Apr 25, 2005

Name: ______________________ Pledge: ______________________

Env Studies 201 Test #3

Point Total: 100 pts possible

4 pts 1. Which use demands more water, irrigation or human consumption (ie, drinking water)?

Irrigation.

12 pts 2. What are the *criteria pollutants* under the Clean Air Act? List them. For each one, state the human activity (or activities) that result in its presence in the air.

- NO_2, nitrogen dioxide. NO_x (ie, NO + NO_2) is emitted into the air by any high temperature processes, primarily fossil fuel combustion. The high temperature causes a reaction between atmospheric N_2 and O_2 to form nitrogen oxides, primarily NO.
- O_3, ozone. O_3 is a secondary pollutant, meaning that it is not emitted directly but formed by the reaction of precursor pollutants. Those precursors are NO_x and reactive organic gases; both are emitted by combustion of fossil fuels. Motor vehicles are the most important sources.
- SO_2, sulfur dioxide. SO_2 is emitted whenever a sulfur-containing fuel is burned. The most common culprit is coal-burning power plants, although gasoline combustion also contributes.
- PM, particulate matter. $PM_{2.5}$ and PM_{10} are emitted directly by many processes, such as combustion processes and wind erosion; there are many natural sources as well. Secondary PM is primarily $PM_{2.5}$ and is formed from the atmospheric reactions of the following precursors: NO_x, SO_2, and VOCs (volatile organic compounds). A majority of atmospheric $PM_{2.5}$ is anthropogenic.
- CO, carbon monoxide. CO is emitted in the combustion of any fossil fuel, primarily from motor vehicles.
- Pb, lead. Historically the major source of atmospheric lead is the combustion of leaded gasoline (additive: tetraethyl lead, TEL). Some countries still use leaded gasoline but it is banned in the US and most industrial countries. The major sources of atmospheric lead in such countries is smelters (where ore is processed) and battery manufacturers (particularly for the lead-acid battery used in cars).

8 pts 3. What are the main pollutants of concern in global climate change? *Be complete.* (Hint: it's not just the greenhouse gases.)

Pollutants that can cause radiative forcing include the greenhouse gases and atmospheric aerosols (ie, PM). The main ones produced directly by human activities are:

- CO_2 (from fossil fuel burning, deforestation, and cement manufacture)
- CH_4 (from landfills and agricultural operations)
- N_2O (from fertilizer application)
- O_3 (from VOC and NO_x emission, which forms smog)
- halocarbons, a group of small organic molecules that contain halogen atoms. Examples include CFCs, HCFCs, HFCs and CCl_4.
- SO_2 (from coal burning) which forms sulfate aerosol
- soot (from combustion processes)
- VOCs (from combustion processes and industrial emissions), some of which forms a part of carbonaceous aerosol
- NO_x, (from combustion processes) which forms nitrate aerosol
- fugitive mineral dust (many sources, eg from wind erosion due to landscape alteration)

8 pts 4. What are the primary justifications for establishing 'pollution markets?'

The basic idea is to 'privatize' a public service (e.g., the ability to discharge pollution into air or water). The justifications given are usually (and these are not completely independent):

- theoretically better economic efficiency by using market forces (Adam Smith's 'invisible hand') so that scarce resources are put to best use, and not to enforce excessively strict cleanup goals (ie, stricter than the public really wants)
- give companies an economic motive not just to meet environmental standards, but to exceed them
- decrease the overall cost of compliance (eg in 'cap and trade' systems)
- stimulate innovation in technologies and pollution prevention practices

8 pts 5. (a) Under CERCLA, liability for cleanup costs is both *retroactive* and *joint and several*. What does that mean?

Retroactive liability means that a company may be liable for cleanup of wastes that are present due to actions that pre-date the passage of CERCLA or RCRA. The actions may not even have been illegal by the standards of the time.

Joint and several liability refers to the fact that the EPA may hold any of several 'potentially responsible parties' liable for any amount up to the entire cost of the cleanup.

10 pts (b) The liability scheme in CERCLA is controversial. Yet Katherine Probst cautions that eliminating it may well cause cleanup costs to rise. What are some reasons this might occur? Answer in a little detail.

Critics of the liability scheme point to the fact that costs of litigation, and other transaction costs, are a significant expense (and also possibly delays the cleanup process). However, there are several reasons that cleanup costs may rise without the current liability scheme.

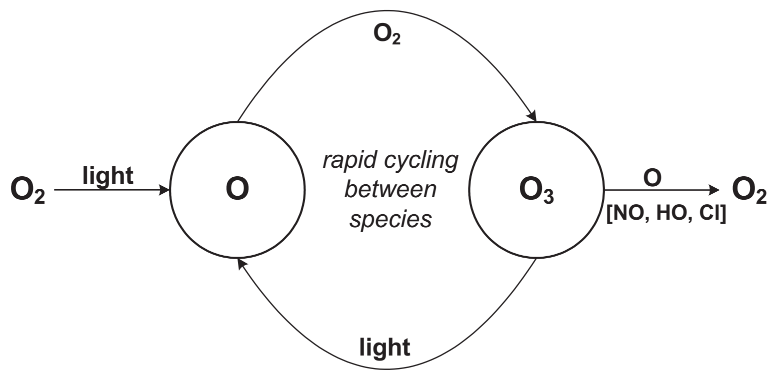
- The current liability scheme is very successful at bringing the polluting parties to the table. These corporations may have confidential and detailed knowledge about the nature of the hazardous waste site which could significantly decrease cleanup expense.
- Under the current liability scheme, EPA encourages the responsible parties to do their own cleanup of the site; given the incentive to control costs, these cleanups are significantly less expensive.
- The current liability scheme is a very effective deterrent for irresponsible behavior that leads to the hazardous waste sites; without this deterrent, there may well be more of such sites, driving overall cleanup costs higher. Moreover, scrapping the liability scheme at this date would penalize those who paid early and reward those who delayed in court, possibly sending the wrong message (ie, that companies should wait and see if Congress is 'really serious').
- Increases in general taxes of polluting industries, necessary to counter the loss in revenue due to liability recovery, would create its own set of compliance costs that would be significant.

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

Dead zones are large areas, in water bodies, that are mostly devoid of oxygen. 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 cased 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).

8 pts 7. How is the ozone layer formed?

Ozone, O_3, is produced by any process that produces atomic oxygen, O. In the stratosphere, uv light with wavelength less than 242 nm can break the bond in dioxygen, O_2, producing two oxygen atoms. Once atomic oxygen is produced, it quickly reacts with a dioxygen molecule to produce ozone. Ozone, in turn, is destroyed by uv light (with wavelengths less than about 330 nm) to produce atomic oxygen, which usually turns right back around and re-forms ozone. This process, called the *Chapman Cycle* is represented by the following figure.



The two 'odd-oxygen' species, O and O_3, are collectively refereed to as O_x species. Any process that creates O_x (O_3 or O) contributes to the ozone layer; any process that destroys O_x depletes the ozone layer. Two O_x species are destroyed by the mechanism originally proposed by Chapman: $O_3 + O \longrightarrow 2O_2$. O_x destruction is also catalyzed by stratospheric NO, OH and Cl.

10 pts 8. Quantitative estimates of the risk posed by low levels of toxic pollutants can be difficult to determine. What are the principal methods used in risk assessment, and what are their associated difficulties?

Estimating human responses to low levels of toxic pollutants is usually done by two major methods:

(i) controlled dose-response experiments involving other species, such as mice or monkeys; and

(ii) epidemiological data where human populations are (perhaps inadvertently) exposed to higher levels of pollution (eg living in cities with poor air quality, or where a chemical spill has tainted the groundwater).

Both of these methods has problems. The controlled dose-response experiments have the problem of inter-species variability: not all species are equally sensitive to toxicants. In practice, it is usually assumed that humans are as sensitive as the most sensitive lab animal tested; an additional safety factor (usually 100X) may also be factored in. Another problem is that estimating low incidence levels—which may be necessary if a large population is exposed to the pollutant—requires extrapolation from much higher dosage levels. It can also be difficult to test for synergism due to simultaneous exposure to many pollutants.

Epidemiological data is hampered by the problem of confounding effects. Since the variables are not strictly controlled, it can be difficult to separate the variable of interest (ie, level of exposure to a pollutant) from other variables that can potentially also affect the health of the population. The main classes of epidemiological experiments are time-series, transversal, and prospective (or cohort) studies, each with its own method of dealing with the problem of confounding variables; prospective studies are the most successful at doing so, but are the most expensive to perform.

12 pts 9. What is the *precautionary principle*? Answer in a little detail, using the concepts of type I and type II errors. Also illustrate the principle using the positions adopted by Carol Browner and Dan Menzel regarding the revised PM air quality standards proposed by the EPA in 1997.

The most common version of the precautionary principle (PP) is represented by Principle 15 of the Rio Declaration (presented at the Rio Earth Summit in 1992):

> Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent degradation.

Under this principle, the familiar refrain of 'more research is needed to prove harm' shall not be sufficient to delay regulation of actions that might be particularly harmful to the ecosystems of human health.

The concept of 'scientific proof' is closely tied to the precautionary principle. Imagine we are interested in the question of whether exposure to a particular pollutant is harmful to human health. To test this scientifically, we would begin with an assumption of no harm (the 'null hypothesis') and attempt to 'prove' the alternate hypothesis, that exposure to levels of the pollutant is harmful above (say) a proposed regulatory limit. Data is collected and analyzed in an attempt to quantify the probability that the null hypothesis is true. If the probability is small—usually below 5%—then the null hypothesis is rejected in favor of the alternate hypothesis. This constitutes scientific 'proof' of harm beyond a 'reasonable' doubt.

However, there is always a chance of error. In this case, there may still be a probability of up to 5% that the pollutant is, in fact, harmless at the proposed level. If we conclude that the pollutant is harmful when in fact it isn't, we have just made a type I error, also called a false positive. When we are specifying the level of certainty needed for proof, we are actually setting the probability of a type I error.

However, there is another kind of error: type II error, where we mistakenly assume that the pollutant is harmless when, in fact it isn't (at the level being tested, at any rate). This type of error is also called a false negative. For example, imagine that, from the data, we would conclude that there is a 10% probability that the null hypothesis is true. This is insufficient to 'prove' no harm, so according to standard practice in science, we do not yet reject the null hypothesis. And yet it is certainly possible—likely, even—that null hypothesis is false and the alternative hypothesis is true. The probability of type II error in this case is high.

The philosophy of the PP is basically that, for potentially serious effects, we should relax our standards of the proof needed before taking action to protect human health and the environment. In other words, if the potential risk is high, we should reduce the type II error by increasing the probability of type I error.

In their testimony about proposed PM air quality standards, Carol Browner adopted a precautionary approach while Menzel insisted that more research was needed. Epidemiological results indicated that PM was likely to be causing harmful effects at levels that were legal at the time, but the results were not yet substantiated by toxicological research. In particular, toxicological research could not with any certainty suggest what level is safe. Nevertheless, Browner felt that a precautionary approach was warranted due to the potentially severe health risks: with such a large population exposed, even small changes in risk translates to a pretty significant increase in mortality.

12 pts 10. What were some of the key elements of the Montreal Protocol in making it surprisingly effective in halting ozone depletion? Answer in some detail.

The treaty itself contained the following importance elements:

- Flexibility. There was a mechanism to update the original treaty to respond to technological and scientific developments. These changes (amendments and adjustments) to the original treaty could change the phase-out schedule and add new ozone-depleting substances. Monitoring, reporting and licensing requirements could also change in response to various compliance issues.
- Treatment of developing countries. The 'article 5' countries had a more generous phase-out schedule, and were provided financial, technical, and planning assistance to meet their needs while minimizing use of ozone-depleting substances.
- Compliance and deterrence of free-riding. Parties to the treaty could not trade (neither import nor export) banned substances with non-parties. Members who violated the treaty might ultimately be suspended from the Protocol. However, rather than assume that violations of the treaty were deliberate, it was recognized that non-compliance was sometimes inadvertent. A 'managerial' approach was used to assure compliance: warnings were issued to violators, and technical and financial assistance was provided to meet targets. Basically, in formulating responses to reports of non-compliance, the actual *ability* of the violator to comply was taken into account.

In addition, the process leading up to the Montreal Protocol was aided by other factors:

- The partnership between the science, private and public sectors. Scientists played a critical role in identifying the nature of the problem, and continually informed the evolution of the Protocol. The private sector was involved early on in developing alternative substances and technologies, minimizing their resistance to regulation.
- Strong and consistent leadership provided by the US (the single largest producer and consumer of ozone-depleting substances) and UNEP. The US was committed to phasing out CFCs and was even prepared to act unilaterally, which did much to spur negotiations. Mostafa Tolba, director of UNEP, was a strong proponent of regulation; his status as a scientist and Egyptian citizen bolstered his reputation, particularly among developing countries.
- The threat of ozone depletion was underscored by the appearance of the 'ozone hole' in Antarctica. At the time the Protocol was signed, blame could not yet be assigned to anthropogenic factors; still, its appearance did help to emphasize the severity and global nature of the danger.