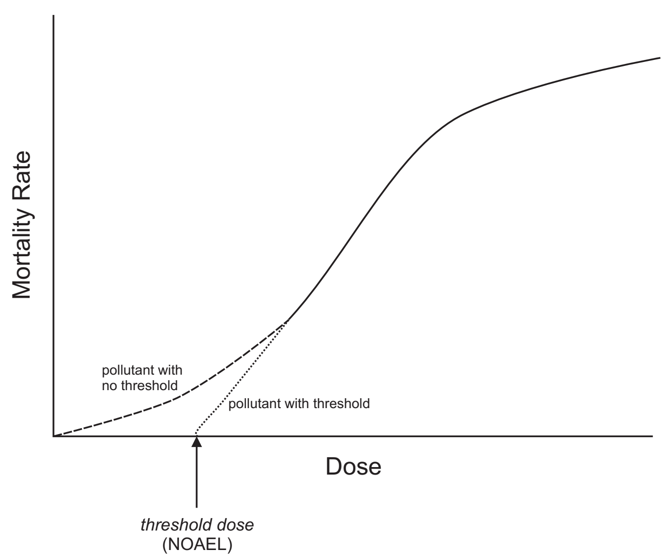
The basic assertion of the Precautionary Principle (PP) is that if the consequences of an action are not known completely, but have some potential for major or irreversible negative consequences, then it is better to avoid that action. The Rio Declaration, drafted at the same meeting that created the UNFCCC, states in particular that "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." Although there is general agreement among climate scientists that human activities have cause global warming and some other changes in climate, the magnitude of future changes—as well as the effects of actions to mitigate those changes—is often characterized by large uncertainties. The relevance of the PP is that such uncertainties should not be used as the sole reason for delaying action.

4 pts (c) What is the main (potential) disadvantage of adopting the precautionary principle?

Broad application of the PP to regulate actions that potentially degrade the environment would lead to an increase in false negatives. Acting sooner—based on evidence that some would deem inconclusive—increases the risk of acting to avert what turns out to be a false alarm. Thus, the decrease in risk that would result in wide adoption of the PP would potentially come at the price of increased expense due to efforts in response to false alarms. Defenders of the PP would respond that earlier action to avert environmental crises are often less costly than waiting until the damage is greater (and more readily apparent). There are also non-economical reasons used to defend the PP.

15 pts 11. Both *health-based* and *economics-based* approaches exits to determine the 'optimal' level of chemical pollution. Describe and contrast these two approaches in detail (use the back of these sheet if necessary). In your answer, be sure to use properly-labelled sketches to explain how dose-response and cost-benefit curves are used to set specific pollution limits.

Let's start with a typical dose-response curve, which in this case shows the effect of dosage on mortality rate (we could just as easily have had 'relative risk' on the y-axis).



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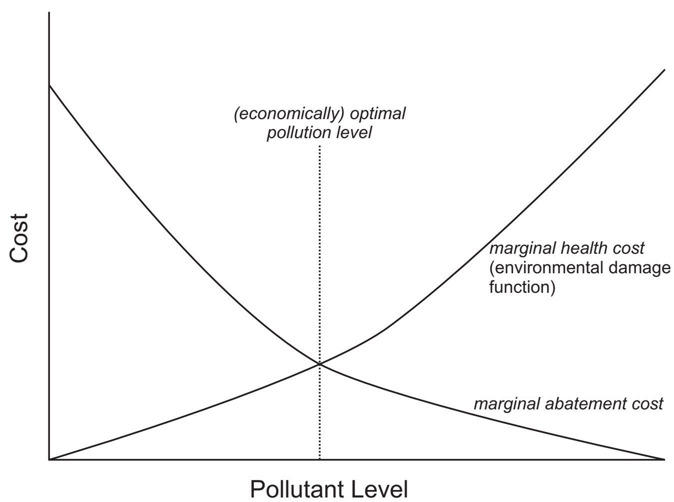
‘threshold’ level below which no adverse effects are apparent (the no adverse effects level, or NOAEL). The theory is that the body can eliminate and/or repair the damage done by small doses of the pollutant. Some pollutants, however, do not appear to have a threshold, a fact that is very difficult to verify. For such pollutants—carcinogens, for example—there is no such thing as a risk-free dosage level; even a very small dosage increases health risk.

Health-based approaches to regulating pollutant exposure basically ammount to an attempt to eliminate or decrease the health risk to ‘acceptable’ levels. For pollutants that exhibit a non-zero NOAEL, the pollutant is regulated so that no one is exposure to levels above the threshold. The value of the NOAEL is typically determined by exposing laboratory animals to controlled dosage levels far above the threshold and extrapolating to low concentrations (using an appropriate model). The threshold level obtained in this manner is divided by a ‘safety’ factor of ten just in case humans are more sensitive to the pollutant than the laboratory animals, and then divided by an additional safety factor of ten to account for susceptible sub-population (such as small children or the elderly). Ideally that means that the pollutant poses no risk to humans. Note that synergistic or additive effects due to exposure to multiple pollutants are generally ignored (which is often used as further justification for the hundred-fold safety factor in this procedure).

For pollutants without a threshold level (usually carcinogens), the risk cannot be reduced to zero. In that case, the typical goal is to reduce the risk to some ‘acceptable’ level (eg, a level similar to the risk posed by natural carcinogens). The EPA often defines this ‘acceptable’ risk as 10^{-4}: ie, a level of exposure which increases the risk (eg of cancer) by 1 in 10,000. A hundred-fold safety factor (used again to adjust for scientific uncertainty in determining risk levels) would reduce this risk level to 10^{-6} (ie, one in a million).

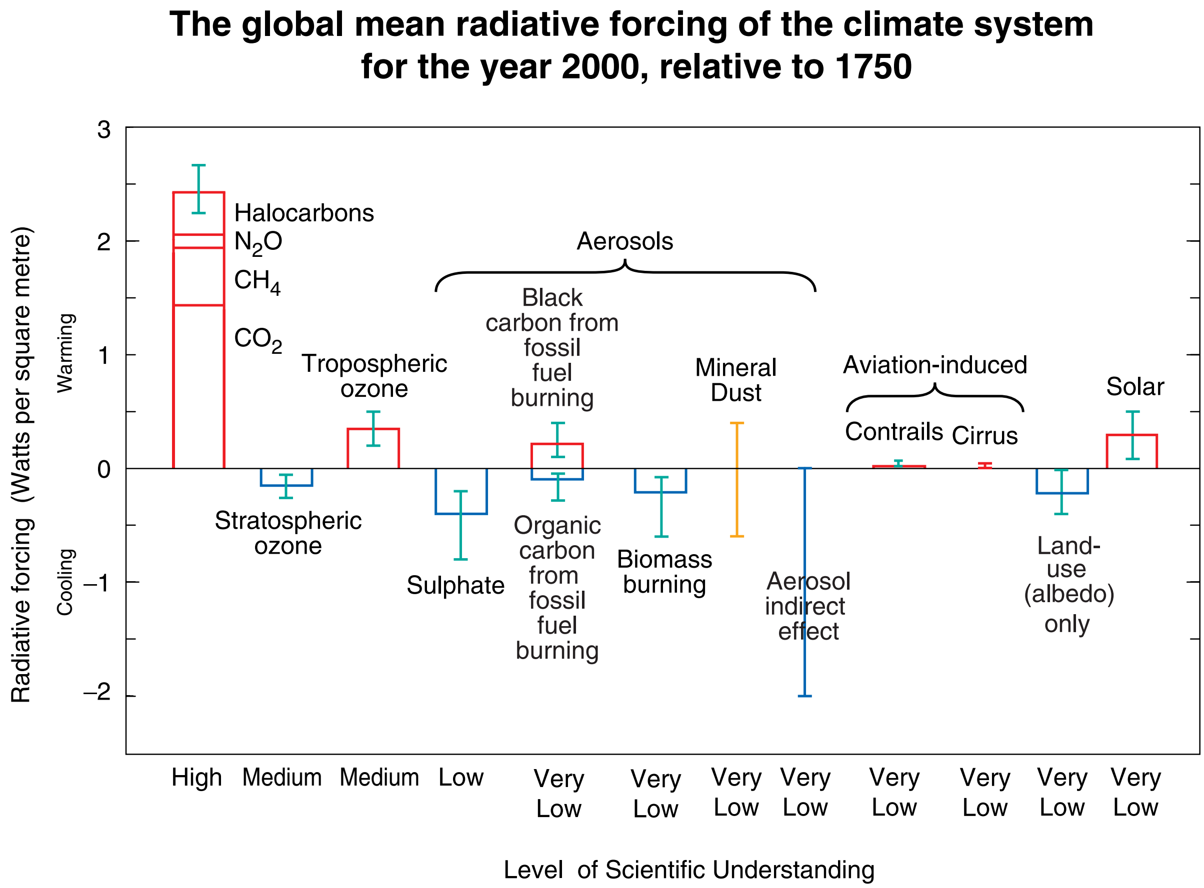
This approach is based on the idea that we have a right to live in a ‘clean’ environment, or at least one in which health risks are not unduly increased by various human activities. A frequent criticism of the health-based approach to risk management is that it ignores the benefits associated with the activities that produce the pollution (eg, growing food or power generation). This regulation can thus increase the price for various critical goods and service—food and heat, for example—a fact that can also negatively impact human health and quality of life. An alternative is to use a cost-benefit approach to risk management, in which the benefits of the activity are weighed against the costs due to increased health risk. In cost-benefit analysis (CBA), the optimal pollutant level is obtained with the marginal abatement costs and the marginal health/environmental benefits are equal, as shown in the following figure.



The *environmental damage function* can include health care costs due to human exposure to pollutant as well as damage to ecosystem functioning. Assuming the abatement cost and environmental damage function are adequately determined—something that can be very difficult to do in practice—this approach will yield the economically efficient level of pollution. Further reduction in pollution level will cost more than the resulting benefit.

Besides the practical difficultly of determining the environmental damage function—which very commonly underestimates the true extent of environmental damage—criticisms of the CBA approach are those typical of any utilitarian approach that maximizes societal ‘happiness’ (ie, wealth) in the aggregate. A problem with both approaches is that those who pay the costs of abatement or increased pollution levels are not always the same people who reap the benefit of increased/decreased abatement.

15 pts 12. The following figure shows the effects of various factors on *radiative forcing*.



Explain the figure in detail. In your answer, be sure to

(i) define radiative forcing and explain how it affects global climate change;

(ii) explain the different effects on radiative forcing of ozone in the troposphere and the stratosphere; and

(iii) explain the effect of aerosols, both direct and indirect, on radiative forcing.

The figure shows the effects of changing atmospheric composition (and a few other factors) on the energy balance of the earth. The vast majority of the energy available to organisms on the earth arrives as sunlight. Some of this incident sunlight (about 30%) is reflected right back to space; the rest is absorbed by various components of the earth system (the atmosphere, oceans, and land). The earth also radiates energy back into space as infrared (IR) radiation. When there is a balance between the amount of energy absorbed as sunlight and the amount of energy lost as IR radiation, then one would anticipate that the global average temperature would remain constant. In such a situation, there is *radiative balance* between incoming and outgoing radiation.

Changes in the atmospheric composition can affect this balance. If a sudden change in composition were to block some outgoing IR light, then there would be a momentary imbalance between incoming and outgoing energy. Eventually balance would be restored but in the meantime there is a net absorption of solar energy and the global average temperature would be expected to increase at some point. The degree of the increase, as well as the magnitude of other effects on climate, would depend on the magnitude of the radiative balance. The extent of this imbalance, specified in units of W/m^2, is called *radiative forcing*.

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One obvious way to cause radiative forcing is to change the concentration of one or more greenhouse gases (GHGs) in the atmosphere. The GHGs absorb outgoing IR radiated by the Earth's surface, so an increase in GHG concentration will cause a positive radiative forcing, where the incoming energy is greater than the outgoing energy. The first bar in the figure shows the effects of increases in four GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the halocarbons (such as CFCs, HCFCs, and HFCs). Increases in these GHGs has caused a combined radiative forcing of almost $2.5\,W/m^2$, most of which is due to increases in CO_2.

Ozone, O_3, is another GHG but its effect on radiative forcing is complicated by the fact that there are *two* trends for ozone. The concentration of ozone in the stratosphere (ie, the ozone layer) has decreased since 1750 due to the effect of CFCs and other ozone-depleting substances. Since there is less stratospheric ozone, this results in a negative radiative forcing—a global cooling effect. However, ozone is the main component of photochemical smog, which is far more prevalent now than in 1750! The increase in tropospheric ozone caused a positive radiative forcing.

It isn't just the gases that affect the radiative balance; changes in both the composition and concentration of PM (ie, aerosol). The concentration of the aerosol has increased since 1750, but the effect of this increase is a little complicated. The atmospheric aerosol affects the radiative balance directly in two ways: it reflects incident sunlight and the aerosol also absorbs outgoing IR light. The balance between these effects depends on the composition of the aerosol. An increase in the concentration of soot ('black carbon' in the figure) tends to warm the Earth because soot is a better absorber of IR light than a scatterer of sunlight. Organic and sulfate PM, on the other hand, scatter incident sunlight more efficiently; the increases in concentrations of these particles thus resulted in a net cooling effect.

Interaction between PM and sunlight/IR light—and the resulting effect on the radiative balance—are termed the *direct* aerosol effect on radiative forcing. But aerosol also affects the nature of clouds in the atmosphere, which has a major impact on climate. This is because clouds consist of tiny water droplets that tend to form on pre-existing particles (ie, PM). Thus, changing the nature of the atmospheric aerosol will change where clouds tend to form. The composition of the aerosol also affects the size of the droplets within the cloud. Like other aerosol, clouds both scatter incident sunlight and absorb outgoing IR light. The net effect (cooling or warming) of a cloud depends on the size of the particles and the position of the cloud in the atmosphere. It is currently believed that the indirect effect of changing PM—through the formation and nature of clouds—will cause a net global cooling, but the exact magnitude of this negative forcing is very uncertain.

It is worth noting that the effects of PM and tropospheric smog are readily reversed. It is ironic that improving air quality (by reducing the concentration of smog and PM) have the effect of contributing somewhat to the global warming problem.

Another major human activity that affects climate are changes in albedo due to land use. The two major activities in this regard are deforestation and increasing urbanization and urban sprawl, both of which increase the Earth's 'reflectivity' (albedo). The last item in the figure is the only natural factor: the sun is somewhat brighter now than in 1750, causing a positive forcing (ie, contributing to global warming).