Dec 18, 2006

Name: ______________________ Pledge (sign): ______________________

Envr Studies 201 Test #3

Point Total: 100 pts possible

16 pts 1. Briefly define and describe each of the following acronyms.

(a) NAAQS

These are the National Ambient Air Quality Standards. They are the means by which the US government regulates health risk due to exposure to the six criteria air pollutants (NO_2, O_3, Pb, CO, PM, SO_2). They are maximum concentration levels of these pollutants in air, as judged by the EPA, that do not endanger public health (or pose an unreasonable risk of doing so).

(b) NPL

The National Priority List is a list, maintained by the EPA, of contaminated sites that will be cleaned up under CERCLA; in other words, the NPL is the list of 'Superfund' sites. A site is included on the NPL if its risk to human health is deemed high enough to trigger remediation, as evaluated by its score under the Hazard Ranking System (HRS). If a hazardous waste site's HRS score exceeds some arbitrary cut-off, as determined by the EPA, then it is placed on the NPL and the cleanup process may begin.

(c) NOAEL

The No Observed Adverse Effect Level is the dosage level at which a toxicant has no discernable harmful impact on (human) health. Often called a 'threshold' level, exposure to pollutants at doses below the NOAEL is not deemed to pose a risk to public health. Presumably below this level the human body can eliminate the pollutant and repair any damage it caused. The NOAEL is used to set health-based ambient pollutant standards, and they are usually determined by a combination of toxicological, epidemiological and clinical studies of pollutants.

(d) $PM_{2.5}$

'Particulate matter,' also called atmospheric aerosol, are small solid/liquid particles that are suspended in the air. $PM_{2.5}$ refers to particulate matter in the atmosphere with an effective diameter of 2.5 μm or less; this fraction of PM is sometimes called 'fine PM' to distinguish it from the 'coarse' PM fraction with larger diameters. Fine PM is usually deemed to be the fraction of the atmospheric aerosol that poses the greatest health risk, due to the fact that (i) it has the longest residence time in air; (ii) it penetrated deeply into the lungs and (iii) it has many anthropogenic sources. The EPA has recently decided to specify separate air quality standards (NAAQS) for $PM_{2.5}$.

10 pts 2. What is photochemical smog? Be brief (3–5 sentences) but as specific as you can.

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.

Photochemical smog requires light to form, and the rate of formation is most rapid in warm weather. Its precursors are emitted by motor vehicles in rush hour traffic; hence, photochemical smog is at its most concentrated in the summer months, particularly in the afternoon.

9 pts 3. List the three major epidemiological methods used to study dose-response of environmental pollutants, and briefly describe each.

In all cases, epidemiology studies the correlation between at least two variables: at least one is an indicator of human health (death, heart attacks, strokes, cancer incidence, asthma, etc) and at least one quantifies the exposure level to a particular pollutant (ambient concentration in air, water, food). The three methods differ are

- Time-series (retrospective) studies. In this case, the variables are studied as a function of time within a particular location. If the pollutant causes the effect in question, one would expect that the two variables would tend to rise and fall together, probably with a lag time between increased exposure and the observed effect. The time frame studied is usually brief (days), and so this method is appropriate for the examination of acute effects of pollutant exposure.
- Transversal studies. In this case, the two variables are studied as a function of location. For example, one may sample from urban and rural locations. The time scale is usually fairly long (years), so that this method is more appropriate for studying chronic effects.
- Prospective studies. Samples are chosen prior to exposure. The exposure level and health effects are determined individually based on questionnaires, lab analysis, medical records, etc; confounding effects can also be determined in this manner. This is the most comprehensive (and expensive) method, and it is the best epidemiological method for studying of chronic effects of pollutants.

8 pts 4. (a) What is the general purpose and the specific goal (emission target) of the Kyoto Protocol? Make sure to be specific.

The Kyoto Protocol is part of the UN Framework Convention on Climate Change (UNFCCC), which was created at the 1992 Rio Convention (the first 'Earth Summit'). The purpose of the UNFCCC—and by extension the Kyoto Protocol—is "stabilization of greenhouse gas concentrations...at a level that would prevent dangerous anthropogenic interference within the climate system." Specifically, in the Kyoto Protocol the so-called Annex I Parties (ie, developed countries who are members of the UNFCCC and who ratified the Protocol) agreed to reduce their aggregate emissions of greenhouse gases to 5.2% below the 1990 emission levels, by 2012. The Annex I countries do not all have the same reductions—these were decided on a country-by-country basis—and the non-Annex countries do not have specific emission restrictions.

9 pts (b) What are the three *flexible mechanisms* available to help achieve this goal? List them and briefly describe each.

There are three flexible mechanisms by which a country may achieve its target reduction:

- Emissions trading. This is a cap-and-trade discharge permit system between the Annex I countries. A country that exceeds its required reductions may sell its excess to another country. Thus, every country may either reduce its emissions or buy emissions reduction credits from another country (or, more likely, a combination of the two).
- Clean Development Mechanisms (CDMs). Annex I countries can get emission reduction credits towards their target by reducing emissions from non-Annex countries through technology transfer.
- Joint Implementation. This is similar to CDMs but is between two Annex I countries, usually involving technology transfer to a Country with an Economy in Transition (CEIT), ie Russia and other eastern-bloc countries.

8 pts 5. Define a *greenhouse gas* (GHG). Which five major GHGs have been most affected by human activity?

A greenhouse gas is a component of air that absorbs outgoing infrared radiation emitted by the Earth's surface. Thus, the GHG affects the radiative energy balance between incoming solar radiation and outgoing longwave radiation. The GHGs most affected directly by human activities are:

- carbon dioxide, CO_2
- methane, CH_4
- nitrous oxide, N_2O
- ozone, O_3
- halocarbons, such as CFCs, HCFCs, HFCs and halons

Another major greenhouse gas is water vapor. Human activities do not *directly* alter that water content of the atmosphere very much (compared to natural processes such as evaporation and precipitation) but indirectly through feedback mechanisms that affect climate (eg, global temperature).

10 pts 6. What are *dead zones*, and how are they caused by human activity?

Dead zones are areas in large water bodies (oceans, large estuaries and lakes), that are mostly devoid of oxygen. Some dead zones can be quite large. Only anaerobic organisms can survive in these regions, and they can produce foul-smelling gases such as methane, ammonia and hydrogen sulfide. They are usually caused by nutrient pollution—usually inorganic nitrogen and phosphorus—generated by human activities such as fertilizer application (both agricultural and residential use), sewage discharges, and combustion processes (which emit NO_x gases that ultimate deposit as nitrate aerosol). The nutrient pollution greatly stimulates the growth of algae, which consume oxygen once they die and decay.

10 pts 7. How do *tropospheric* emissions of the chlorofluoromethanes $CFCl_3$ and CF_2Cl_2 result in the release of chlorine in the *stratosphere*?

Chlorofluorocarbons (CFCs), like the two chlorofluoromethanes here, are both chemically inert and insoluble in water. They are also transparent to light above 290 nm, which is the shortest wavelength available in the troposphere. The consequence of these three properties is that CFCs are not rapidly removed from the troposphere; in fact, their main removal mechanism is transport across the tropopause (10–15 km high) into the stratosphere. But exchange across the tropopause is slow; it takes about 5–10 years on average for CFC molecules to enter the stratosphere from the troposphere.

Once CFCs enter the stratosphere, with increasing altitude they are exposed to more energetic uv light—particularly that within a 'spectral window' between 195–225 nm that penetrates more deeply into the stratosphere (down to 15–25 km). When exposed to this energetic uv radiation, CFCs will photodissociate to release chlorine atoms. For example:

$$\mathrm{CFCl_3} + h\nu \longrightarrow \mathrm{CFCl_2} + \mathrm{Cl}$$

where $h\nu$ stands for a single 'photon' of light energy. Further photodissociation of the $CFCl_2$ radical can liberate still more chlorine atoms.

To summarize: CFCs linger in the troposphere long enough to reach the stratosphere, where the more energetic uv light will liberate chlorine atoms from the CFC molecule.

20 pts 8. Choose *one* of the following and answer in detail (use the back of this sheet if necessary).

(a) In her article, Beverly Paigen mentions 'type I' and 'type II errors.' What are these, and what role do they play in risk assessment and policy decisions? How do they relate to the *precautionary principle*?

In quantitative risk assessment, the risk to human health associated with environmental degradation of some sort—such as the emission of chemical pollution—is reduced to a number, such as the probability that a particular outcome (death, birth defects, etc) will occur. So in managing the risk posed by the activity that causes the pollution, there are two possible conclusions: (i) the risk is considered negligible or (ii) the risk is considered significant. Theoretically there is some *threshold level* above which a risk becomes significant.

The problem is that quantitative risk assessment will contain some uncertainty. In other words, the results of a quantitative risk assessment is an estimate of the true (unknown) risk. Thus, there is always the risk of *error*: the estimate of the risk may be higher than the actual risk, leading one to reduce the risk when the true risk was actually at an acceptable (even negligible) level. This is a type I error, or a *false positive*, incorrectly believing that the risk is significant. Similarly, due to imperfect knowledge or faulty experiments, the results of quantitative risk assessment may actually underestimate the true risk, so that we decide not to take action to reduce risk (or may not reduce it sufficiently). The result would be a type II error, or a *false negative*: incorrectly concluding that the risk is not significant. The following table illustrates the distinction.

	Decision in response to potential risk	
Actual risk level	*take no action*	*take action to reduce risk*
risk level is acceptable	correct decision	false positive (false alarm)
risk level is too high	false negative	correct decision

In managing risk, it is important to keep in mind the *consequences* of false positive or false negatives. A health risk associated with the discharge of chemical pollution (or some other form of environmental degradation) is usually due to activity that benefits human society in some manner. If the benefits of the activity are very high, then the consequences of a false positive—incorrectly curtailing the activity that produces the risk—will also be high. But if the activity produces a more minor or trivial benefit then the risk of false positive is much less. Similarly, if the risk to human health and well-being by the environmental degradation is potentially very high, then the consequences of a false negative—incorrectly continuing the activity—is also high. Such factors should be considered explicitly when choosing our actions and assessing our tolerance for type I and II errors.

Scientists are generally trained to keep the type I error small (5% or less), in other words to impose a fairly high burden of proof for the conclusion that risk is present. Paigen believes that this barrier is frequently set too high; she believes the requirements of *prudent avoidance of potential risk* should generally be less onerous than the requirements of absolute *proof of unacceptable risk*. This is a view also articulated in the Precautionary Principle, one version of which states "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." Or as put in the Rio Declaration: '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.' In other words, action can be taken even in the face of some significant scientific uncertainty when the potential risk to human society is great enough.

(b) In pollution regulation, what are *tradeable discharge permits*? What are their advantages relative to command-and-control regulation? What are some potential difficulties?

In a tradeable discharge permit (TDP) system, the right to discharge pollutants into the environment is made into a tradeable market commodity. This is a way to privatize a common pool resource, in this case the ability of the environment to assimilate pollutants. Note that such a system can also be generalized to privatize non-pollutant ecosystem services; for example, one can create a tradeable permit system for access to fisheries or some other common pool resource. The term ‘tradeable environmental permits’ (or allowances) is sometimes used to emphasize its applicability beyond pollution control.

The most common TDP system is the ‘cap and trade’ system where the total volume of discharge permits is limited. A certain number of these permits are created initially and distributed to polluters. These polluters are then free to discharge pollution up to the number of permits they possess; any unused permits may be sold to other polluters. Thus, each polluter faces the choice of either taking steps to limit is pollution discharge and make money by selling its permits, or using up the permits it owns and perhaps buying additional permits from other polluters. Over time, the total volume of permits can be reduced to meet target timetables and better protect public health.

The major advantage of the TDP system, relative to command-and-control (CAC), is economic efficiency. Ideally each polluter will do a cost-benefit analysis to decide how many of its discharge permits to use; the polluters that can most efficiently reduce their discharge rate will be the ones to do so, since they can make more money by selling their discharges. Polluters who find it very expensive to reduce their discharge will be willing to pay relatively higher prices for discharge permits.

Under CAC systems, all polluters must discharge the same amount (ie, ‘use up’ all their own permits). That means that there is also no incentive for polluters to reduce their pollution level below that mandated by the central agency. The TDP system, on the other hand, encourages the development of innovative, cost-effective ways to limit pollution to levels below the limits set under a CAC system.

The TDP also reduces adversarial conflict between regulators and polluters, who usually prefer the TDP system to CAC.

However, the TDP system is not without its problems, including:

- finding an equitable initial distribution of permits;
- avoiding ‘hot spots’ of high pollution levels (and associated environmental justice issues);
- higher requirements for monitoring discharge rates;
- higher transactional costs associated with trading activities.