**Environmental Science III**

MS Word Version – Please note – this file is designed for the instructor to use for

making modifications to the original Environmental Science III Course created by NCSR.

Some re-formatting may be required due to different versions of word processing programs.

 If in doubt about the original text or formatting,

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Environmental Science III

Evaluation of Hanford Reservation (correlates with pages 13-19 in PDF file and book)

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**Evaluation of Environmental Issues**

**at the Hanford Nuclear Reservation**

The Hanford Nuclear Reservation was established in 1943 as a site for the production of high-grade plutonium for use in nuclear weapons. A site in southern Washington along the Columbia River was chosen due to its remote location and abundant supply of clean water. At its peak of operation the facility employed and housed 50,000 workers. In addition to the production of plutonium, huge amounts of nuclear waste were also produced and stored in steel and concrete tanks on site. Concerns of environmental contamination and human health effects have prompted governmental agencies responsible for management of the site to initiate the largest environmental cleanup project in the history of the United States.

**PROCEDURE**

View the following videotapes produced by Oregon Field Guide:

“Cleaning Up Hanford - A Special Report.” - Oregon Field Guide, 1994, 60 min.

“Hanford Nuclear Reservation as a Wildlife Refuge.” Oregon Field Guide, May 1996, 10 min.

*Use information from these videotapes and the accompanying article (Zorpette, 1996) to respond to the following questions:*

1. Which federal and state governmental agencies are responsible for overseeing the cleanup of Hanford?
2. What types of studies are being conducted to monitor the potential effects of environmental

contamination from Hanford?

1. What are the results of these studies?
2. At the present time there is no long-term solution for dealing with radioactive waste. Describe

the various methods that have been attempted to deal with radioactive waste in the short-term.

1. The storage tanks at Hanford are often described as containing a “witch’s brew” of chemicals.

Besides radionuclides, which may release radiation into the environment, what other types of contaminants exist at the Hanford site?

1. What are the main concerns related to the contaminants you have listed in the question above?

7. The Hanford facility is divided into several different zones - each with a different history of use, level of contamination and potential for cleanup. These zones are illustrated in the figure below. For each of these zones describe:

1. How the area was used during the time Hanford was in full operation.
2. What types of contamination exist on the site?
3. To what degree are these contaminants “contained”? (i.e., are any leaking into the soil or groundwater?)
4. What are the cleanup plans for this area?
5. In your opinion, taking into account such elements as cost, human health and environmental

degradation, what should be the ultimate fate of this zone?

***Record your answers on the pages that follow.***

******

**North Slope *and* Arid Lands Ecology Reserve**

**Original Use**

**Types of Contamination**

**Containment of Contaminants**

**Cleanup Plans**

**Ultimate Fate**

**100 Area**

**Original Use**

**Types of Contamination**

**Containment of Contaminants**

**Cleanup Plans**

**Ultimate Fate**

**200 Area**

**Original Use**

**Types of Contamination**

**Containment of Contaminants**

**Cleanup Plans**

**Ultimate Fate**

**300 Area**

**Original Use**

**Types of Contamination**

**Containment of Contaminants**

**Cleanup Plans**

**Ultimate Fate**

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGES 20-26

Environmental Science III

Alternative Energy Sources (correlates with pages 27-44 in PDF file and book)

**How Can We Evaluate Alternative Energy Sources?**

**INTRODUCTION**

This handout is designed as a supplement for Botkin and Keller’s *Environmental Issue* on p. 359. In this activity you are asked to evaluate alternative energy sources (i.e., those sources other than traditional fossil fuels) in an objective manner. Upon completing this evaluation, you should be able to rank the various alternative energy sources using several criteria.

**I. ENVIRONMENTAL IMPACTS SUMMARY**

The first step in this analysis is to examine the environmental impacts of each alternative energy source. In the table below, list the “pros” and “cons” for each energy source. Wind power has already

been completed as an example.

NOTE: *Omit*  “*Combined Cycle Coal*” *from this analysis.*

**PROS CONS**

**Wind** Non polluting noise, kill birds, land disturbance,

scenic degradation

**Geothermal**

**Photovoltaic**

**Solar Thermal**

**Biomass**

**Nuclear**

**II. RATING ALTERNATIVE ENERGY SOURCES**

*Complete the following:*

1. As described on page 359 of your text, assign a score of “1” (worst rating) to “10” (best rating)

for each column on the following table entitled “PRE-WEIGHTED TOTALS.” Use only whole numbers. Since you will lack complete information for some energy sources, you will have to use your best judgement. Use your analysis of “Environmental Impacts” on page 1 of this handout to complete the last column. Leave the “Weights” row empty for now.

1. Although we could evaluate alternative energy sources on this information alone by summing up the scores on the chart, you may find that not all of these criteria carry equal weight. For example, you may feel that the cost to produce a particular energy source is much more important than its environmental impact. We can take this into account by assigning “weights” to each of the criteria.
2. To keep results consistent from one student to the next, assign weights that are some fraction of 1.0 to each of the criteria according to their importance. For example, if you feel that all criteria

carry exactly the same importance (highly unlikely), you would assign a weight of 0.142 (1/7th) to each criterion. The total of all of your weights should be exactly 1.0.

Enter these weights on the chart entitled “PRE-WEIGHTED TOTALS.”

1. Now you can apply these weights to each of the numbers on the chart. Simply multiply each

score you have assigned to the criteria by the weighting factor and enter this new number in the

chart entitled “WEIGHTED TOTALS.”

1. Add the weighted totals for each energy source, enter these numbers on the chart in the appropriate column.
2. Rank each energy source according to these numbers. Assign a #1 rank to the highest number, a

#2 rank to the next highest, etc. You have now created your personalized priority list for alternative energy sources.

Use all of this information to form a *national energy policy for the future* (see chart on following page).

**PRE-WEIGHTED TOTALS**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|   | U.S. Recoverable | Costs | Land Use | Carbon Reduction | Carbon Avoidance \* | Jobs | Environmental Impacts |
| Weights |   |   |   |   |   |   |   |
| Wind |   |   |   |   |   |   |   |
| Geothermal |   |   |   |   |   |   |   |
| Photovoltaic |   |   |   |   |   |   |   |
| Solar Thermal |   |   |   |   |   |   |   |
| Biomass |   |   |   |   |   |   |   |
| Nuclear |   |   |   |   |   |   |   |
| Hydroelectric |   |   |   |   |   |   |   |

**\* Carbon avoidance cost is a way to estimate the cost of replacing coal-fired electric generating plants with an alternative energy source. Fuel, operating costs and environmental pollution for a coal plant are estimated to be 3.5 cents, so anything above this amount is considered to be a cost for C-avoidance. NOTE: lower numbers indicate lower cost to avoid release of C into the environment.**

(NOTE TO INSTRUCTOR – THIS PAGE CAN BE REFORMATTED IN A SEPARATE DOCUMENT TO PRINT LANDSCAPE FOR LARGER TEXT / SPACE TO WRITE DATA)

**WEIGHTED TOTALS**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|   | U.S. Recoverable | Costs | Land Use | Carbon Reduction | Carbon Avoidance \* | Jobs | Environmental Impacts | Weighted Total | Rank |
| Weights |   |   |   |   |   |   |   |   |   |
| Wind |   |   |   |   |   |   |   |   |   |
| Geothermal |   |   |   |   |   |   |   |   |   |
| Photovoltaic |   |   |   |   |   |   |   |   |   |
| Solar Thermal |   |   |   |   |   |   |   |   |   |
| Biomass |   |   |   |   |   |   |   |   |   |
| Nuclear |   |   |   |   |   |   |   |   |   |
| Hydroelectric |   |   |   |   |   |   |   |   |   |

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Now assume that you are designated the “U.S. Energy Czar” for the next 100 years. In this position you are responsible for designing and implementing an integrated energy policy that takes into account all of the factors examined above. *What would your policy look like?* In the table below indicate changes that would take place in energy production over the time frame indicated across the top. Coal, for example, currently accounts for 28% of energy generation in the United States. What would this number be according to your policy for the years 2010, 2050 and 2100? The eyes of the public will be upon you - *so be prepared to defend your numbers!*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | 2000 | 2010 | 2050 | 2100 |
| Wind |   |   |   |   |
| Geothermal |   |   |   |   |
| Photovoltaic |   |   |   |   |
| Solar Thermal |   |   |   |   |
| Biomass |   |   |   |   |
| Coal |   |   |   |   |
| Nuclear |   |   |   |   |
| Petroleum |   |   |   |   |
| Hydropower |   |   |   |   |
| Natural Gas |   |   |   |   |
| Hydrogen |   |   |   |   |

(NOTE TO INSTRUCTOR – THIS PAGE CAN BE REFORMATTED IN A SEPARATE DOCUMENT TO PRINT LANDSCAPE FOR LARGER TEXT / SPACE TO WRITE DATA)

**III. ALTERNATIVE ENERGY SOURCES** - **ANALYSIS**

**A. Narrative**

Use the chart you have prepared on the previous page to prepare a short narrative that describes your energy policy in words. Be sure to include your rationale for changes in energy sources over the duration of your reign as “Energy Czar.” Use the space below.

**B. Questions**

*Answer each of the questions below as completely as possible in the space provided.*

1. A number of different criteria (cost, environmental impact, etc.) have been used to evaluate alternative energy sources. In your opinion, are there any criteria that are missing from the evaluation? What are they?
2. What factors did you assign the greatest weight in your evaluation of alternative energy sources? Why were these factors important to you?
3. Examine the rankings of alternative energy sources generated by other students. Does there appear to be “a consensus view”?
4. Where would you place “Coal” in your rankings? Explain.
5. If a safe way for disposing of nuclear waste were found, would this change your ranking for this energy source? Explain why or why not.
6. If energy from nuclear fusion were available for commercial use tomorrow, what alternative energy sources would you eliminate, and why?
7. Which energy sources would you favor if one of your main objectives was to reduce global warming due to the greenhouse effect? Explain why.
8. If the analysis was done on a regional scale rather than a national scale, as we have done, the rankings may change. Some regions of the country, for example, have better access to solar energy while others may have readily available sources of coal or hydropower. What would your rankings be for the two regions listed below?

**Southwestern U.S. Willamette Valley, Oregon**

1.

2.

3.

4.

5.

6.

7.

1. What could be done to encourage the development and use of alternative energy sources?

**REFERENCES**

The following resources are but a small sample of articles that have been published regarding the future of various energy sources.

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Dunn, S. 1999. *King coal*’*s weakening grip on power*. WorldWatch Sep./Oct. 1999:10-19.

Flavin, C. and N. Lenssen. 1999. *Nuclear power nears its peak*. WorldWatch July/Aug:36-38.

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Gibbons, J.H., P.D. Blair and H.L. Gwin. 1989. *Strategies for energy use*. Sci. Am. 261:82-89.

Rist, C. 1999. *Why we’ll never run out of oil*. Discover June 1999:79-87.

Weinberg, C.J. and R.H. Williams. 1990. *Energy from the sun.* Sci. Am. Sept. 1990:147-155.

**American-Indian Cultural Perspectives**

**Energy Resources**

*Developed by NCSR Tribal partners*

**Objectives**

1. To introduce students to Native American cultural perspectives regarding energy production, particularly coal mining, and effects on water and land resources on Indian reservations*.*
2. To present historical and anecdotal information on these topics, regarding their place in indigenous culture; including social, religious, and economic significance.
3. To make students aware of energy/ore production, problems, and concerns now occurring on Native American reservations. Tribal examples include Hopi and Navajo in Arizona; Lakota Sioux in South Dakota; Gros Ventre/Assiniboine at Ft. Belknap; and Crow and Northern Cheyenne in Montana.

**Introduction**

**“Hopi Indian Religious Leader’s Letter to the President of the USA”**

*Last year the Peabody Coal Company, a subsidiary of Kennecott Copper Company, began stripping coal from 65,000 acres it has leased from the Navajo and Hopi tribes. Company officials declared that this mining would not damage Indian lands and in fact would improve the lives and subsistence of many Navajos and Hopis. In disagreement with this action a group of high spiritual leaders of the Hopi wrote the following letter to President Nixon (In McLujan, T.C.* ***Touch The Earth****. New York: Simon & Schuster, 1971, pp 170-171).*

Dear Mr. President:

We, the true and traditional religious leaders, recognized as such by the Hopi People, maintain full authority over all land and life contained within the Western Hemisphere. We are granted our stewardship by virtue of our instruction as the meaning of Nature, Peace, and Harmony as spoken to our People by Him, known to us as Massau’u, the Great Spirit, who long ago provided for us the sacred stone tablets which we preserve to this day. For many generations before the coming of the white man, for many generations before the coming of the Navajo, the Hopi People have lived in the sacred place known to you as the Southwest and known to us to be the spiritual center of our continent. Those of us of the Hopi Nation who have followed the path of the Great Spirit without compromise have a message which we are committed, through our prophecy, to convey to you.

The white man, through his insensitivity to the way of Nature, has desecrated the face of Mother Earth. The white man’s advanced technological capacity has occurred as a result of his lack of regard for the spiritual path, and for the way of all living things. The white man’s desire for material possessions and power has blinded him to the pain he has caused Mother Earth by his quest for what he calls natural resources. And the path of the Great Spirit has become difficult to see by almost all men, even by many Indians who have chosen instead to follow the path of the white man…

Today the sacred lands where the Hopi live are being desecrated by men who seek coal and water from our soil that they may create more power for the white man’s cities. This must not be allowed to continue for if it does, Mother Nature will react in such a way that almost all men will suffer the end of life as they now know it. The Great Spirit said not to allow this to happen even as it was prophesied to our ancestors. The Great Spirit said not to take from the Earth - not to destroy living things. The Great Spirit, Massau.u, said that man was to live in Harmony and maintain a good clean land for all children to come. All Hopi People and other Indian Brothers are standing on this religious principle and the Traditional Spiritual Unity Movement today is endeavoring to reawaken the spiritual nature in Indian people throughout this land. Your government has almost destroyed our basic religion, which actually is a way of life for all our people in this land of the Great Spirit. We feel that to survive the coming Purification Day, we must return to the basic religious principles and to meet together on this basis as leaders of our people…

**Discussion**

Historical and anthropological records, and numerous government documents, have clearly demonstrated that there has been a continuous conflict of values between traditional Native-American cultures and Western society: clashes among *spiritual versus economic* values. This conflict of values and perspectives, and resulting political-legal issues are very evident in concerns over the needs, utilization, and management of natural resources and energy. Many natural resources, including energy resources, are found on or near Indian reservations. Examples of reservations with energy resources include: the Hopi and Navajo located in the Four Corners region that includes Arizona; the Lakota Sioux in South Dakota; and the Assiniboine and Gros Ventre, the Crow, and the Northern Cheyenne tribes of Montana.

Native-American people residing in such areas often live in extreme poverty, suffer very poor health, and live in isolation. As a consequence, education levels are very low, while unemployment rates are among the highest in the nation. To survive and raise standards of living, tribal people must have jobs; hence, vast deposits of natural energy, minerals, ores and metal resources not only offer the opportunity for tribal economic development, income, and employment, they also create a dilemma for the Indian people in terms of values conflict. These conflicts arise among “progressives” and “traditional” - tribal “progressives” are usually those who are more educated, and who have a tendency to sit on administrative positions of authority and power for the tribe, and who strongly advocate economic exploitation and development of the resources. Tribal “traditionals” are generally

less educated in “Western Knowledge” and values, and are frequently the spiritual and religious leaders for the tribe; often they strongly argue against exploitation while warning about the possible dangers of environmental pollution, health hazards, and spiritual reprimand.

**Tribal Case Studies**

*Hopi, Navajo, and Lakota Sioux*

See the reference on the Hopi, Navajo, and Lakota Sioux by Ward Churchill and Winona LaDuke

(Chapter VIII, pp 241-266).

**Navajo Uranium Operations**: From studies conducted between 1964 and 1981, the rate of Navajo newborn birth defects in the Shiprock Uranium Mining area was two to eight times as high as the national average. Microcephaly and Down Syndrome, among other birth defects, had tripled since the commencement of uranium mining and milling activities in the area.

*Cheyenne*

For Cheyenne perspectives and information, refer to the article by Gail Small (Small, Gail. *War Stories.* The Amicus Journal. Spring, 1994. Vol. 16.).

*Crow*

Refer to *The Oil Daily*. Dec. 20, 1984. p.2.

A joint venture partnership was reported between the Crow Tribe and three independent oil and gas producers for the first time, giving the tribe an equity interest in energy exploration. This partnership

may be used as a prototype for future mineral rights agreements between Indians and energy companies.

**Raven Oil Company** formed under the aegis of the **Indian Mineral Development Act**, and was approved by the Bureau of Indian Affairs. Raven Oil consists of the tribe and Buffalo Exploration

Company, which is a partnership of companies. The agreement gave control of Raven to the tribe, which would receive 51 percent of all profits, plus the normal 16 percent royalty that tribes have traditionally received for leasing their oil and gas resources. Buffalo Exploration receives 49 percent of the profits.

Raven is run by a management committee, consisting of four Crow representatives, and three from Buffalo Exploration.

*Assiniboine and Gros Ventre*

*Zortman-Landusky Mines*, (In) National Wildlife Federation Newsletter, 1997.

Spirit Mountain, a sacred site to the Assiniboine and Gros Ventre tribes of north-central Montana, was laid waste by bulldozers for [Western] society’s passion for gold, and thus it was no longer available for Native American traditional ceremonies and vision quests. It has been replaced by the Gold Bug Pit, its summit destroyed, its flanks scarred, and its rivers and wildlife polluted*.*

When gold was discovered in the Little Rocky Mountains in the late 1880s, in an area formerly part of the Fort Belknap Indian Reservation, the Federal Government pressured the tribes to cede the gold-bearing land areas of the reservation to the United States. Small-scale gold mining occurred in the area until the late 1970s, when Zortman-Landusky Mines, Inc. (ZMI) began operating in 1979. The use of cyanide heap-leach technology facilitated large-scale mining of low-grade ores found in these Mountains. Numerous expansions of mining operations created environmental problems, ranging from cyanide spills, to leach pad stability failures, and to bird and wildlife deaths. A series of lawsuits by the Tribes regarding these problems alleged numerous, significant and ongoing water quality violations, resulting in a Consent Decree in which legal actions which required ZMI to pay over $29 million for water quality violations, water quality studies, and other tribal amenities.

In 1992, ZMI applied once again to expand its operation from the then-400 to over 1200 acres. In 1996, after four years and preparation of an Environmental Impact Statement (EIS), the Department

of Environmental Quality (DEQ) approved the ZMI’s permit to expand. In 1997, the tribes and conservation organizations filed suit against Montana’s DEQ, citing, among other issues, these problems with the EIS:

* The EIS fails to address possible contamination of local aquifers, even though the DEQ recognizes that such groundwater contamination may already be occurring on the Fort Belknap Indian Reservation.
* The EIS contains no mitigation measures.
* The mine expansion would continue over 100 years of significant disruption to Native-American traditional cultural practices in the Little Rockies. It would impact 41 cultural sites, including vision quest and fasting sites, rock art sites, and a pow-wow grounds. The EIS fails to discuss these concerns.
* It lacks comprehensive study of impacts on wildlife. The expansion would cause cumulative loss of over 10% of existing wildlife habitat in the Little Rocky Mountains.
* Air emissions resulting from the expansion would violate federal and state air quality standards.

**Questions/Assignments**

Using resources and readings provided, research the following and prepare a research report:

1. The United States of America (the “dominant Western society”) needs energy and related ore resources, and impoverished Native-American people need employment and a steady source of income. Research and discuss how the differing value systems among tribal and non-tribal individuals might be resolved in such a way as to meet all the needs; and, if not, what alternatives do you suggest?
2. What forms of energy, ore, mineral, and metal resources are located on or near Indian reservations? Describe energy resources in detail for one of the reservations listed. Include examples of past and current problems, concerns, and issues involving energy resources on that Indian reservation.
3. In what ways would conversion to “alternative” forms of energy (i.e., geothermal, wind, solar, etc.) impact Indian society and reservation lands? Include both positive and negative impacts.

**SUGGESTED TEXTS, REFERENCES, AND INTERNET RESOURCES**

Churchill, Ward and Winona LaDuke (ed. Jaimes, M. Annette). *Native North America: The Political*

*Economy of Radioactive Colonialism.* Chapter VIII, pp 241-266.

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Sorenson, J.B. *Radiation Issues: Government Decision Making and Uranium Expansion Mining*, Black Hills/Paha Sapa Report, Vol. 1, No.1, 1979.

Samet, J.M., et.al. *Uranium Mining and Lung Cancer in Navajo Men*, New England Journal of Medicine, No.310, 1984, pp. 1481-84. (And) Barry, Tom. *Bury My Lungs At Red Rock*, The Progressive, Feb.1979, pp. 25-27.

Irvin, Amelia, *Energy Development and the Effects of Mining on the Lakota Nation*, Journal of Ethnic

Studies, Vol. 10, No.1, Spring, 1982.

Women Of All Red Nations, *Radiation: Dangerous To Pine Ridge Women*, Akwesasne Notes, Rooseveltown, N.Y. Spring, 1980.

*Films:*

Paha Sapa: *The Struggle For The Black Hills*; Navajo: *The Last Red Man;* The Four Corners: *A National Sacrifice Area* (all from Earth Image Films).

*Internet searches:*

1982 *Indian Mineral Development Act* (www4.law.cornell.edu/uscode/25/2101.html)

U. S. Code, Title 25, Indian child welfare (www4.law.cornell.edu/uscode/25/ch3.html)

Native Americans and the Environment Bibliographies ([www.Indians.org/library/biblios.html](http://www.Indians.org/library/biblios.html))

Native American Environmental Enforcements (www.mineralpolicy.org/bittersweet.html)

*Indian Country Today*

Obtain past reports and articles related to Indian tribes, and problems or accomplishments concerning

energy, ore, mining, environmental hazards, and pollution. Visit the newspaper’s website at:

[www.indiancountry.com](http://www.indiancountry.com)

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGES 45-47

Environmental Science III

Constructed Wetlands for Wastewater Treatment (correlates with pages 48-74 in PDF file and book)

**Constructed Wetlands for Wastewater Treatment**

**INTRODUCTION**

The treatment of wastewater from municipal, agricultural and industrial sources is of primary concern in modern societies. Water that contains pollutants from raw sewage to chemical contaminants must be processed before entry into natural waterways to avoid environmental contamination and resulting threats to environmental quality and human health. For years, modern societies have constructed large, centralized wastewater treatment facilities that treat large volumes of water using both chemical and biological processes. The utility of such facilities has come into question lately, particularly when considering their high cost and increased demands put upon them by growing populations. Consequently, there has been a great deal of interest in the development of alternative methods of treatment that capitalize on natural processes that occur in ecosystems. Among these alternatives is the use of natural and constructed wetlands to replace or (more commonly) augment the actions of technology-based wastewater treatment plants. Arcata, California, for example, has used a wetland for treatment of domestic sewage from that community since the 1970s. More recently, the city of Salem, Oregon has proposed a 630-acre plantation of poplar trees to treat cannery waste. Large-scale efforts often provide secondary benefits as well such as wildlife habitat or even recreational opportunities.

In this lab, you will evaluate how effectively a constructed wetland (a “wetland mimic,” so to speak) is

able to treat agricultural wastewater. This laboratory was developed for Chemeketa Community College’s *Aquatic Ecology Laboratory*; your instructor will provide background on your particular study site.

**PROCEDURE**

This laboratory begins a six-week study which will culminate in a final report. In today’s laboratory

we will:

* Learn and practice the protocols to be followed for water quality measurements in a constructed wetland
* Measure the initial conditions in the wastewater
* Discuss the experimental design of the study

**I. Preparation of Wastewater**

Two tanks (B4 and B5) were prepared as agricultural wastewater by adding 400 g of 16-16-16 pelletized fertilizer to each of these 300-gallon tanks. Tank B4 was designated as the **source tank**, which contains water to be processed by the wetlands. Tank B5 was designated as the **control tank**, and will be used to monitor water quality changes in wastewater that is *not* processed by the wetlands.

**II. Measure Initial Conditions in Wastewater**

**Protocols** (step-wise instructions) have been developed (see handout) that describe *how* each of nine

water quality measurements should be taken.

Each group should carefully examine and test each of these protocols using water samples taken from source tank B4. These measurements will represent the initial conditions in the source tank prior to treatment.

IMPORTANT NOTE: *Be sure that by the end of today’s lab, every group member knows how to take each measurement according to the protocols.*

The wastewater should be carefully mixed before measurements are taken. (*Don*’*t overdo it!* Vigorous

mixing could add oxygen to the water and influence the dissolved oxygen measurement.)

Take initial measurements on wastewater carefully following “Water Quality Measurement Protocols.”

Enter your data on the data sheet provided.

**III. Experimental Design**

The overall goal of this study is to test the effectiveness of constructed wetlands in the improvement of water quality. The approach is quite simple - agricultural wastewater containing high levels of phosphates and nitrates is added to a constructed wetland. Water quality parameters are monitored in samples that have passed through this wetland over a period of approximately 4 weeks. These results are compared to water quality changes in identically prepared wastewater that just sits in a control tank without a wetland.

The main elements of the experimental design are as follows:

* Six identical constructed wetlands (Tanks C1 º C6) will be used to treat the wastewater
* Each lab group will be assigned to one of these tanks
* One tank (B4) will be used as the source water to be treated
* One tank (B5) will be used as a control
* At the start of the study, wastewater will be added and the first sample will be taken (see start-up section below)
* Consequent measurements will be taken on a weekly basis
* All water samples must be taken and analyzed prior to preparing the final report

**IV. Measurement start-up**

On the first day, follow this procedure:

1. Drain existing water in wetlands (water can run out on gravel)
2. Close spigot
3. Add wastewater from Tank B4 to your tank in the following manner:
* dump water *gently* along edge of wetland
* bring volume up to one inch above level of soil shelf
1. Water samples for testing will be taken through spigot after allowing 5 seconds of free flow first (return this water to the tank)
2. Take all measurements as indicated in “Water Quality Measurement Protocols”
3. Record all information on data sheets provided
4. Your signature on the data form indicates that you have taken those measurements
5. Submit your original data sheets with your final report

On all subsequent sampling days, follow steps 4 through 8 above.

NOTE: *Sampling should be done on at least a weekly basis. Including the first sample, there should be a total of six measurements made over about four weeks.*

**V. Control Tank Measurements**

In addition to measurements made on wastewater that has been treated by each of your tanks, identical water quality measurements will also need to be taken on the control tank (B5). These measurements should be made simultaneously with measurements from your tanks. To spread out the work load, each group will have the responsibility of taking control tank measurements *once* during the study. The schedule is indicated below. Find the date that you will be responsible for control tank measurements and be sure that they are taken.

**If your tank is: You will take control tank (B5) measurements on:**

C1 Day 1

C2 Day 3

C3 Day 8

C4 Day 15

C5 Day 22

C6 Day 29

**VI. Other Data Collection**

All of the measurements described in the “Water Quality Measurement Protocols” are taken on the

treated water after it exits the wetlands. There are additional variables that we may want to measure

to monitor the effectiveness of the wetlands. Some examples include:

* Rainfall
* Solar radiation
* Air temperature
* Relative humidity

These variables will be recorded automatically by the Environmental Monitoring Equipment permanently installed in the *Aquatic Ecology Laboratory*. Later in the term we will discuss how the measurement of these variables might be used in our study.

IMPORTANT NOTES: *Complete and accurate data collection is an essential element of this study. Since each student will be using class data to prepare his/her report, missing or inaccurate data has consequences for everyone. For this reason, there will be point deductions for your group’s failure to provide complete and accurate information.*

**Constructed Wetlands for Wastewater Treatment Data Sheet**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Tank # | Signature of Observer(s) | pH | Water Temp (oC) | D.O. (ppm) | Turbidity (%T) | Algal Conc. (%T) | Phosphate | Nitrate | Odor | Comments |
|   |   |   |   |   |   |   |   |   |   |   |   |
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 (NOTE TO INSTRUCTOR – THIS PAGE CAN BE REFORMATTED IN A SEPARATE DOCUMENT TO PRINT LANDSCAPE FOR LARGER TEXT / SPACE TO WRITE DATA)

**Constructed Wetlands for Wastewater Treatment Data Sheet for Control Tank**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Tank # | Signature of Observer(s) | pH | Water Temp (oC) | D.O. (ppm) | Turbidity (%T) | Algal Conc. (%T) | Phosphate | Nitrate | Odor | Comments |
|   | **B5** |   |   |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |   |   |
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**Constructed Wetlands for Wastewater Treatment Data Sheet for Control Tank**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Tank # | *Chlamydomonas* | *Euglena* | *Chlorella* | *Oscillatoria* | *Lepocinclis* | *Chlorogonium* | *Pandorina* | *Scendesmus* |
|   |  |   |   |   |   |   |   |   |   |
|   |  |   |   |   |   |   |   |   |   |
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|   |   |   |   |   |   |   |   |   |   |

Record “percent of individuals” in the appropriate box. Add additional species to top row if necessary.

(NOTE TO INSTRUCTOR – THIS PAGE CAN BE REFORMATTED IN A SEPARATE DOCUMENT TO PRINT LANDSCAPE FOR LARGER TEXT / SPACE TO WRITE DATA)

**Constructed Wetlands for Wastewater Treatment Data Sheet for Control Tank**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Tank # | *Chlamydomonas* | *Euglena* | *Chlorella* | *Oscillatoria* | *Lepocinclis* | *Chlorogonium* | *Pandorina* | *Scendesmus* |
|   | **B5** |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |
|   | **B5** |   |   |   |   |   |   |   |   |
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Record “percent of individuals” in the appropriate box. Add additional species to top row if necessary.

(NOTE TO INSTRUCTOR – THIS PAGE CAN BE REFORMATTED IN A SEPARATE DOCUMENT TO PRINT LANDSCAPE FOR LARGER TEXT / SPACE TO WRITE DATA)

**Final Report Guidelines**

**GENERAL GUIDELINES**

The final report for the Constructed Wetlands Project will be due upon completion of data collection and analysis (in about six weeks). Each student will prepare an individual written report which will summarize what was learned about the effectiveness of constructed wetlands for the treatment of wastewater.

*Important points:*

* Reports will be due later in the term; late reports will not be accepted
* Reports should make use of *all* information available (i.e., all water quality measurements from replicates and controls, weather data collected by the monitoring station at the Aquatic Ecology Lab, plus other pertinent resources).
* Prepare graphs and tables of data using *EXCEL* or any other spreadsheet program where appropriate
* You will find all the Constructed Wetland lab handouts very useful (e.g., original “Constructed Wetlands for Wastewater Treatment” handout, *How should we interpret water quality measurements?*)
* The report must be typewritten, and include 4-5 pages of narrative plus tables, graphs, and figures

**FORMAT**

**I. INTRODUCTION** (1 paragraph). Use this section to briefly set the stage for what the report will cover Briefly describe what a constructed wetland is, why the study was done, what your major hypotheses were (i.e., What did you expect to find?), and what applications there might be for the study.

**II. METHODS AND MATERIALS** (1 to 2 paragraphs). Use this section to describe the experimental design of the study and procedures you have followed to obtain the data you have collected. *Include sufficient detail such that another researcher could duplicate your efforts.*

NOTE: *Rather than describing the intricate details of the procedure for each water quality parameter, simply provide an overview and cite the* “*Protocols” sheet for the details.*

**III. RESULTS** (2 to 3 paragraphs - plus graphs, charts, etc.). This section should include only data that were collected during this study. Information for this section should come from summarized class data. Where possible, summarize information in tables, charts and graphs that *help to visualize* the data (i.e., provide a graph that illustrates turbidity levels vs. time). Data from control tank and test (wetland) tanks should be put on the same graph for easy comparison. Where possible, enter your data into a spreadsheet program such as *EXCEL* and use the software to generate the graphs. Be sure to reference your tables, charts and graphs in the body of this section by indicating *major trends* (e.g., do not try to recount every item in tables, charts and graphs). No graph or table should stand alone without being referenced in this section.

*Example:*

“Turbidity levels remained high for the first two weeks of the study, declined rapidly and then dropped to near zero for the remainder of the sampling period (Table 1).”

**IV. CONCLUSIONS** and **DISCUSSION**. In these sections, you will summarize your conclusions

(logically drawn from the RESULTS section).

*Example:*

“We have obtained some evidence that constructed wetlands could be used to treat agricultural wastewater. Turbidity levels were significantly lower in water that had been in the wetlands at least two weeks and nitrate levels declined from an initial value of 40 ppm to a final value of 2 ppm.”

To help guide you, answer the following:

* Which of your findings were unexpected?
* Which hypotheses were supported by the data? Which hypotheses were not supported by the data?
* What changes or improvements would you make in your experimental design if you were to duplicate the study?

Also, attempt to place your findings into a broader context and apply them to real-world situations (i.e., answer the question, “*So what?”*). Here are some *examples* of questions that might be addressed in this section:

* What applications might your findings have to farmers who must meet environmental regulations for the release of agricultural wastewater?
* What other benefits might be achieved by constructing wetlands besides treating wastewater?
* What limitations are there on the use of constructed wetlands for the treatment of wastewater?
* Should natural wetlands be used for treating wastewater?

**MATERIALS**

**Quantity Materials and Equipment**

6 LaMotte\_s Limnology Test Kits

1 Orion Portable pH Meter

1 Orion Portable Dissolved Oxygen Meter

2 Hanna Ion Specific Meter (Phosphate)

2 Hanna Ion Specific Meter (Nitrate)

6 Wash bottles

12 250 ml bottles with screw cap

3 Spectronic 20 Spectrophotometers

12 Cuvettes for Spec-20

6 Alcohol thermometers

25 Microscope slides

25 Coverslips

6 Algae guides (e.g., Rainis and Russell 1996 or Palmer 1977)

6 Funnels

12 De-ionized water in wash bottles

12 250 ml beakers

1 Large capacity digital balance

2 2000 ml beakers

2 2000 ml (approx) glass jar with screw lids (to transport water samples)

24 Pasteur pipettes and bulbs

6 5-gallon buckets

**HANDOUT**

**WATER QUALITY MEASUREMENT PROTOCOLS**

IMPORTANT NOTE: *It is imperative that each group follow the same procedure each time the measurement is taken!*

**pH**

Follow the procedure described in the Limnology Test Kit to determine the pH of the wastewater.

* 1. Take sample from spigot in 300 ml beaker after allowing 5 seconds of free flow
	2. Return free flow to tank
	3. Thoroughly mix sample
	4. Rinse a test tube (from Limnology Test Kit - pH Test) with the water sample
	5. Fill tube to 5 ml line with water sample
	6. Add 10 drops of indicator solution while holding dropper bottle (or pipette) vertically
	7. Cap and invert several times to mix
	8. Insert test tube into comparator and match sample color to color standard
	9. Record pH (measurements can be verified with the Orion pH Meter.)

**Temperature**

1. Obtain sample from spigot in a 300 ml beaker
2. Place a thermometer into the beaker about half way down
3. Allow to sit for one minute
4. Pull out thermometer and record temperature

**Dissolved Oxygen**

NOTE: *Numbers in parentheses refer to part and reagent numbers in the LaMotte’s Limnology Test Kits.*

1. Thoroughly rinse 25 ml sampling bottle (#0688-DO) with sample water
2. Fill 25 ml sampling bottle completely with sample water
3. Gently tap sides of sampling bottle to dislodge any bubbles

NOTES: *Be careful not to introduce air into the sample while adding the reagents in the following steps. Simply drop the reagents into the sample, cap carefully, and mix gently.*

1. Add 8 drops Manganese Sulfate Solution (#4167)
2. Add 8 drops Alkaline Potassium Iodide Azide (#7166)
3. Cap and mix by inverting sample several times and allow particles to settle below shoulder of sampling bottle before proceeding.
4. Use the 1.0 g spoon (#0697) to add 1 g Sulfamic Acid Powder (#6286)
5. Cap and mix until reagent and precipitate dissolves (sample is now “fixed”)
6. Fill titration tube (#0299) to 20 ml line with the fixed sample; then cap titration tube
7. Fill Direct Reading Titrator (#0377) with Sodium Thiosulfate (#4169)
8. Add one drop at a time to sample and swirl between each drop until color is faint yellow
9. Remove titrator and cap
10. Add 8 drops Starch Solution (sample should turn blue-black)
11. Replace cap and titrator
12. Continue to add Sodium Thiosulfate until the blue color *just* disappears
13. Read the total amount of Sodium Thiosulfate added where plunger tip meets the scale. This reading is equal to dissolved oxygen concentration of the sample in ppm.

NOTE: *Each minor division on the Titrator scale equals 0.2 ppm*.

NOTES: *If the plunger tip reaches the bottom line on the titrator scale (10 ppm) before the endpoint color change occurs, refill the titrator and continue adding drops. When recording the test result, be sure to include the value of the original amount of Sodium Thiosulfate added (10 ppm).*

1. Record dissolved oxygen (measurements can be verified with Orion D.O. Meter)

**Turbidity**

A device called a “spectrophotometer” will be used to estimate turbidity and algal concentration. This

device passes a known quantity of light through a sample in a glass tube called a “cuvette.” A sensor on the opposite side of the cuvette detects the amount of light that passes through and displays this amount on a scale. The wavelength of light can be adjusted to measure the amount of various materials dissolved in the sample. We will use two wavelengths - one for turbidity and one for chlorophyll. The proper use of the spectrophotometer will be demonstrated in lab.

1. Turn on the spectrophotometer and allow it to warm up for 10 minutes
2. Select a wavelength of 550 nm and select correct filter position (if so equipped)
3. Set spectrophotometer to 0% Transmittance using knob on left
4. Place distilled water in cuvette (= blank) and wipe clean
5. Insert the blank into spectrophotometer, lining up the white lines on the cuvette with indicator line on spectrophotometer
6. Adjust spectrophotometer to 100% Transmittance with light adjustment knob on right
7. Remove blank
8. Place cuvette with water sample in spectrophotometer
9. Close lid and read % Transmittance from scale to tenth place.

*Record data.*

**Algal Concentration**

1. Turn on spectrophotometer and allow it to warm up for 10 minutes
2. Select a wavelength of 660 nm and select correct filter position (if so equipped)
3. Set spectrophotometer to 0% Transmittance using knob on left
4. Place distilled water in cuvette (= blank) and wipe clean
5. Insert the blank into spectrophotometer lining up white lines on cuvette with indicator line on spectrophotometer
6. Adjust spectrophotometer to 100% Transmittance with light adjustment knob on right
7. Remove blank
8. Place cuvette with water sample in spectrophotometer
9. Close lid and read % Transmittance from scale (to the tenths place)

*Record data.*

**Phosphates (Orthophosphates only)**

We will use a high range ion-specific meter made by *Hanna Instruments, Inc.* for phosphate measurements. Follow the instructions provided with the meter.

If we are unable to obtain accurate measurements with this meter, we may use the test provided in the

Limnology Test Kits as an alternative. The instructions for this test follow:

1. Fill test tube (#0844) to 10 ml line with sample water
2. Use the 1.0 ml pipette (#0354) to add 1.0 ml of Phosphate Acid Reagent (V-6282)
3. Cap and mix
4. Use second 0.1 g spoon (#0699) to add one level measure of Phosphate Reducing Reagent (V-6283)
5. Cap and mix until dissolved. Wait 5 minutes
6. Remove cap. Place into Nitrate and Phosphate Comparator (#3120) with Axial Reader (#2071). Match sample color to color standard on reader

*Record data as ppm phosphate.*

**Nitrates**

We will use a high range ion-specific meter made by *Hanna Instruments, Inc.* for nitrate measurements. Follow the instructions provided with the meter.

If we are unable to obtain accurate measurements with this meter, we may use the test provided in the

Limnology Test Kits as an alternative. The instructions for this test follow:

1. Fill test tube (#0844) to 2.5 ml line with sample water
2. Dilute to 5 ml line with Mixed Acid Reagent (V-6278)
3. Cap and mix. Wait 2 minutes before proceeding
4. Use the 0.1 g spoon (#0699) to add one level measure of Nitrate Reducing Reagent (V-6279)
5. Cap and invert 30 times in one minute. Wait 10 minutes
6. Mix and remove cap. Insert test tube into the Nitrate-N and Phosphate Comparator (#3120). Match

sample color to a color standard

*Record data as ppm Nitrate-N.*

**Odor**

1. Smell the water sample for any odor
2. Record in classes:

3 – “strong” (*Yuk!*)

2 – “moderate” (easily detectable but not obnoxious)

1 – “slight” (barely detectable)

0 – “none” (not detectable)

1. Identify odor as:

“Rotten egg” (Hydrogen sulfide)

“Musty” (Molds)

“Raw sewage” (Organic waste and bacteria)

“Frog pond” (Algae)

*For example:*

A sample that had a barely detectable odor that smelled like raw sewage would be recorded as “*Raw sewage – 1”*

Additional categories of odors may be added, if needed.

**Microscopic Examination**

1. Take one 100 ml sample from spigot in a small beaker
2. Allow the sample to settle for 5 minutes
3. Using a Pasteur pipette, extract a small sample from anywhere in the beaker where algae has settled (look for areas of green)
4. Prepare a wet mount using a microscope slide and coverslip
5. Examine at 100X and 450X using a compound microscope
6. Use identification guides to identify algal species
7. Record approximate \_percent of individuals\_ for each species on data sheet provided
8. Note whether species are indicators of clean water, slightly polluted water, or heavily polluted water (see available references)

NOTES: *You will almost certainly encounter microscopic crustaceans and protozoans cruising around in your microscopic samples. You are not required to estimate percent of individuals for these species, but it may be useful to identify them and record their presence or absence on the data sheet.*

**HOW SHOULD WE INTERPRET WATER QUALITY MEASUREMENTS?**

As we proceed with experiments designed to determine the effectiveness of constructed wetlands to treat agricultural wastewater, we will be comparing the initial conditions of the wastewater with the conditions of water that has been treated by the wetlands. The parameters that have been selected for measurement are representative of some of the best indicators of water quality. The following descriptions provide an indication of why these parameters are important and how the values you obtain might be interpreted.

**A. pH**

pH is a measure of the hydrogen ion (H+) concentration in a solution. Acid strength is based on how readily it releases hydrogen ions in water - strong acids release lots of H+, weak acids release smaller amounts. A pH reading of 7.0 indicates neutrality (neither acidic nor basic); numbers less than 7.0 are acids, greater than 7.0 are bases (alkaline). Since the pH scale is logarithmic, a change of one pH unit represents a ten-fold change in the acidity of the solution. Most species can tolerate pH values from 6.0 to 8.0; optimal levels for most fish are between 7.1 and 7.8 (Table 1). Values above or below these values may affect some species. Amphibians and some aquatic insect larvae are particularly sensitive to acidic conditions.

****

Most biochemical reactions that occur in living organisms are sensitive to pH. Therefore, pH values that lie outside of a species range of tolerance can have direct effects on survivability and overall health of the organism. In addition to these direct effects of pH changes, there are indirect effects as well. Acidic conditions (low pH) can increase the release of metals such as aluminum or copper from sediments and increase their concentration in the water. These metals can disrupt gill function or cause deformities in fish. Another indirect effect is illustrated by the relationship between pH and ammonia. Ammonia in water may occur either as ammonium ion (NH4 +) or ammonia (NH3). NH3 is highly toxic to fish and other aquatic organisms. As pH levels increase, a greater portion of the ammonia exists in this toxic form. High acidity (low pH) in waterways can be caused by carbon dioxide dissolved in water, tannic acid from the decomposition of conifer needles and bark, acid rain, coal mining operations and industrial pollutants.

**B. Water temperature**

Water temperature in small ponds is closely tied to ambient temperature. Temperatures influence those organisms that can occur in ponds (Table 2). Since most aquatic organisms are cold-blooded, water temperature controls metabolic rate and, often, the timing of reproductive activities. In our area, thermal pollution (high temperatures) is generally more limiting than low temperatures. Aquatic organisms are generally more susceptible to the influences of toxic chemicals, parasites and diseases at temperatures at the upper end of their range of tolerance. Water temperature also influences dissolved oxygen levels (see discussion below).

**Table 2. Optimal Temperatures for Some Aquatic Organisms**

(Adapted from Murdoch and Cheo, 1996)



**C. Dissolved Oxygen (DO)**

Dissolved oxygen is measured in parts per million (ppm) with a dissolved oxygen meter or chemically with a Winkler Titration (Note: The procedure we used in the Limnology Test Kits is a modified version of this test). Dissolved oxygen levels of 7-10 ppm are typical in unpolluted water and generally considered adequate for most aquatic life. In salmonid streams, dissolved oxygen requirements are higher. Salmon embryo and larval stages can show some impairment at DO levels as high as 8 or 9 ppm. In other aquatic habitats, levels below 4.5 ppm can cause acute mortality of fish and invertebrates. The primary sources of oxygen in the tanks are photosynthetic production by algae and higher plants and diffusion from the air above the water surface. Dissolved oxygen levels may fluctuate significantly throughout the day especially in bodies of water with extensive plant growth. For this reason, if dissolved oxygen levels are to be compared through time, samples should be collected at approximately the same time of day and under similar conditions of light intensity. Levels rise from morning to afternoon as a result of photosynthesis, reaching a peak in late afternoon. Photosynthesis then begins to shut down as light intensity decreases. At night photosynthesis stops but plants and animals continue to respire - thus consuming oxygen. Dissolved oxygen levels typically decline at night.

Low dissolved oxygen levels generally indicate polluted water and high Biological Oxygen Demand (BOD). Low dissolved oxygen readings can be expected in stagnant water with large amounts of organic material. As the organic material decomposes, oxygen is consumed in the process. Dissolved oxygen can influence the species that occur in a body of water. When dissolved oxygen levels drop below a critical level, fish, amphibians, aquatic invertebrates and aerobic bacteria which rely on this oxygen for aerobic metabolism will decline and eventually perish. Additionally, at low dissolved oxygen levels, anaerobic bacteria proliferate and break down the remaining organic material, producing toxic gases such as hydrogen sulfide and methane.

The amount of dissolved oxygen is also a function of water temperature - cold water is capable of retaining high amounts of dissolved oxygen, warmer water is less capable. This relationship is illustrated for temperatures from 10 to 41°C in Table 3. This information can be used to determine the percent saturation for dissolved oxygen in a water sample. Percent saturation is a measure of the amount of dissolved oxygen in a water sample relative to the maximum amount that could be in that sample. For example, suppose we obtained a dissolved oxygen reading of 8.0 ppm for a water sample and the temperature of the sample was 20°C. The percent saturation could be calculated by dividing your reading with the maximum dissolved oxygen concentration at 20°C (“9.07 ppm” From the Table 3) and multiplying by 100:

**Percent Saturation = (8.0/9.07) X 100 = 88.2 %**

****

Stream habitats are considered healthy at 90-100% saturation; levels for ponds are generally lower.

**D. Turbidity**

Turbidity is a measure of the “cloudiness” of the water. Sediment, algae, bacteria and zooplankton all contribute to what is technically known as the Total Suspended Solids (TSS) that increase the turbidity. As turbidity increases, the degree to which sunlight penetrates the water column declines. This obviously has an impact on photosynthetic rates in algae and submerged vegetation. High turbidity can also raise surface water temperature as suspended particles near the surface absorb more heat from sunlight. Suspended soil particles may also carry nutrients, pesticides and other pollutants and they can bury benthic organisms. Turbid waters tend to be low in dissolved oxygen.

Turbidity can be measured with a turbidimeter in nephelometric turbidity units (NTU). Drinking water is generally very clear and would have a turbidity measurement less than 10 NTU. Very cloudy water would read about 1000 NTU. Alternatively, relative measures of turbidity can be obtained by using a “spectrophotometer.” This device passes a known quantity of light through a sample in a glass tube called a “cuvette.” A sensor on the opposite side of the cuvette detects the amount of light (% transmittance) that passes through and displays this amount on a scale. The wavelength of light can be adjusted to measure the amount of various materials dissolved in the sample. The accepted wavelength for the measure of turbidity is 550 nm.

**E. Algal Concentration**

Algae can have both positive and negative impacts on aquatic ecosystems. Algae produce oxygen through photosynthesis during the day - thus increasing dissolved oxygen concentrations. They also absorb both ammonia and nitrate and use them as nutrients. However, when algal blooms occur, turbidity is increased and algal die offs consume oxygen and release toxic substances such as ammonia, methane and hydrogen sulfide. The concentration and type of algae in a water sample can be used as indirect measures of water quality. High algal concentrations generally indicate abnormally high levels of nutrients - typically nitrates and phosphates.

Algal concentrations will be measured in a manner similar to that which we have used for turbidity. Chlorophyll is the primary pigment in water samples that contain algae and the intensity of the color can be used as a rough measure of algal concentration. Although there are several types of chlorophyll, each with its own spectral properties, we will estimate the abundance of .chlorophyll a. which absorbs best at 660 nm.

**F. Nitrate**

Nitrogen appears in several forms in water sources, including nitrate (NO3-), nitrite (NO2-) and ammonia (NH3). Of these, nitrates are probably the most common inorganic pollutant tested in water. Ammonia is a product of the decomposition of plant and animal protein but tends to be taken up quickly by algae and plants. Nitrites tend to occur at fairly low levels in most water samples because they are readily converted to nitrates by bacteria. Nitrates are a common component of multi-nutrient fertilizers whose nutrient content is indicated by three numbers called the “grade.”

The first of these numbers indicates the nitrogen content of the fertilizer. A fertilizer grade of 16-16-16, for example, contains 16% by weight nitrogen, 16% phosphate (P2O5) and 16% potassium (K2O). Both nitrates and ammonia stimulate algal growth and may be responsible for causing cultural eutrophication. If ingested, they are converted to nitrites in the intestines of humans where they combine with hemoglobin in red blood cells, causing the oxygen-carrying capacity to decline. In infants this condition may be fatal. Contamination of groundwater by nitrates that are applied as fertilizer or runoff from feedlots and dairies is a widespread problem in agricultural regions of the country. Improperly treated sewage from sewage treatment plants and septic systems that finds its way into waterways is also an important source. Nitrates can be measured by following the procedure described in the Limnology Test Kit.

The national drinking standard for nitrates in the U.S. is 10 ppm. Waters that have levels as low as 1 ppm, however, can be sufficiently polluted to cause algal blooms.

**G. Phosphorus**

Phosphorus usually occurs in natural systems as phosphate (PO4-3 ). This phosphate may be bound to organic compounds (organic phosphate) or inorganic compounds (inorganic phosphate or orthophosphate). Inorganic phosphate is the form most readily available to plants and therefore is generally of greater interest than organic phosphate. Phosphorus tends to be less abundant than nitrates in freshwater ecosystems and is, therefore, often a limiting factor for plant and algal growth. The addition of phosphorus (in the form of phosphates) commonly results in algal blooms (cultural eutrophication). Domestic sewage (particularly those containing significant amounts of laundry detergents) and agricultural runoff are important sources of phosphates. Most sewage treatment plants remove only about 50% of the nitrogen and 33% of the phosphorus from domestic sewage. The remainder is dumped in the effluent into surface water. Phosphorus levels as low as 0.01 ppm can have an impact. Phosphates (inorganic phosphates only) can be measured by following the procedure described in the Limnology Test Kit.

**H. Odor**

Unpolluted water should be odor-free. Any noticeable odor in the water supplies may be due to contamination caused by chemicals, raw sewage or action of anaerobic bacteria. A “rotten egg” smell, for example, usually indicates the presence of hydrogen sulfide (H2S), a common byproduct of anaerobic breakdown of organic matter.

**I. Microscopic Examination**

The type of algae and protozoans in a water sample often provide some indication of water quality. Some species are tolerant of conditions found in polluted water while others are far less tolerant. Table 4 lists some species that are used as indicators of water quality. A more complete list and identification aids can be found in the reference cited below.

**Table 4. Algal species Used as Indicators of Water Quality in Freshwater**

**(from Palmer, 1977)**

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Although there are a number of methods available to measure the quantity of algal species in a water sample, we will simply estimate the “percent of individuals” for those that can be readily identified. Wet mounts of water samples will be prepared and examined at 100X and 450X with a compound microscope. Use the available guides to identify algal species and estimate the percent of each species. Record this information on the data sheet.

**REFERENCES**

**Aquaculture**

*These resources specifically address the various aspects of raising aquatic organisms (primarily fish) in artificial environments.*

AquaNIC (*Aquaculture Network Information Center*) - An excellent source for aquaculture curriculum,

publications, media and career opportunities; thousands of links to related sites.

[www.ag.ansc.purdue.edu/aquanic/](http://www.ag.ansc.purdue.edu/aquanic/)

Huet, M. 1986. Textbook of fish culture - Breeding and Cultivation of Fish, 2nd ed. Fishing News Books, Ltd. Farnham, England.

Kosinski, R.J. 1993. Fish Farm - a simulation of commercial aquaculture. The Benjamin/Cummings Publishing Co. Redwood City, CA. 98 pp.

Van Gorder, S.D. and D.J. Strange. 1992. Home Aquaculture: A guide to backyard fish farming. Alternative Aquaculture Association, Inc. Breinigsville, PA 136 pp.

**Mesocosms and Microcosms in Ecological Research**

*Constructed ecosystems at meso- and micro-scales have been used to test a number of hypotheses at population, community and ecosystem levels. These resources are but a small sample of such studies.*

Blaustein, A. and D.B. Wake. 1995. The puzzle of declining amphibian populations. Sci. Am. April 1995:52-57.

Carpenter, S.R., S.W. Chisolm, C.J. Krebs, D.W. Schindler and R.F. Wright. 1995. Ecosystem Experiments. Science 269:324-327.

Larsen, D., P.F. Denoyelles Jr., F. Stay, and T. Shiroyama. 1986. Comparisons of single species microcosm and experimental pond responses to atrazine exposure. Evironmental Toxicology and Chemistry 5: 179-190.

Lawton, J.H. 1995. Ecological experiments with model systems. Science 269:328-331.

Roush, W. 1995. When rigor meets reality. Science 269:313-315.

Rowe, C.L. and W.A. Dunson. 1994. The value of simulated pond communities in mesocosms for studies of amphibian ecology and ecotoxicology. J. of Herpetology 28(3):346-356.

Wilbur, H. 1987. Regulation of structure in complex systems: experimental temporary pond communities. Ecology 68: 1437-1452.

Wilbur, H.M., P.J. Morin and R.N. Harris. 1983. Salamander predation and the structure of experimental communities: Amphibian responses. Ecology 64:1423-1429

**Wetland Creation and Restoration**

*Wetland creation, enhancement and restoration projects are routinely conducted to mitigate the loss of natural wetlands due to development. Our knowledge of the effectiveness of these efforts, however, is very limited. These two resources provide some information on the “science of wetland creation and restoration.”*

Kuster, J.A. and M.E. Kentula. 1990. Wetland creation and restoration - The status of the science.

Mitsch, W.J., X. Wu, R.W. Nairn, P.E. Wiehe, N. Wang, R. Deal and C.E. Boucher. 1998. Creating and restoring wetlands. Bioscience 48 (12): 1019-1030.

**Waste Treatment by Constructed Wetlands**

*Constructed wetlands have been used to treat industrial, agricultural and municipal wastewater. These sources provide a sample of some of these efforts.*

Triangle School Water Recycling Project (North Carolina State University) - A detailed description of an ecological wastewater recycling system in Chatham County, North Carolina that uses constructed wetlands.

[www.waterrecycling.com/index.htm](http://www.waterrecycling.com/index.htm)

Mitsch. W.J. 1993. Ecological engineering: a comparative role with the planetary life-support system. Env. Sci. and Tech. 27:438-445.

Brown, K.S. 1995. The green clean. Bioscience 45(9): 579-582.

Carnevale, E. 1995. Cattails treat leachate and save thousands. Environmental Protection Nov. 1995:35-36.

EPA. 1993. Constructed Wetlands for Wastewater treatment and wildlife habitat: 17 Case studies.

Kadlec and Knight. 1996. Treatment Wetlands. CRC Press, Inc.

Hammer, D.A. 1989. Constructed wetlands for wastewater treatment. Municipal, Industrial and Agricultural. Lewis Publishers, Inc.

Wetlands for Waste Treatment - An annotated bibliography of resources on the use of wetlands for waste treatment.

[www.gus.nsac.ns.ca/~piinfo/resman/wetlands/anno/annobib.html](http://www.gus.nsac.ns.ca/~piinfo/resman/wetlands/anno/annobib.html)

Lesley, D., H. Van Zee and J.A. Moore, eds. 1993. Constructed wetlands wastewater treatment

systems: How do they work? Oregon State University Extension Service Misc. Publication 8543.

Moore, J.A. 1993. Using constructed wetlands to improve water quality. Oregon State University Extension Service # EC 1408. 4 pp.

Soil Conservation Service. 1982. Ponds - Planning, Design, Construction . Agriculture Handbook No. 590. 51 pp.

USA Constructed Wetlands Page.

[www.usouthal.edu/usa/civileng/wetlands.htm](http://www.usouthal.edu/usa/civileng/wetlands.htm)

A comprehensive site for natural and constructed wetlands (definitions, processes, functions, importance, human impacts, management, mitigation).

[www.h2osparc.wq.ncsu.edu/info/wetlands/index.html](http://www.h2osparc.wq.ncsu.edu/info/wetlands/index.html)

Texas On-Site Wastewater Treatment Research Council. Constructed wetlands fact sheet can be downloaded from this site. Describes components, design, operation and maintenance of constructed

wetlands for wastewater treatment.

[www.towtrc.tamu.edu](http://www.towtrc.tamu.edu)

Humboldt State Environmental Engineering Department. Includes some general guidelines for

constructed wetland design (soil, plants, etc.)

[www.humboldt.edu/~ere\_dept/marsh/ownmarsh.html](http://www.humboldt.edu/~ere_dept/marsh/ownmarsh.html)

The Environmental News Network posts current and archived articles on environmental issues from a variety of sources. A search for “constructed wetlands” articles will yield a number of pertinent articles (including some on “phytoremediation” - the use of plants to uptake contaminants from soils or water).

[www.enn.com/search/search.asp](http://www.enn.com/search/search.asp)

**General References on Wetlands**

Niering, W. 1995. Wetlands. Alfred P. Knopf, Inc. New York, NY

Mistsch, W.J. 1993. Wetlands. Van Nostrand Reinhold, New York, NY

Schodari, P.F. Wetlands protection: The role of economics. Environmental Law Institute, Washington, D.C.

EPA. 1995. Wetlands Fact Sheets. EPA Office of Wetlands, Oceans and Watersheds.

EPA. 1993. Natural Wetlands and Urban Stormwater: Potential Impacts and Management. EPA Office of Water.

EPA. 1988. America’s Wetlands: Our vital link between land and water. EPA Office of Wetlands Protection.

Lewis, M. 1998. Plants do the dirty work: Cleaning wastewater, saving the environment. Nation’s Cities Weekly 19 (38) p: 1-5.

U.S. Fish and Wildlife Service National Wetlands Inventory.

[www.nwi.fws.gov](http://www.nwi.fws.gov)

[www.enn.com/newslenn-stories/020298/chevron.shtm](http://www.enn.com/newslenn-stories/020298/chevron.shtm)

[www.waterrecycling.com/soilfilt.htm](http://www.waterrecycling.com/soilfilt.htm)

Another comprehensive wetlands site with lots of links to other sites (agencies, publishers, universities,

sites designed for middle school and high schools students).

[www.sws.org/wetlandweblinks.html](http://www.sws.org/wetlandweblinks.html)

**Wetland Plant and Algae Identification**

*Activities in model aquatic ecosystems usually require the identification of native species of plants, animals and algae. Also, plant selection for the construction of these systems often requires identification of native plants. These references will be particularly helpful in the Pacific Northwest.*

Guard, J. B. 1995. Wetland plants of Oregon and Washington. Lone Pine Publishing, Redmond, WA. 239 pp.

Palmer, C.M. 1977. Algae and water pollution: An illustrated manual on the identification, significance and control of algae in water supplies and polluted water. EPA-600/9-77-036, U.S. Environmental Protection Agency, Cincinnati, Ohio. 123 pp.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest coast. Lone Pine Publishing, Redmond, WA. 527 pp.

Rainis, K.G. and B.J. Russell. 1996. Guide to microlife. Franklin Watts Publishing, Danbury, CT. 287 pp.

**Water Quality Testing**

*Laboratory activities that use model aquatic ecosystems frequently require the measurement of physical and biological water quality parameters. These resources describe some of the parameters that may be measured along with descriptions of their ecological impacts.*

American Public Health Association. Standard Methods for the Examination of Water and Wastewater.

Campbell and Wildberger. 1992. The Monitor’s handbook. LaMotte Company.

Mitchell and Stapp. Field manual for Water Quality Monitoring. GREEN Project.

Murdoch, T. and M. Cheo. 1996. Streamkeepers’ field guide - Watershed inventory and stream monitoring methods. Adopt-A-Stream Foundation, Everett, WA. 296 pp.

This Ecological Society of America report entitled “Non-point Pollution of Surface Waters with

Phosphorus and Nitrogen” is an excellent review of ecological impacts of these contaminants.

[www.esa.sdsc.edu/carpenter.htm](http://www.esa.sdsc.edu/carpenter.htm)

Water Quality and Land Treatment - Excellent site for description, measurement and interpretation of water quality parameters.

[www.h2osparc.wq.ncsu.edu/info/index.html](http://www.h2osparc.wq.ncsu.edu/info/index.html)

**Other Aquatic Microcosm Laboratory Activities**

*A number of laboratory activities that use aquatic microcosms have been developed by other authors for students at all levels of education. The activities below represent a selection of activities that are appropriate for high school and college-level curriculum.*

Hydro/Aquatic Technologies (a source for aquaculture-related curriculum).

[www.intercom.net/biz/aquaedu/hatech/](http://www.intercom.net/biz/aquaedu/hatech/)

Carlson, S. 1998. The pleasures of pond scum. Sci. Am. Mar. 1998: 96-98.

Koeniger, J. 1997. Making a splash in the classroom. Carolina Tips 60(1):1-8.

Marcus, B. 1994. Microcosms for lake acidification studies. The American Biology Teacher 56: 433-437.

Murphy, T.M., D. Canington and D.E. Walker. 1992. Herbivory, predation and biological control. The American Biology Teacher, 54:416-419.

Nicol, E. 1990. Hydroponics and aquaculture in the high school classroom. American Biology Teacher 52:182-184.

Porter, J.R. 1989. Herbivory-induced alteration of community structure - a classroom model. American Biology Teacher 51:300-302.

Yensen, N.P. 1988. Ecosystems in glass. Carolina Tips 51(4)13-15.

**Measurement of Net Primary Productivity**

Botkin, D. and E. Keller. 2000. Environmental Science: Earth as a Living Planet. 3rd ed. John Wiley and Sons, Inc. New York. 649 pp.

Brower, J.E., J.H. Zar and C.N. von Ende. 1990. Field and laboratory methods for general ecology. 3rd ed. Wm. C. Brown Publishers, Dubuque, IA. 237 pp.

Cox, G.W. 1990. Laboratory manual of general ecology. 6th ed. Wm. C. Brown Publishers, Dubuque, IA. 251 pp.

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGES 75-80

Environmental Science III

Aquatic Invertebrates as Bioindicators (correlates with pages 81-87 in PDF file and book)

**Aquatic Invertebrates as**

**Bioindicators of Water Quality**

**INTRODUCTION**

As our knowledge of ecosystems increases, the impacts of human activities on ecological systems are being more carefully monitored. Waste products that result from a number of these activities may accumulate in natural systems to levels that are harmful to living organisms including ourselves. The combustion of fossil fuels, mining operations, landfills and agricultural practices, for example, may all generate waste products that result in pollution of soil, air and water resources. This pollution may cause a domino-like effect that impacts several components of an ecosystem.

Pollution may be evaluated either by direct measurement (using instrumentation that measures dissolved oxygen, toxin levels, etc.) or by examination of its effects on living organisms. Indicator organisms may be exposed to different concentrations of a pollutant to determine their toxicity. In Europe, for example, water quality is often evaluated by exposing trout to test water in an aquarium. Alternatively, the diversity and abundance of animal species such as aquatic insects, fish or amphibians

may be used in the field as an indicator of environmental quality.

The presence of a diverse animal community that contains a number of species that are known to be intolerant of pollution indicates good water quality. The use of living organisms to evaluate environmental quality, or **biomonitoring**, has some advantages over direct measurement of pollutants,

including:

* Less sophisticated instrumentation is required
* Costs are generally less
* Unlike direct measurement where contaminant levels are being measured at a single point in time, living organisms that are used in these monitoring programs (**bioindicators**) are exposed for long periods of time - often for their entire lives

In today’s laboratory we will use a common freshwater crustacean, the water flea, *Daphnia magna,* as

an indicator organism to investigate the effects of various pollutants. This species normally occupies

freshwater sites with summer temperature of 15-25 degrees C and a pH range of 5.5-7.0. They are

quite intolerant of chemical contamination - including pesticides.

NOTE: *pH is a measure of the acidity of a solution measured on a scale of 0 to 14; 7 indicates neutrality, numbers less than 7 are acids, numbers greater than 7 are bases.*

**PROCEDURE**

Each group will test the effects of temperature, pH and exposure to a dilute solution of an insecticide on the subject organism. Class results will be summarized and interpreted by each laboratory group. Conduct the following procedures, and record all of your observations on the data sheets provided:

1. Place a small sample of the *Daphnia* culture on a watch glass and observe the normal activity level and behavior of the species with a dissecting microscope.

NOTE: *An understanding of the normal behavior of the species is important for comparison to those*

*individuals that have been exposed to pollutants.*

1. Set up three series of test tubes as indicated to measure the following:

**A. Temperature**

Three water baths have been set up at temperatures of 25, 30 and 35 degrees C. Room temperature is approximately 20 degrees C, therefore, four different temperatures are available for testing.

* Representing the 4 temperatures, mark 4 test tubes room temperature, 25ºC, 30ºC and 35ºC
* Add 15 ml of pond water (*not tap water!*) to each test tube and place it in the appropriate water bath (or leave it at room temperature) with the corresponding temperature.
* Allow at least 5 minutes for temperature equilibration.

**B. pH**

* Fill 5 test tubes with 15 ml of pond water (at room temperature) that has had the pH adjusted to pH 7, 6, 5, 4, and 3.
* Place these tubes in the test tube rack.

**C. Pesticide (Diazinon) concentration**

* Fill 4 test tubes with 15 ml of pond water at room temperature.
* Add the following amounts of the pesticide solution to the 4 tubes:

Tube #1: 0 pesticide solution

Tube #2: 5 drops pesticide solution

Tube #3: 10 drops pesticide solution

Tube #4: 15 drops pesticide solution

* Mark each test tube appropriately; stopper each test tube and mix thoroughly.
1. Add 10 *Daphnia* to each of the test tubes prepared in step 2. Gently extract them from the culture using a bulb pipette and quickly place them in the test tubes.

NOTES: *Be sure the Daphnia are alive and well at the beginning of the experiment. Record the exact time that the Daphnia were added to the test tubes (see data sheet).*

1. Observe the behavior and survival of the *Daphnia* in the tubes following exposure times of 15, 30 and 60 minutes. At each observation, record the number of living and dead *Daphnia* as well as any observations on behavior or activity level (see data sheet).

**LABORATORY REPORT**

The final product of this lab is a report that summarizes and evaluates the results this study. The following guidelines should help you in the preparation of the report:

*Length*

The report must be typewritten, 3-4 pages of narrative, plus tables, graphs, and other supporting information.

*Format*

**I. Introduction** (1 paragraph)

Use this section to briefly set the stage for what the report will cover. Briefly describe why the study was done, what your major hypotheses were (i.e., What did you expect to find?) and what applications there might be for the study.

**II. Methods and materials** (1 to 2 paragraphs)

Use this section to describe the experimental design of the study and procedures you have followed to obtain the data you have collected. Include sufficient detail such that another researcher could duplicate your efforts.

**III. Results** (2 to 3 paragraphs, plus graphs, charts, etc.)

This section should include only data that were collected during this study. Where possible, summarize information in tables, charts and graphs that *help to visualize* the data (i.e., provide a graph that illustrates temperature vs. *Daphnia* survival). Enter your data into a spreadsheet program such as *EXCEL* and use the software to generate the graphs. Reference your tables, charts and graphs in the body of this section by indicating *major trends* (i.e., do not try to recount everything in the tables, charts and graphs).

*Example:*

“Daphnia showed no response to temperatures below 30 degrees C, but temperatures above 30 degrees C were 100% lethal (Table 1).”

NOTE: *information for this section should come from summarized class data.*

**IV. Conclusions and discussion**

In this section you will summarize your conclusions (logically drawn from the *Results* section) and also attempt to place your findings into a broader context (i.e., answer the question, “*Who cares?”*).

Here are some *examples* of questions that might be addressed in this section:

* What applications might your findings have to farmers who apply the insecticide you tested? to companies that transport the insecticide? to homeowners who use the insecticide?
* What implications do your results have for a power plant that releases warm water into a local river? predictions of global warming?
* What implication do your findings have for federal and state agencies that establish emission standards for sulfur dioxide and nitrous oxides from power plants? (e.g., since these emissions contribute to acid rain and therefore may influence the pH of a body of water)
* Which of your findings were unexpected?
* Which hypotheses were supported by the data? Which hypotheses were not supported by the data?
* What changes or improvements would you make in experimental design if you were to duplicate the study?
* We used “mortality” as an indication of the impact of a pollutant on a living organism. What are some other measures that might be more sophisticated or useful?

These questions are *only* suggestions - *do not* answer them in a sequential manner as you would on an

exam. Rather, use them as possible topics for discussion in a series of well-constructed paragraphs.

I encourage you to explore other topics for this section as well.

*Show some creativity!*

**Data Sheet**

**I. Initial Observations of *Daphnia*.**

**II. Temperature Experiment**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temp (oC) | Initial Time | 15 min. Exposure | 30 min. Exposure | 60 min. Exposure | Comments |
| # A | # D | # A | # D | # A | # D |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |

**NOTE: #A = number alive; #D = number dead**

**III. pH Experiment**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temp (oC) | Initial Time | 15 min. Exposure | 30 min. Exposure | 60 min. Exposure | Comments |
| # A | # D | # A | # D | # A | # D |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
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|   |   |   |   |   |   |   |   |   |

**IV. Pesticide Experiment**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Temp (oC) | Initial Time | 15 min. Exposure | 30 min. Exposure | 60 min. Exposure | Comments |
| # A | # D | # A | # D | # A | # D |
|   |   |   |   |   |   |   |   |   |
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**MATERIALS**

**Quantity Materials and Equipment**

4 *Daphnia magna* (Ward’s 87W5210) large size culture

1 *Daphnia magna* (Ward’s 87W5215) mixed size culture

NOTE: *large copepods or seed shrimp may be used as alternative subject organisms*.

24 250 ml beakers

200 ml 0.12% Diazinon solution (in dropper bottle)

12 Graduate cylinder - 25 or 50 ml

3 Hot water baths set at 25, 30 and 35EC

24 Eye droppers with bulbs

75 Test tubes - 20 X 150.s

12 Test tube racks

12 Alcohol thermometers (we will be measuring 20-40 degrees C range)

35 Rubber stoppers (to fit test tubes)

500 ml ea. Water adjusted to pH\_s of 7, 6, 5, 4 and 3

12 Watch glasses (coaster type)

12 Crystallization dishes

4 pH meters (Orion portable meter and pH testers)

48 10 ml beakers

2 2000 ml Erlenmeyer flasks

24 Beral pipettes

1 roll Glassware marking tape

6 Sharpies (any color)

NOTE: *all solutions should use pond water or untreated well water as a solvent.*

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGES 88-90

Environmental Science III

Amphibians as Bioindicators (correlates with pages 91-95 in PDF file and book)

**Amphibians and Other Species as**

**Bioindicators of Environmental Quality**

**INTRODUCTION**

As ecosystem management becomes the guiding principle of management on public and some private lands, more information is required to assure that ecosystem integrity is maintained. Human activities, including agriculture, development, logging, etc., must be evaluated in light of the potential impact on ecosystem processes and components, including impacts on individual species. **Environmental Impact Statements**, for example, must be submitted on some lands when there is a significant change in land use at the site. Impacts on soils, water, air and wildlife must be evaluated. If these impacts are judged to be greater than some previously defined level, a development project may be halted or altered in some way.

**Environmental quality** can be measured in a number of ways, depending on the site and the objectives of the evaluation. Two methods commonly employed in aquatic environments include the measurement of physical parameters such as temperature, dissolved oxygen, pH, etc., and the use of living organisms present on the site as indicators of site conditions. Amphibians (frogs, salamanders and their relatives) are generally considered to be good indicators of environmental quality for a number of reasons:

1. They have permeable skin and would therefore be expected to absorb any contaminants on the site
2. Most species lay their unshelled eggs in water
3. Their life histories usually expose them to both aquatic and terrestrial environments
4. They are sufficiently abundant and widespread to use as indicator organisms
5. Most species remain in a fairly confined area their entire lives

Worldwide declines of amphibian populations have been documented by a number of scientists. Declines have been documented in both disturbed and pristine environments on all continents where amphibians occur. Although a definitive explanation for these declines has not yet been ascertained, there appear to be a number of likely causes, including habitat destruction, environmental contamination, fungal infections, diseases, overharvesting, predation by introduced species, and genetic damage due to elevated levels of ultraviolet radiation.

In today’s laboratory, we will visit a local wetland to sample amphibians as well as other bioindicators by using various methods. We will also measure and discuss some of the factors that may influence amphibian abundance and diversity on the site.

**PROCEDURE**

**I. Amphibians** - **Measuring diversity and abundance**

A variety of methods will be employed to determine the diversity and relative abundance of the

species of amphibians found at this site:

* **Minnow Traps**: these are cone-shaped, wire mesh traps which may be used to sample some aquatic amphibians. They may be set out in a systematic or random fashion, and should be left out at least one day prior to sampling.

Six un-baited wire minnow traps were set in one of the larger ponds on the site one day prior to our visit. Aquatic salamanders such as rough-skinned newts (*Taricha granulosa*) and northwestern salamanders (*Ambystoma gracile*) can be sampled in this manner. The traps will be checked, and any captures will be recorded.

* **Dip nets and seines:** these are of various sizes, and may be used to sample aquatic salamanders and frogs (bullfrogs, *Rana catesbiana*; red-legged frogs, *Rana aurora*) and egg masses in shallow water along margins of lakes and ponds. Sampling may be done randomly or systematically, and is conducted by drawing these nets through the water.

For our purposes today, numbers of captures will be recorded (by species).

* **Time-constraint searches**: these sampling methods are conducted for a set amount of time (thus, “time constrained”). The sampling effort is recorded as “number of individuals per unit time,” and can be used to compare relative population sizes at different sites. Logs, bark, rock, and other debris on the forest floor may be examined (i.e., by turning logs over) for terrestrial forms of amphibians (Pacific treefrogs, *Hyla regilla;* Ensatina, *Ensatina escholtzi*; and rough-skinned newts), and this is done during a pre-established sampling period (e.g., 15-, 30-, 45-minutes).

Since our ultimate goal is to measure the relative abundance of each species of amphibian at the

site, it is important to have some approximate measure of *the effort required* to capture a given number

of animals (see data sheets).

**II. Preliminary Analysis of Water Quality**

Although we will not have time for a detailed analysis of water quality, we will examine two factors that may influence amphibian diversity and abundance: 1) zooplankton diversity and abundance and,

2) pH.

**Zooplankton**: aquatic insect larvae, aquatic worms, and crustaceans such as copepods and clam shrimp are an important food source for salamander larvae. Also, some zooplankton are sensitive indicators of water quality. We will sample the diversity and abundance of zooplankton with a plankton net at each of the several small and large ponds. The sampling protocol will be designed and implemented by the group. Samples will be examined in lab at a later date.

**pH**: the measure of acidity in a solution. Amphibian egg masses, embryos and larvae are particularly sensitive to acidic conditions. We will measure pH with portable pH meters at each pond that is sampled for zooplankton. The sampling protocol will be designed and implemented by the group.

**III. Rapid Biological Assessment (RBA)**

Rapid biological assessment, as the name suggests, is a method of quickly evaluating the biological diversity of an area, typically where such information is not available. For instance, many pristine regions of tropical rainforests are being assessed today in this manner. These areas are experiencing such rapid losses of biodiversity that RBA provides the most efficient way to either catalog species which may be lost in the near future, or, to perhaps stop development in rare species - habitats.

RBA uses teams of experts in the identification and biology of plants, mammals, amphibians, insects, etc., being deployed to use specific sampling techniques over a short period of time. The results are entered in a common database for the site; this database should be archived and maintained to determine baseline levels of species occurrence (for future assessments). Today’s field activity has much in common with RBA’s.

NOTE: *Record all information from the sampling activities above on the attached data sheet.*

**DATA SHEET**

**LOCATION:**

**DESCRIPTION OF HABITAT:**

**OBSERVERS:**

**DATE: AIR TEMPERATURE: WATER pH:**

**TIME: WATER TEMPERATURE:**

**WEATHER CONDITIONS:**

**Enter all observations or captures of birds, mammals, fish and amphibians in the table below:**

|  |  |  |  |
| --- | --- | --- | --- |
| **SAMPLE METHOD** | **SPECIFIC LOCATION OF SAMPLE** | **SPECIES** | **NUMBER OF INDIVIDUALS** |
|   |   |   |   |
|   |   |   |   |
|   |   |   |   |
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**MATERIALS**

**Quantity Materials**

3 Plankton nets

12 Screw-cap jars (250 - 500 ml)

6 Binoculars

1 Orion pH meter

1 Orion dissolved oxygen meter

24 Clipboards

1 Seine (20-foot)

6 Plastic buckets (5-gal.)

25 Zip lock bags (1-gal.)

6 Minnow traps

6 Dip nets

6 Field thermometers

6 Thermohygrometers

6 Meter sticks

6 Tapes (30-m)

6 Stopwatches

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGES 96-98

Environmental Science III

Going for the Gold! (correlates with page 99 in PDF file and book)

***Going for the Gold! -***

**Environmental Impacts of Mining**

After viewing the videotape, “Public Lands, Private Profits,” please respond to the following questions:

1. Describe how the General Mining Law of 1872 works.
2. Under the Mining Law of 1872, the government cannot require mining companies to pay royalties for mine claims on public lands. The oil, coal, and gas industries, by contrast, pay a 12.5% royalty for use of federal lands. In the fall of 1993, the House of Representatives passed a bill that would require mine owners to pay an 8% royalty to mine on public lands. The bill did not pass the Senate, where some western senators attempted to reduce the royalty to 2%. Would you favor reform of the 1872 bill? If so, in what way?
3. Describe how sodium cyanide can be used to extract gold from low grade ore.
4. Describe the various environmental impacts of heap leach mining as described in the videotape. Address each of the following areas:
* Air pollution
* Water pollution
* Land disruption
* Wildlife endangerment
* Water supply (consumption)
1. What efforts were made by Newmont Mining to address each of these environmental concerns? In your opinion, were these measures appropriate and adequate? Explain.
2. Mining creates 4,000 jobs directly and 11,000 indirectly in the area of the Carlin Trend, Nevada. Mine wages are the highest in the state of Nevada. Do you think the present situation represents the best possible balance between environmental concerns and economic conditions? What changes, if any, would you suggest?
3. Approximately 75-85% of gold is used in jewelry. Gold is also used as a monetary standard, an investment, and in the manufacture of electronics and other industrial products. Considering the environmental costs associated with gold mining and processing, do you consider gold mining to be a worthwhile endeavor? Explain.

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGE 100

Environmental Science III

Lichens as Bioindicators of Air Pollution (correlates with pages 101-105 in PDF file and book)

**Lichens as Bioindicators of Air Pollution**

**INTRODUCTION**

Lichens are among the most abundant living organisms in Pacific Northwest ecosystems. Epiphytic lichens often cover the stems and branches of trees where they are sometimes mistaken for mosses or other plants. Although highly variable in color, many common species are gray-green, readily distinguishing them from most mosses, which are usually brilliant green and have distinct leaves. Lichens are not plants, rather they are the result of a mutualistic symbiotic relationship between an

alga (or cyanobacteria) and a fungus. Recent studies of lichen DNA suggest that the relationship has evolved multiple times throughout evolutionary history and that the various groups are not closely related. The alga or cyanobacteria is the photosynthetic partner producing carbohydrates which can be used by the lichen as an energy source. For this reason, lichens are sometimes considered “the fungi that have discovered agriculture.” The fungal partner is responsible for anchorage to substrates and for retention of moisture. Lichens are not parasitic and do not harm their host trees.

Lichens obtain nutrients directly from rain water and nutrients suspended in the air rather than from the soil. They are quite efficient at absorbing nutrients for the air, but are equally efficient in absorbing non-essential or harmful substances. This characteristic has lead to their demise in areas where contaminants of various types are present in the air. They are particularly sensitive to acid pollution associated with high levels of sulfur dioxide. Great Britain, for example, has lost most of its epiphytic lichens, largely due to SO2 emissions from coal-burning power plants. In northern Siberia, a particularly polluted region of the former Soviet Union, lichen diversity has declined from 50 to 3 species and production is about 2% of historic levels.

In addition to SO2, lichens have been shown to be sensitive indicators of nitrous oxides, heavy metals, ozone - and even radioactivity. Part of the reason for their sensitivity is that, unlike many plants which become dormant or lose their leaves during at least part of the year, lichens remain active and exposed to potential pollutants throughout the year. In fact, the absence of lichens on trees often indicate highly air-polluted areas, and compared to sophisticated instrumentation required to monitor air pollution, lichens are an inexpensive alternative for monitoring air quality.

Lichen distribution studies have produced “lichen maps” that are among the most widely used bioindication models. The U.S. Forest Service has been checking lichens since 1994 at 1,200 sampling

locations in Oregon and Washington. European scientists have even solicited the help of school children in England, Ireland and Italy to conduct lichen surveys in their local communities. These studies have helped identify air pollution problem areas.

In the Pacific Northwest, air quality is generally quite good, resulting in a high abundance and diversity of lichens. Over 1,000 species occur in Washington, Oregon, British Columbia and Alaska.

In today’s lab we will investigate the potential use of five of these species as bioindicators of air pollution.

**PROCEDURE**

1. Prior to lab read the article from Discover Magazine, “Prophets of Gloom” [Kiester, E. 1991. *Prophets of gloom.* Discover. Nov. 1991:53-56].
2. Samples of the following lichens were collected in the Oregon’s Coast Range (east of Lincoln City, OR):

*Peltigera neopolydactyla* (“frog pelt”)

*Platismatia glauca* (“rag bag”)

*Lobaria pulmonaria* (“lung wort”)

*Lobaria oregana* (“lobaria”)

*Hypogymnia inactiva* (”forking bone”)

1. Using available resources, research the natural history information on these species, including their sensitivity to air pollution. Using this information, rank these 5 lichen species from “most sensitive” to “least sensitive” to air pollution. Enter these hypotheses on the data sheet provided.
2. Working in groups of 3-4 students each, select one of the lichen species for study. Using a cork borer, cut out enough disks from the lichen so that five disks can be placed in each chloride solution to be tested as well as five for a distilled water control.
3. Place all of the disks you have cut out into the methylene blue solution and let them absorb the blue dye for 30 minutes.
4. While waiting for the disks to absorb methylene blue, watch the Oregon Field Guide video, “Lichens in old growth,” [31 January 1999 (12 minutes)] on lichen studies in old-growth forests. Note the methods that are being used to study lichens and what researchers have learned so far.
5. After 30 minutes, remove the disks from the methylene blue solution, place them in an aquarium net, and rinse off the excess methylene blue with distilled water.
6. Transfer five washed disks to each of the test tubes containing 7 ml of the various chloride solutions and one tube containing 7 ml of distilled water (the control). Allow them to soak in the chloride solutions for 60 minutes at room temperature, shaking them occasionally. During this period, the methylene blue **cations** (positive ions) previously absorbed by the lichens are released as they are replaced by metallic cations from the chloride solutions. This exchange results in the gradual development of a blue color in the solution.
7. After 60 minutes, evaluate the degree to which the lichen has absorbed the metallic cations by measuring the amount of methylene blue dye that has eluted out of the lichen disks into the supernatant. If a large amount of the metallic cation has been absorbed by the lichen, the supernatant will appear dark blue. Lighter colors of blue indicate smaller amounts of cation exchange.
8. The differences in supernatant color between the various chloride solutions can be quantified using an instrument called a **spectrophotometer**.
* Pour a sample of the supernatant in a sample tube called a **cuvette**.
* Set the wavelength at 540 nm on the spectrophotometer. This is the optimum wavelength for detection of methylene blue.
* Turn the instrument on by rotating the “0” control knob in a clockwise direction. Allow 5 minutes for the instrument to warm up.
* With the cover of the sample holder closed, adjust the “0” control knob until the needle is at the zero measurement on the *transmittance scale.*
* *Fill a cuvette with the test solution* (solutions in dropper bottles without disks), place the cuvette in the sample holder and close the cover.

IMPORTANT NOTES: *This cuvette is called the* ***blank*** *and is used to* ***calibrate*** *the spectrophotometer. In other words, it is telling the machine that* “*this is what the solution looks like before any methylene blue has leached into solution.*”

*Since each of the test solutions (NaCl, CoCl2, FeCl3, etc.) differs somewhat in color, the spectrophotometer must be calibrated before each test with a cuvette that contains* ***only*** *that solution.*

* Now, rotate the light control knob so that the needle is at 100 on the transmittance scale (0.00 absorbance).
* Place the cuvette containing the *test sample* (the solution that has been soaking the lichen disks) in the tube holder and read the % transmittance and absorbence from the scale. The needle should return to zero when the tube is removed. Check the 0% and 100% transmittance occasionally with the **blank** to be sure the instrument is calibrated.

NOTES: *There may be slight imperfections in the cuvettes resulting from their manufacture or use (i.e., slightly different thicknesses or scratches on the surface). These imperfections may affect the % transmittance of light through them. It is therefore best practice to use the same cuvette for all readings.*

1. Record the % transmittance and absorbence for each of your samples and the control.
2. Using the standard curve generated for methylene blue, convert “absorbence” or “% transmittance” into mM. Your instructor will describe how this is done.
3. Use *EXCEL* to graph your results.

**ANALYSIS AND INTERPRETATION**

1. Obtain the results of other lichen species from other groups. Graph these results as you have your own. Submit all graphs as part of your lab product.
2. Which cations (metals) were most readily absorbed by each lichen species? Which were not very readily absorbed?
3. What are some of the potential sources of pollutants that would contain these readily-absorbed cations? (NOTE: *This may take some research on your part*.)
4. Of those lichen species we tested, which one(s) would be most useful as a bioindicator for air pollution? Use the results of these experiments and explain how you have arrived at this conclusion.
5. How do your results compare with your predictions of lichen sensitivity to air pollution? Discuss both correct and incorrect predictions. What might account for any discrepancies?
6. Describe a study of your own design that would use the information you have obtained in this lab to evaluate air quality in the local area. Include sufficient detail such that another scientist could duplicate your efforts.

**DATA SHEET**

**HYPOTHESES**

Based on information available in lab, our lab group predicts that these 5 lichen species will differ in their sensitivity to air pollution. The *predicted order* of this sensitivity is as follows:

**1 (Most sensitive) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**4 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**5 (Least sensitive) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**RESULTS**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   | ***Lobaria oregana*** | ***Lobaria pulmonaria*** | ***Hypogymnia inactiva*** | ***Peltigera neopolydactyla*** | ***Platismatia glauca*** |
| **TEST IONS** | **% T** | **A** | **% T** | **A** | **% T** | **A** | **% T** | **A** | **% T** | **A** |
| **CONTROL** |   |   |   |   |   |   |   |   |   |   |
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**%T = percent transmittance**

**A = absorbence**

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGE 106-109

Environmental Science III

Constructed Wetlands (correlates with pages 110-112 in PDF file and book)

**Constructed Wetlands for Wastewater Treatment**

**Analysis and Interpretation**

**INTRODUCTION**

For the past several weeks we have evaluated the effectiveness of constructed wetlands to treat agricultural wastewater. A number of water quality parameters have been measured at one week intervals from pre-treatment (initial conditions) to post-treatment (approximately six weeks).

In today’s laboratory we will begin to interpret the results of this term-long study. You will work in small groups and identify major trends in the data and discuss possible reasons for these trends. A more detailed analysis will be presented in your written report for the project. Today’s activity should give you some guidance on the “Results” and “Discussion/Conclusions” sections of your report.

You will find the following very useful in today’s lab (bring them with you):

* 1. All handouts related to the constructed wetlands lab (including “Final Report Guidelines”)
	2. Handout: “How should we interpret water quality measurements?”
	3. Any data that have not yet been submitted
	4. Your Botkin and Keller text

**PROCEDURE**

1. Complete the final measurements on your wetlands as indicated in the water quality measurement protocols.
2. A table with all data you have submitted to date will be available. After you have taken today’s

measurements, enter your data on the table. This information will be made available to all groups.

1. Using class data, enter into *EXCEL* the values for *one* of the water quality parameters (pH, dissolved oxygen, etc.). Generate a line graph that illustrates the change in that parameter over the length of the study in both the control tank and the test tanks. Submit this graph with your lab product.
2. Examine the attached graphs and tables which were generated from a 1999 study similar to the one we have conducted. Use these graphs to respond to the questions below. Put all of your answers on a separate sheet. In all questions, “control tank” refers to Tank B5 and “test tanks” refers to the six tanks with wetlands that were used to treat wastewater (C1 through C6).

**A. pH**

1. Identify major trends in data.
2. Is there a difference between control and test tanks?
3. Explanation for these trends and differences (e.g., what do you think caused them?)
4. What is the biological significance of the range in pH observed?

**B. Dissolved Oxygen**

1. Identify major trends in data.
2. Is there a difference between control and test tanks?
3. Explanation for these trends and differences (e.g., what do you think caused them?)
4. What is the biological significance of the range of dissolved oxygen observed?

**C. Turbidity**

1. What is the relationship between Turbidity and % Transmittance?
2. Identify major trends in data.
3. Is there a difference between control and test tanks?
4. Explanation for these trends and differences (e.g., what do you think caused them?)
5. What is the biological significance of the range of turbidity observed?

**D. Algal Concentration**

1. What is the relationship between Algal Concentration and % Transmittance?
2. Identify major trends in the data.
3. Is there a difference between control and test tanks?
4. Explanation for these trends and differences (e.g., what do you think caused them?)
5. What is the biological significance of the range of algal concentrations seen here?

**E. Microscopic Examination**

1. Describe any changes in the algal community in the control and the test tanks as time progressed. Why do you think these changes occurred?
2. What does the change in algal species tell us about changes in water quality?
3. In a single paragraph, describe how effective the constructed wetlands were in treating agricultural wastewater in 1999. Select the most relevant evidence from #4 above to support your answer.

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGE 113-114

Environmental Science III

Aerial Photography (correlates with pages 115-120 in PDF file and book)

**Using Aerial Photography to Evaluate Land Use Changes**

**INTRODUCTION**

The sophisticated use of aerial photography was developed during World War II when it was used as an effective tool to gather intelligence data. Since that time, aerial photography has been applied to a myriad of nonmilitary uses including such diverse applications as fire monitoring, geologic studies, irrigation analysis, soil surveys, urban planning, wildlife protection, forestry studies, and land use

analysis. Like other image-producing tools, such as microscopes, telescopes, and the like, aerial photographs heighten the power of observation and provide the observer with a perspective that

cannot be obtained on the ground. With current trends in natural resources management leaning towards management on broader scales of time and space, aerial photography, particularly when paired with satellite imagery, other data bases, and use of GIS software, has become an indispensable tool in modern natural resources management. Aerial photographs permit a land area of significant size (typically 9-73 square miles per image) to be viewed and studied while retaining a significant amount of easily recognizable detail. With a little training and careful observation, common cultural and natural features can be readily identified and relationships between them understood.

Since aerial photography has been so widely applied, there is a great demand for high quality photographs. Consequently, several historical aerial photographs are commonly available for a given site. Observation of these photos allows the observer to interpret natural and anthropogenic (human caused) changes in the landscape. In today’s lab we will use aerial photographs to evaluate land use changes at six sites in the Salem area. These sites differ dramatically in historical use, future use, degree of human impact and ownership.

**INTERPRETATION OF AERIAL PHOTOGRAPHS**

A number of different attributes can be used to identify features on an aerial photo. The following is a brief description of some of the more useful ones:

1. *Size.* The size of an object is a useful clue to aid in identification. Cultural features such as houses tend to have some degree of uniformity of size while natural features generally do not. The scale of a photograph must be calculated prior to making any identifications based on size. A barn, for example, looks quite different on 1:20,000 scale vs. a 1:60,000 scale.
2. *Shape.* Keep in mind that features in an aerial photo are being viewed from an unusual perspective (i.e., top view). Many natural and cultural features have characteristic shapes. Consider for example the narrow bands with smooth gradual curves of railroads compared to the wider bands and sweeping curves of roads. Individual trees, various types of buildings, etc., can all be identified based primarily on shape.
3. *Tone.* In black and white aerial photographs, features are seen in various tones of gray. In general, objects that reflect a large amount of light will appear lighter than those that absorb light. Smooth surfaces such as open fields, clearcuts, mowed lawns, plowed fields and roads usually appear in light tones. Rough surfaces such as forests, mature crops and pastures will appear as darker tones. Water surfaces may vary considerably in tone depending on the angle of the sun at the time the photo was taken.
4. *Texture.* Texture is particularly useful in determination of various types of vegetation or soil characteristics. Subjective categories such as smooth, fine, rough, coarse, mottled, rippled, etc., are often useful. Mottled textures in agricultural fields indicate variations in soil moisture. A regular lined texture may be due to plowing or harvesting in parallel rows. Texture may therefore be used to determine the type of crop being grown in a field. Forested stands change with age from finely textured young stands to coarsely textured mature and old-growth stands.
5. *Pattern.* The spatial arrangement of objects is often a useful clue in identification. The regular pattern of fruit or nut trees in an orchard, for example, is readily distinguished from the irregular pattern of individual trees in a natural forest. Lines of windrows or the regular placement of bales in a field would readily identify a field as a hayfield. Patterns of buildings can often be used to distinguish between new residential areas, old residential areas, mobile home parks, etc.
6. *Association.* Association allows the observer to identify features based on their proximity to another object. In a cluster of farm buildings, for example, individual structures such as barns, sheds, silos, water tanks and farm machinery may be identified based on their close association with each other. Riparian forests dominated by cottonwood and alder are often associated with rivers, streams and the margins of wetlands.
7. *Season.* Most aerial photographs will have a date stamped on to the image. Knowledge of both natural and human-caused seasonal changes is often very useful in the identification of features. For example, the timing of agricultural activities such as plowing, harvesting, baling or agrochemical application may be used to determine the type of crop that appears in an aerial photograph.

**PROCEDURE**

Your group will be given a series of historical aerial photographs from a single site in the Salem area. These photos were obtained from the University of Oregon Map Library and will span a time from the late 1930’s to the 1990’s depending on map availability. You will also be given a topographic map of the area that includes your study area. Your report will be based on analyses of these photos, the topographic map and a site visit which will be done outside of scheduled lab time.

**I. Determination of scale**

To properly interpret the features on an aerial photograph, it is important to be able to estimate the size of various features. The difference between a house and a factory (or a goat and a cow, for that matter), for example, may be easily determined if the scale of the photo is known. There are a number of ways to accomplish this. One of the easiest is to identify your site on a topographic map (which has the scale identified) and then measure a linear feature such as a road or stream section that can be identified in each. Set up a proportion to determine the scale of the photo.

*For example:*

You measure a feature on an aerial photograph that is 3.25". The same feature measures 1.25" on a topographic map that has a scale of 1:24,000. Set up the following proportion and solve for X:

1.25"TOPO = 1/24,000

3.25"PHOTO X

Scales are normally reported as a ratio. A scale of “1: 20,000”, for example, indicates that every inch on the photo represents 20,000 inches (or 0.316 miles) on the ground. *Large scale* images are taken at low altitudes and generally show greater detail of smaller geographic areas. *Small scale* images are taken at higher altitudes and show less detail of larger geographic areas. The photos you will be working with today are large scale photographs.

Using the method described above, determine the scale of one of your photos.

NOTE: *Since each of your photos was taken at a different time, using different photographic equipment and at different altitudes, the scales of each photo are probably somewhat different.*

**II. Unique features**

List any unique features that can be identified on your site (e.g., athletic facilities, clearcuts, drainage patterns, industrial buildings, mill ponds, etc.)

For each feature, briefly describe the type of information you have used to identify the feature (see INTERPRETATION OF AERIAL PHOTOGRAPHS above).

**III. Estimation of land use change**

1. For each of the photos available for your site, identify the major land uses present. Use the following classification:

**Urban/Developed Land:**

* **Residential**
* **Commercial and Services (businesses, schools, stores, libraries, etc.)**
* **Industrial (manufacturing, lumber mills, sewage treatment plants, etc.)**
* **Roads (or other transportation features)**

**Agricultural:**

* **Cropland and Pasture**
* **Orchards**

**Forests:**

* **Coniferous forest (young vs. mature)**
* **Deciduous forest**

**Disturbed lands:**

* **Recent clearcut**
* **Recent excavation (e.g. mining operation, excavation for buildings, etc.)**

**Water:**

* **Rivers and streams**
* **Lakes and ponds**

NOTE: *If land uses other than those listed above are easily identifiable, add them to your list.*

1. In each of your aerial photos, estimate the percent coverage for each major land use. Although there are a number ways this could accomplished, I suggest the following:
* Start by identifying the photo with the largest scale (i.e., the photo that covers the smallest geographical area). This must be done to assure that all areas of interest are covered by each photo.
* Select one land use category (e.g., “agricultural/orchards”), place a piece of acetate over the photograph and draw a boundary around each area covered by that land use category (i.e., “orchards”) with a fine tip marker.
* After each area covered by this land use category on the photo has been delineated, place the acetate sheet over a grid and count the number of squares that are occupied by this category (“orchards” in this example).
* Continue this process for each major land use area on the photo.
* Repeat the process for each photo in the time series.

Your results can either be expressed as:

* percentages of each land use category

***-or-***

* actual measurements of area by converting the percentages to square miles or acres using the scale you developed for each photo

Enter your data into *EXCEL* and graph your data as a function of time. These graphs must be prepared for next week when each group will describe the results of this exercise for their site (see LAB PRODUCT below).

**IV. Site Visit**

1. Plan to visit your site at some time in the next two weeks to record land use changes that have occurred since your last available photograph. The site visit can also be used to confirm identification of features you have identified in aerial photos.

NOTE: *Although the site visit may be conducted at any time during the study, it is probably best to become familiar with the area through interpretation of the aerial photographs first.*

1. Plan to spend approximately 1-2 hours at your site. Make your observations from public roads and properties - ***do not trespass on private property!***Bring a copy of the latest aerial photograph with you and record any changes that have occurred since that date. Possible changes are highly site specific, but may include the following:
* removal or addition of buildings
* implemented forest practices - cutting, replanting, etc.
* changes in agricultural practices
* changes in hydrology - e.g., removal or addition of ponds
1. Record these changes and be prepared to report your findings to the class next week. You will find this information useful in making projections concerning the future of this site.

**LAB PRODUCT**

Each group will describe their findings in an informal, group presentation next week in lab. All aerial photographs of your site and graphs you have generated to illustrate land use changes should be available. Your presentation should include all group members and describe the nature of land use change at your site.

Include the following in your presentation:

* What are the major trends indicated in your graphs?
* What external forces may have been responsible for the changes you have seen?
* What are the consequences to natural resources for the changes you have seen?
* What do you think your site looked like 50 years prior to your earliest photograph? 150 years prior to your earliest photograph? How would you get detailed information on this?
* Based on your site visit, what changes have occurred since the last photograph was taken?
* What is your projected future for this site? (use information from your site visit)
* Determine, where possible, the ownership of areas represented on your photos (private, county, state, federal). Topographic maps may be helpful. How has ownership influenced land use on the site?
* How do you think Oregon’s Land Use laws have influenced the changes in land use at your site?

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGE 121-126

Environmental Science III

H.J. Andrews Field Trip (correlates with pages 127-130 in PDF file and book)

**H.J. Andrews Experimental Forest Field Trip**

**INTRODUCTION**

The H.J. Andrews Experimental Forest is located in the Cascade Mountains approximately 50 miles east of Eugene, Oregon. It is managed jointly by the U.S. Forest Service and Oregon State University as a Long-Term Ecological Research (LTER) site. Prominent scientists from around the world have conducted research here and much of what we know about the forests and streams of the Pacific Northwest is the direct result of their work.

This one day field trip is designed as a “capstone experience” that engages students in a number of activities that relate to environmental issues we have discussed in *Environmental Science* throughout the year. Activities and discussions concerning land use, forest management, biodiversity, riparian zone management, stream ecology and water quality are included.

**PLANNED ACTIVITIES**

1. Introduction to H.J. Andrews Experimental Forest and Central Cascades Adaptive Management Area.
2. Hike on Lookout Creek Old Growth Trail to review old-growth forest characteristics.
3. Visit log decomposition study sites to review log decomposition studies and the role of old growth

forests in global carbon budgets.

1. Lunch - please bring your own sack lunch and something to drink. Coolers will be provided.
2. Discuss stream ecology and the use of macroinvertebrates as indicators of water quality, and the role of streams and riparian areas in natural resource management.
3. Conduct amphibian sampling in stream and terrestrial environments.

*Please bring the following:*

* Lunch and drink
* Field notebook
* Rain gear/warm clothes
* Sturdy hiking boots
* Hip boots/waders
* Binoculars/camera

**LAB PRODUCT**

A field journal that provides an account of the days activities and discussions. The appropriate format will be described later.

**SAFETY GUIDELINES**

Students will be engaged in a variety of field activities, some of which may present potentially hazardous situations. Although I do not plan to expose you to unusually dangerous conditions, be aware that we will be working primarily in old growth stands which usually include the following hazards: slippery rocks, large fallen logs, large snags and dead limbs and an occasional yellow-jacket

nest.

*The following guidelines are established to reduce the likelihood of accidents and injuries:*

1. *Know your limitations!* If you feel the work exceeds your physical limits (pace too fast, slope too steep, etc.) inform the instructor immediately.
2. *Be aware of your surroundings!* Old growth forests are *the ultimate* in a three-dimensional habitat.
3. *Do not jump off of fallen logs!* Watch your footing; moss-covered logs (especially those across streams) may be slippery.
4. *Wear comfortable, appropriate clothing and footwear*. Sturdy hiking boots are required.
5. *Drive vehicles cautiously*. Driving on logging roads is a new experience; assume there is a log truck coming around every corner.
6. *Yellow-jackets* are ground nesters and do not take kindly to having their nests disturbed – be aware! If you are allergic to bee stings, bring a bee sting kit and tell instructor how to use it.
7. *Do not enter stands alone!* All planned activities are *group* activities - please maintain sight contact with the group at all times.
8. *Rough-skinned newts* (*Taricha granulosa*) and some other amphibians have toxic skin secretions which may be irritating to the skin or eyes. These secretions are released only when the animal is mishandled and may be removed by wiping with a cloth or washing in water.
9. *In the absence of specific guidelines for a situation, common sense should prevail!*

**MATERIALS LIST**

*Please pack for travel:*

QUANTITY ITEM

6 rolls Flagging (any color)

20 Clipboards

6 Metric, 30 m tapes

20 1-gallon size plastic bags (Zip-lock or twist tie)

6 Potato rakes

6 Dipnets (large mesh, D-type)

6 Dipnets (small mesh, D-type, macroinvertebrate nets)

6 Small aquarium nets

6 Approx. 1/2 gallon plastic aquaria w/ snap lids

6 1 gal. plastic buckets w/ lids (animal feed buckets)

12 Forceps (tie small piece of flagging to each)

6 Ceramic/metal pans (white)

6 White plastic ice cube trays

6 Stream macroinvertebrate guides

1 Fluorescene dye

1 Stopwatch

1 Pack basket

2 Food coolers

**FIELD TRIP ITINERARY**

8:00 AM Leave Chemeketa Community College

8:00 - 10:00 Travel to H.J. Andrews Experimental Forest, Blue River, Oregon

10:00 - 10:30 Introduction to H.J. Andrews and Cascade Center for Ecosystem Management

10:30 - 12:00 Lookout Creek Old Growth Trail - Old growth forest characteristics

12:00 - 2:00 Lunch at Log Decomposition Research Site - How forest ecosystems are studied, carbon budgets, the role of woody debris in forest ecosystems and terrestrial amphibians

2:00 - 4:00 Stream Ecology - riparian buffers, stream macroinvertebrates and aquatic amphibians

4:00 - 6:00PM Return to Campus

(approximate)

**LAB PRODUCT**

Your lab product for today’s lab is a field journal that documents the day’s activities. Natural resource technicians and researchers frequently conduct field activities and sampling that are used to evaluate the condition of natural resources. Although some information that results from these activities is likely to be recorded on formal data sheets, a field journal is often required as well. The purpose of a field journal is two-fold. First, it provides a written record of what was observed in the field and adds information that may not be included on data sheets. Second, it serves as a reminder to the observer about the day’s activities.

Field journals should be *legible*, *organized* (clearly separate different activities), and *complete* (include all activities). Although formats vary with the activity being documented, all field journals should include:

1.] Header\_*Who, What, When, Where?*

*and*

2.] Body - Brief descriptions of specific activities, specific locations, observations, context of these activities and your personal reflections.

ADDITONAL NOTES FOR INSTRUCTORS FOUND IN PDF FILE PAGE 131

Environmental Science III

Permanent Plots (correlates with pages 132 -139 in PDF file and book)

**Using Permanent Plots to Monitor**

**Long-term Changes in Vegetation**

**INTRODUCTION**

You are already familiar with the concept of **ecological succession** which we described earlier as the changes in plant and animal communities that occur over time. In modern natural resource management, there is often a need for documenting these changes as part of a management plan.

*Here are some examples:*

Wetland Restoration A wetland restoration project may be monitored to see if restoration efforts are resulting in an ecosystem approximating a natural wetland. The only way to document this is to take vegetation measurements over time and to compare vegetation changes with a natural wetland that is already established.

Wildlife Management In wildlife management, late successional species may appear in a forested area only after certain structural characteristics such as snags, logs or large trees are established. Vegetation monitoring could be used to see how young stands are progressing towards this goal.

Timber Production Vegetation monitoring can be used to document growth rates of trees after planting, thinning or some other forest practice has been implemented. Predictions can be made to see if trees in a particular stand will reach marketable size within a given time frame.

In today’s laboratory we will establish six permanent circular plots that will be used to monitor longterm changes in vegetation. We will also take initial measurements on these plots. These measurements will be repeated by future classes on an annual basis to document changes in trees and shrubs.

**PROCEDURE**

1. Work in groups of 3 or 4 and be sure that at least one member of the group is proficient in tree and shrub identification. Each group should also have an identification guide for trees and shrubs.
2. Centers of circular plots have been marked with flags at representative points within the field site. Identify your plot center and pound in your 5 foot length of rebar until a 2.5 foot length is protruding from the soil. Place the white PVC pipe over the rebar to permanently mark the site with an easily identified marker.
3. Flag out two circles - one with a 5.6 m radius (creating a plot of 100 m2) and the other with a 12.6 m radius (500 m2). The smaller plot will be used to measure the abundance of shrubs and ferns. The larger plot will be used to measure the abundance of trees.
4. Measure the trees in your plot first. Proceed through your large plot like the sweep second hand of a clock. One group member should stand at the origin and direct the measurement of trees to be sure that every tree in the plot is measured. Another should identify trees and measure the diameter at breast height (DBH) for every tree greater than or equal to 5.0 cm (see definition for “tree” below). Tree identifications should be confirmed by a knowledgeable group member or the instructor. A third group member should record data. Rotate group members between the various tasks and be sure to check each others’ work.

NOTE: *A tree is* “*in”* *your plot if* ***the center*** *of the tree falls within the plot.*

1. Measure the shrubs and ferns (see definitions below) in your smaller plot as follows:
* Move through your smaller plot and identify the various shrub species. Identifications should be confirmed by a knowledgeable group member or the instructor.
* Count the number of individuals for each species. A shrub or fern is “in” your plot if the base of the stem falls within the plot. Plants with multiple stems such as Sword fern and Western hazelnut are counted as a single plant if all stems seem to originate from a common base. Record numbers on the data sheet.
* Then, estimate “percent cover” for each shrub or fern species. Imagine yourself perched about 20 feet directly over your plot. From this view estimate the percent of the plot that is covered by that species. It is usually best to start with the most abundant species and work your way down to the least abundant. Record data.
* In the example at the right, percent covers are approximately:

50% gray species

40% black species

10% white species

**DEFINITIONS**

**Tree** any woody vegetation with a DBH (diameter at breast height) of 5.0 cm or greater; dead trees (snags) will be included here (if 5.0 cm or greater)

**Shrub** any woody vegetation with a DBH less than 5.0 cm; note that small individuals of tree species are counted as “shrubs” by our definition (do not include dead shrubs)

**Ferns** lady fern, sword fern or bracken fern

**DATA SHEET – TREES**

**Group Members: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Plot # \_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_**

**Measure the DBH of every tree 5.0 cm DBH or greater that falls within your 500 m2 plot. A tree is** “**in”** **your plot if the *center* of the tree falls within the plot.**

|  |  |
| --- | --- |
| **Species** | **Diameter at Breast Height (DBH) in cm.** |
| Douglas -fir |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
| Bigleaf maple |   |   |   |   |   |   |   |   |
|   |   |   |   |   |   |   |   |   |
| Garry oak |   |   |   |   |   |   |   |   |
| Wild cherry |   |   |   |   |   |   |   |   |
| Oregon ash |   |   |   |   |   |   |   |   |
| Black cottonwood |   |   |   |   |   |   |   |   |
| Vine maple |   |   |   |   |   |   |   |   |
| Red alder |   |   |   |   |   |   |   |   |
| Grand fir |   |   |   |   |   |   |   |   |
| Snags (any species) |   |   |   |   |   |   |   |   |

**COMMENTS**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**DATA SHEET – SHRUBS AND FERNS**

**Group Members: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Plot # \_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_**

**Count every shrub or fern that falls within your 100 m2 plot. A shrub or fern is “in”** **your plot if the base of the stem falls within the plot. Plants with multiple stems such as Sword fern and Western hazelnut are counted as a single plant if all stems seem to originate from a common base.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Species** | **Number**  | **% Cover** | **Species** | **Number** | **% Cover** |
| English ivy |   |   | Snowberry |   |   |
| Scotch broom |   |   | Poisonoak |   |   |
| Himalayan blackberry |   |   | Black twinberry |   |   |
| Holly |   |   | Red elderberry |   |   |
|   |   |   | Creek dogwood |   |   |
| Sword fern |   |   | Salal |   |   |
| Bracken fern |   |   | Cascara |   |   |
| Lady fern |   |   | Pacific nine bark |   |   |
|   |   |   | Black hawthorn |   |   |
| Vine maple |   |   | Thimbleberry |   |   |
| Big-leaf maple |   |   | Pacific blackberry |   |   |
| Red alder |   |   | Douglas' spiraca |   |   |
| Garry oak |   |   | Oceanspray |   |   |
| Oregon ash |   |   | Indian plum |   |   |
| Douglas-fir |   |   | Mountain ash |   |   |
| Black cottonwood |   |   | Willows |   |   |
| Wild cherry |   |   | Red-flowering currant |   |   |
|   |   |   | Western hazelnut |   |   |

**SPECIES LIST**

**TREES, SHRUBS AND FERNS**

The following list of tree, shrub and fern species was developed from previous studies conducted at the Aumsville Site for Environmental Studies. Please consider it a starting point for those species we are likely to encounter. As new species are found on the site they will be added to the list. Species marked with an asterisk (\*) are introduced (non-native) species.

**TREES**

*Acer circinatum* Vine maple

*Acer macrophyllum* Big-leaf maple

*Alnus rubra* Red alder

*Quercus garryana* Garry oak

*Fraxinus latifolia* Oregon ash

*Pseudotsuga menziesii* Douglas-fir

*Populus balsamifera* Black cottonwood

*\*Prunus* sp. Wild cherry

**SHRUBS**

*Rhus diversiloba* Poison oak

\**Hedera helix* English ivy

*Symphoricarpos albus* Snowberry

*Lonicera involucrata* Black twinberry

*Sambucus callicarpa* Red elderberry

*Cornus stolonifera* Creek dogwood

*Gaultheria shallon* Salal

\**Cytisus scoparius* Scotch broom

*Rhamnus purshiana* Cascara

*Physocarpus capitatus* Pacific ninebark

*Crataegus douglasii* Black (Western) hawthorn

\**Rubus discolor* Himalayan blackberry

*Rubus parviflorus* Thimbleberry

*Rubus ursinus* Pacific blackberry

*Spiraea douglasii* Douglas. spiraea

*Holodiscus discolor* Oceanspray

*Oemleria cerasiformis* Indian plum

*Sorbus sitchensis* Mountain ash

*Salix* spp. Willow species

*Ribes sanguineum* Red-flowering currant

\**Ilex aquifolium* Holly

*Corylus cornuta* Western hazelnut

**FERNS**

*Athyrium filix-femina* Lady fern

*Polystichum munitum* Sword fern

*Pteridium aquilinum* Bracken fern

**LAB PRODUCT**

There is no formal lab product for this laboratory other than your active participation in the event. Future classes will be required to prepare a report that documents changes in vegetation over time.

**MATERIALS**

**Quantity Item**

6 5’ lengths of 5/8" rebar

6 5’ lengths of 1 1/2" white PVC

6 rolls flagging

6 Metal tags and wires (permanent markers)

6 Sharpies

6 30 m tapes

12 DBH tapes (metric)

12 Flagged pins (to mark temporary plot centers)

6 Clipboards

1 Fence post driver (or sledge hammer)

**REFERENCES**

*The following Identification Guides are suggested for western Oregon and Washington:*

Pojar, J. and A. MacKinnon. 1994. *Plants of the Pacific Northwest Coast*. Lone Pine Publ. Co., Redmond, Washington. 527 pp.

Petrides, G.A. 1972. *A field guide to trees and shrubs*. 2nd ed. Houghton Mifflin Co., Boston, Massachussetts. 428 pp.

Broskman, C.F. 1968. *Trees of North America*. Golden Press Western Publ. Co., New York. NY. 280 pp.

Preston, R.J. 1961. *North American Trees*. Revised edition. The M.I.T. Press, Cambridge, MA. 395pp.

Arno, S.F. and R.P. Hammerly. 1977. *Northwest trees.* The Mountaineers. Seattle, WA, pp. 222.

Ross, C.R. 1978. *Trees to know in Oregon*. Oregon State University Extension Service and Oregon State Forestry Department. Corvallis, OR. 96 pp.

Environmental Science III

Land Use Planning (correlates with pages 140-141 in PDF file and book)

**Land Use Planning Presentations**

Land use planning is an important element of a sustainable society. Choosing appropriate human uses of the land must be done to achieve a high quality of living for all members of a society. Land use planning strives to conserve natural resources and protect the environment while at the same time making required goods and services available to all citizens. However, such planning is not without controversy. The goals of individual property owners, for example, may not be compatible with the broader goals of a regional land use plan.

We will explore some of the issues related to land use planning through oral presentations by students. Students may work in pairs or singly in the selection of a topic, researching that topic and presenting their findings to the class. There are a number of local and regional land use topics that students may find to be particularly interesting:

1. The loss of farmland to development
2. Urban growth boundaries
3. Secondary lands - how should they be used?
4. Site selection for mines or landfills
5. Private property rights vs. public rights
6. Wetland designation and its consequences to private landowners
7. Role of the Land Conservation and Development Commission (LCDC) in Oregon land use planning
8. Zoning laws and urban land use planning

Other ideas for topics may be obtained by scanning recent issues of local and regional newspapers or from pages 624-635 in your text.

*You will be evaluated as follows:*

1. *Quality of Research* (15 points). How well have you researched the topic and prepared for the discussion? Each group should seek information from at least 5 substantial and current sources that address your particular issue. To document this research and assist you in the preparation of your presentation, first prepare a 1-page outline followed the next week by a 2-3 page summary that describes the main points you plan to address.

*Suggested sources:*

* Articles in resources available in the Chemeketa Library or Salem Public Library
* Interviews with knowledgeable persons (e.g., LCDC, city or county planning commissions, Division of State Lands)

2. *Quality of Presentation* (10 points). How well have you organized and presented the information

you have collected? To get a maximum number of points:

* Each member should contribute during the presentation.
* Visual aids of some type should be used- overhead transparencies, videotape, poster, handouts, etc. *Please feel free to use your imagination!* If you need assistance with copying or production of any of these, let me know.
* Presentation should be clear and concise. Do not run past 15 minutes - practice and time your presentations. I would strongly discourage reading to your audience.
* Allow 5 minutes for questions after your 15 minute presentation and answer questions appropriately.

**Timetable**

**Week One.** Inform instructor of topic selection.

**Week Two.** Submit list of at least 5 resources that provide information pertinent to your topic.

**Week Three.** Submit a 1-page outline of your presentation.

**Week Four.** Present topic and submit a written 2 or 3-page summary of your topic.

Environmental Science III

Wastewater Use (correlates with pages 142-143 in PDF file and book)

**Wastewater Use and Treatment in a Dairy Operation**

We will visit a local, a state-of-the-art dairy. The owner has agreed to describe to us the day-to-day operation of the dairy and some of the environmental challenges that relate to its operation. The following topics have been provided to him as an outline for his presentation:

1. *Description of operation.*

* how does operation work? feed, housing, products, etc.
* history of operation
* how much of feed is produced on-site/how much off-site?

2. *Production*.

* how many cows? calves? how much milk?
* production over a lifetime of a cow? daily?
* meat production

3. *Environmental challenges*.

* waste management - lagoons, irrigation of fields, nitrogen uptake by crops, salinization and mineralization of soils (accumulation of excesses from irrigation water)
* manure, straw, others
* soil and water analysis
* water use and reuse
* pesticide use (on crops/ on animals)
* odors
* public relations

4. *Environmental regulations*.

* what agencies are involved in regulation?
* what are concerns of the dairy? what could be done to change regulations to make farming easier for the dairy and/or better for the environment?
* what has been done to meet regulations?

Consider this trip a “fact-finding mission” designed to determine the nature of the operation, environmental challenges, and how these challenges are being addressed. I would suggest developing a set of questions prior to the trip. I am particularly interested in your leaving with an understanding of the use and treatment of wastewater generated by the dairy operation.

*Following the field trip, prepare a report that addresses the following:*

1. How does this operation differ from traditional dairying? (i.e., the way the dairy was run in the past)

\*2. What are the primary or “on-site” environmental effects of this operation? What are the secondary or “off-site” effects? (see text, p. 209)

\*3. How is wastewater used as a resource by the operation?

\*4. What are the primary environmental concerns related to land application of wastewater? How are these monitored?

5. What concerns do you think should be addressed in choosing future sites for dairies of this type?

6. Is this operation an example of sustainable agriculture? Do you have any suggestions for alternatives that might make the operation more “sustainable”?

\* *Give these questions the highest priority.*

Environmental Science III

Study Guide –Exam # 1 (correlates with pages 144-145 in PDF file and book)

**Study Guide Exam #1**

**COVERAGE**

Botkin and Keller - Chapters 15, 16, 17, 18 and 20

Labs - #1 (Hanford Cleanup), #2 (Constructed Wetlands), #3 (Biomonitoring), #4 (Amphibian Survey)

Supplemental Readings: Hanford article, Exxon Valdez case study, Frog deformities article, Phytoremediation article

Videotapes - Hanford Cleanup, “We All Live Downstream”, “Willamette River- Currents of Change”, Water Treatment

**BE FAMILIAR WITH THE FOLLOWING**

1. The elements of a sustainable society.
2. The history of energy use in the U.S.
3. The role of fossil fuels in past, present and future energy production.
4. For each of the various fossil fuels be familiar with:
* their formation
* known supplies and sources
* advantages and disadvantages as a fuel
* environmental concerns and risks
1. Patterns of global energy use
2. Alternative energy sources - advantages and disadvantages of each
3. The basics of radioactivity and how it is used to generate useable energy
4. Be able to objectively evaluate or propose a comprehensive energy plan for the U.S. based on your understanding of various sources of energy and the activity on p. 359 in your text
5. The environmental concerns at Hanford Nuclear Reservation including types of contaminants, monitoring programs, short and long-term plans for cleanup and ultimate fate of various zones.
6. The causes and results of nuclear accidents such as Three-mile Island and Chernobyl
7. The interconnections between energy issues and other environmental problems
8. Why are amphibians useful indicators of environmental quality?
9. The use of living organisms to evaluate the toxicity of water pollutants and water quality – be able to design an experiment that uses a bioassay to evaluate toxicity.
10. The various categories of water pollutants - sources and environmental impacts
11. The Willamette River as a case study in water quality
12. Conventional methods of wastewater treatment - septic systems, municipal sewage treatment
13. Alternative methods of wastewater treatment that use natural processes - land application, aquaculture, bioremediation - limitations, advantages, disadvantages of each.
14. The specifics of wastewater treatment in the Willamette Valley - food processing plants, dairy operations and municipal sewage treatment
15. The use of constructed wetlands to treat wastewater - experimental design, methods of measurement, anticipated results, etc.

**TERMINOLOGY**

sustainable society cogeneration energy conservation

subbituminous bituminous anthracite

carbon cycle acid mine drainage strip mining

overburden reclamation sulfur dioxide

nitrous oxides carbon dioxide heavy metal

coal gasification methane natural gas

hard path soft path crude oil

coal fossil fuel hydrocarbon

oil shale biomass geothermal energy

renewable energy nonrenewable energy active solar energy

passive solar energy photovoltaics solar collectors

solar towers tidal power hydropower

wind power alpha particle beta particle

breeder reactor nuclear fission nuclear fusion

gamma rays half-life nuclear waste

nuclear energy neutron radioisotope

radioactive decay rads rems

plutonium uranium strontium

tritium vitrification fuel rod

contaminant plume reactor core enrichment

pH biomonitoring bioassay

bioremediation *Daphnia* pesticide

pollutant *Cryptosporidium* point source

nonpoint source groundwater surface water

biological oxygen demand (BOD) dissolved oxygen (DO) decomposition zone

recovery zone clean zone pathogen

typhoid cholera fecal coliform bacteria

cultural eutrophication PCB.s biological magnification

turbidity coral bleaching nitrogen bubble disease

pseudoestrogens environmental hormones phthalates

BHA DDT primary treatment

secondary treatment advanced treatment aquaculture

bioremediation phytoremediation phytoextraction

rhizofiltration *Arthrobacter* water reuse

LC-50 *Pfiesteria* POP’s

red tide

Environmental Science III

Study Guide – Exam # 2 (correlates with pages 146-147 in PDF file and book)

**Study Guide Exam II**

**COVERAGE**

Botkin and Keller Chapters 22, 23, 24, 27

Labs - Mining videotape, Lichen adsorption lab

Supplemental Readings - *Going for the Gold*, *Prophets of Gloom*

Videotapes – “Public lands - Private Profits,” “Only One Atmosphere” (ozone depletion), Oregon

Field Guide - *Solid Waste Management* and *Lichen Biology in Forest Canopies*

**BE FAMILIAR WITH THE FOLLOWING**

1. Natural and human-made sources of air pollution
2. Trends in U.S. levels of various air pollutants over the past 50 years
3. Categories of air pollutants - sources and human health/ecosystem effects of each
4. The concept of “nuclear winter” and examples of how it has been studied
5. Atmospheric chemistry that produces acid deposition
6. Impacts of acid rain on terrestrial and aquatic ecosystems
7. Potential solutions to the acid rain problem
8. The most common sources of indoor air pollution
9. Sources and human health effects of radon gas
10. Environmental issues concerning mining - videotape and discussion questions
11. The Mining Act of 1872 - its implementation and reform efforts
12. Lichens as bioindicators of air pollution
13. Have a good understanding of the lichen adsorption experiments conducted in the laboratory
14. The various forms in which oxygen may appear in the atmosphere
15. The role of ozone in the lower and upper atmosphere
16. Trends in ozone depletion over Antarctica, Arctic and temperate areas
17. Proposed causes for ozone depletion and supporting evidence
18. Ozone depleting chemicals and the chemical reactions that result in the loss of ozone
19. Environmental and human effects of ozone depletion
20. Proposed solutions to ozone depletion
21. “Dilution and dispersion” waste management vs. “integrated” waste management
22. Considerations for sanitary landfill site selection, design and operation
23. The nature of the solid waste and hazardous waste problems in the United States
24. Ocean dumping as an environmental issue

**TERMINOLOGY**

*Waldsterben* sulfur dioxide hydrogen sulfide

ozone nitrous oxides particulates

stationary source mobile source point source

non-point source primary pollutant secondary pollutant

carbon dioxide carbon monoxide hemoglobin

volatile organic compounds photochemical smog asbestos

pH hydrogen ion calcium

potassium aluminum decomposers

air quality standards atmospheric inversion buffers

coal gasification scrubbers sick building syndrome

nitrogen cycle heavy metal magnesium

methylmercury lime allowance trading

chimney effect hydrocarbon vapor-recovery systems

catalytic converter formaldehyde radon

polonium alpha particle heap leach mining

sodium cyanide standard curve bioindicator

transmittance spectrophotometer cuvette

supernatant methylene blue composting

hazardous waste integrated waste management incineration

land application leachate monitoring well

recycle sanitary landfill source reduction

groundwater surface water landfill liner

ocean dumping capping surface impoundment

secure landfill Dobson Unit Montreal Protocol

HCFC HFC ozone

ozone shield polar stratospheric clouds polar vortex

UVA UVB UVC

monatomic diatomic chlorine

chlorine oxide cataract propane

helium methyl bromide photolyase

Environmental Science III

Study Guide – Final Exam (correlates with pages 148-149 in PDF file and book)

**Study Guide - Final Exam**

**COVERAGE**

Botkin and Keller - Chapters 25, 29 and 30

Aerial Photo/Land Use Lab, Constructed Wetland Lab, H.J. Andrews Field Trip

Supplemental Readings - Environmental Economics articles, Wetlands Mitigation article, Handouts from field trip

Video - Excerpts from David Suzuki lecture and .Willamette River - Currents of Change. (KGWTV)

**BE FAMILIAR WITH THE FOLLOWING**

1. How does free-market environmentalism differ from the traditional relationship between the environment and the economy?
2. What are some of the pros and cons of assigning “actual cost” or “real value” to the goods and services we value?
3. What are some of the alternatives to “command and control” environmental regulation?
4. What is the relationship between good environmental policy and a strong economy?
5. What is the “Tragedy of the Commons” and how does it apply to environmental problems?
6. What are the various functions of “land-use planning”? How is land-use planning accomplished in Oregon?
7. What type of land use changes can be documented using historical aerial photos?
8. Why is land use planning a critical element of a sustainable society?
9. What are some of the strengths and weaknesses of wetland mitigation?
10. How could wetland mitigation be improved?
11. What is a lumber certification program and how does it relate to sustainable forestry?
12. The various ways human cultures have perceived the “human-nature” relationship.
13. The use of constructed wetlands in the Aquatic Ecology Laboratory for the treatment of agricultural wastewater:
* initial conditions
* experimental design
* techniques for measurement
* data collection and analysis
* results and conclusions
* strengths and weaknesses of model constructed wetlands

14. All aspects of the H.J. Andrews Experimental Forest, including:

* ecological characteristics of old growth forests
* log decomposition study
* terrestrial amphibian sampling
* stream ecology
* aquatic amphibian sampling

**TERMINOLOGY**

externality internality allowance trading

discount factor risk-benefit analysis commons

land use planning urban growth boundary EIS

compensatory mitigation GIS green plan

ecological restoration adaptive management sustainable forestry

forest analog strip clearcutting agroforestry

environmental ethics

Environmental Science III

Exam # 1 (correlates with pages 150-156 in PDF file and book)

**Exam #1**

**Multiple Choice (2 points each):** Select the most appropriate answer and place the letter on the answer sheet.

1. Of the following energy sources, which one is not considered “renewable”?

A. wind D. solar thermal

B. photovoltaic E. biomass

C. natural gas

1. At present rates of consumption, known oil reserves will be depleted in approximately \_\_\_\_\_

years.

A. 45 D. 200

B. 75 E. 500

C. 125

1. The sulfur content of coal is of great concern when considering coal as a source of energy.

When sulfur is burned it is converted to \_\_\_\_\_\_\_\_ which contributes to \_\_\_\_\_\_\_\_.

A. sulfur dioxide/global warming D. nitrous oxide/water pollution

B. carbon dioxide/global warming E. sulfur dioxide/acid rain

C. carbon dioxide/air pollution

1. Uranium-235 is described as a “fissionable radioisotope”. This means that:

A. it must be enriched to be a useable fuel

B. it can be split by neutrons to release energy

C. it can be used to produce an atomic bomb but not in a nuclear reactor

D. it has a very long half-life

1. Atoms of Deuterium and Tritium are forced together at extremely high temperatures and energy

is released. This process best describes:

A. nuclear fusion D. radioactive decay

B. breeder nuclear fission E. radioactive dating

C. core meltdown

1. At the Hanford Nuclear Reservation in Washington there are various levels of nuclear waste stored on site. Among the most dangerous high-level wastes is the unused nuclear fuel, \_\_\_\_\_\_\_\_ , which is stored under water in the old reactor buildings.

A. Cesium D. Plutonium

B. Uranium E. Tritium

C. Iodine

1. Which of the following alternative energy sources converts solar energy into readily usable

electricity?

A. solar tower D. solar thermal

B. photovoltaic E. biomass burning

C. geothermal

1. Which environmental pollutant may result in fish kills when large volumes of water pass rapidly

over a dam?

A. oxygen D. carbon dioxide

B. dioxin E. BOD

C. nitrogen

1. In a conventional wastewater treatment plant, the chlorination of wastewater is considered to be

part of:

A. primary treatment C. advanced water treatment

B. secondary treatment D. all of the above

1. Rhizofiltration, phytoremediation and phytoextraction are all methods to extract toxic chemicals

using \_\_\_\_\_\_\_\_ (fill-in).

1. The abundance of insoluble particles of soil and other solids may decrease water quality dramatically. This characteristic is measured as \_\_\_\_\_\_\_\_ (fill-in).
2. What process is responsible for the harmful effects of high B.O.D. on water quality?

A. photosynthesis D. biological magnification

B. decomposition E. rhizofiltration

C. formation of nitrogen bubbles

1. Which of the following pollutants would most likely cause cultural eutrophication?

A. pesticide spill D. oil spill

B. heavy metals E. agricultural runoff

C. coliform bacteria

1. In the U.S., water quality would be most improved by decreasing non-point source pollution

rather than point source pollution from their current levels.

A. True B. False

1. Which of the following statements best describes the relationship between BOD and dissolved oxygen?

A. when BOD is high dissolved oxygen is also high

B. when BOD is high, dissolved oxygen is low

C. there is no clear relationship between BOD and dissolved oxygen

1. The recent spill by Mitsubishi into Pringle Creek in Salem resulted in dramatic change in which of the following water quality values?

A. dissolved oxygen D. pH

B. turbidity E. pesticide level

C. nitrate level

1. You are studying an aquatic ecosystem that was contaminated with PCB’s back in the 1960’s. In which of the following organisms would you expect to find the highest concentration of the pollutant?

A. Daphnia D. algae

B. killer whale E. fish

C. shrimp

1. Amphibians are considered to be good indicators of environmental quality because:

A. they readily absorb pollutants through their thin skins

B. they are widely distributed

C. most species have aquatic and terrestrial stages in their life history

D. they are relatively long-lived

E. all of the above

1. A high fecal coliform bacteria count is found in a water supply that you are monitoring. Which of the following could explain this result?

A. human sewage has leaked into the water supply

B. runoff from a confined animal feeding operation has contaminated the water supply

C. an industrial oil spill has contaminated the water supply

D. both A and B are possible

E. all of the above are possible sources

1. According to recent research conducted by Andy Blaustein at Oregon State University, deformities in frogs may be caused by \_\_\_\_\_\_\_\_ in ponds used as breeding sites.

A. PCB.s D. high temperatures

B. nitrates and nitrites E. low dissolved oxygen

C. petroleum products

1. When the *New Carissa* ran ashore off the Oregon Coast and began leaking oil into the Pacific Ocean, this was considered a \_\_\_\_\_\_\_\_\_ source of water pollution.

A. point B. non-point

1. According to data compiled by the Environmental Protection Agency, which industry in Oregon is responsible for the greatest releases of toxic chemicals?

A. wood and paper products D. agriculture

B. silicon chip manufacturing E. health care

C. tourism

1. The Oregon Department of Environmental Quality is responsible for listing those rivers and streams in Oregon with degraded water quality. What is the most common reason cited for a stream or river being placed on this list?

A. pesticides D. nitrates

B. PCB.s E. exotic species

C. heat

1. The Columbia Slough in Portland was listed in March 2000 as a “Superfund Site” by the Environmental Protection Agency. What pollutant is primarily responsible for this listing?

A. PCB’s D. DDT

B. nitrates E. Cryptosporidiosis

C. lead

1. Which of the following produces a natural toxin that has been shown to cause shellfish poisoning in humans and 158 manatee deaths in Florida in 1996?

A. *Pfiesteria* D. Cryptosporidiosis

B. .red tide. E. *E. coli*

C. Elian Gonzalez

1. Environmental hormones (or “pseudoestrogens”) are a relatively new category of pollutants that has been linked to developmental and reproductive effects in humans and animals. Which of the following pollutants is considered to be an environmental hormone?

A. brevitoxin C. phosphate E. nitrate

B. mercury D. DDT

1. Based on discussions in class, which of the following is probably the most reasonable conclusion to draw from the results of the Diazinon trials in the Water Pollution Lab?

A. *Daphnia* and seed shrimp are unaffected by Diazinon

B. *Daphnia* and seed shrimp are highly susceptible to Diazinon

C. Diazinon has a low chronic toxicity

D. Diazinon has a shelf-life that exceeds 5 years

E. Diazinon is effective only in water that has a pH of approximately 7

1. In the Constructed Wetlands Lab we are using a spectrophotometer to measure:

A. dissolved oxygen D. pH

B. turbidity E. nitrate level

C. phosphate level

1. Which of the following Willamette Valley cities gets the majority of its drinking water from the

Willamette River?

A. Salem D. Corvallis

B. Eugene E. Portland

E. Newberg

1. The Aumsville Site for Environmental Studies was recently surveyed for amphibian diversity.

Based on our sampling, each of the following species occurs there, except:

A. Bullfrogs C. Northwestern salamanders

B. Red-legged frogs D. Rough-skinned newts

**Short Answer - #31-33 (10 Points Each)** Select **two** (and only two) of the following questions and answer on blank sheet

1. We have used the Willamette River in western Oregon as an example several times in our discussion of water quality. List 5 specific water quality problems that exist in the Willamette and describe what actions could be taken to improve these values.
2. List the methods employed in the containment and cleanup of the *Exxon Valdez* oil spill and comment briefly on their environmental impact and effectiveness.



1. Wastewater treatment facilities of Arcata, California and Lima, Peru were described in a videotape shown in class. Describe how each of these systems differ from conventional wastewater treatment facilities.

**Essay Question (20 points)** - Answer the following question on a blank sheet of paper.

1. A hypothetical U.S. energy policy has been proposed by the Bush Administration that includes an estimate of the percent contribution by each energy source by the year 2010. These percentages are presented in the table at right. Please comment on the strengths and weaknesses of this policy taking into account your knowledge of the elements of a sustainable society and the realities of the current energy situation. Use the knowledge you have gained from the Energy Policy Activity conducted in class as a basis for your answer.

**Extra Credit (5 points)**

1. You have conducted a bioassay study to determine the toxicity of various concentrations of DDT. You subject 50 goldfish to concentrations that vary from 0% to 2.5 % DDT for 60 minute exposures. When the study is complete you submit your data to Wynn’s Graphing Service which prepares the following graph.

A. Based on these data, what DDT concentration is 100% lethal to goldfish?

B. What is the “LC-50” for DDT?

C. If a similar test was run using dioxin rather than DDT and the LC-50 was found to be 0.4%, what would this tell you about the relative toxicity of DDT and dioxin?



Environmental Science III

Exam # 2 (correlates with pages 157-164 in PDF file and book)

**Exam #2**

**Matching Questions** (**2 points each**)

Select the most appropriate answer(s) and place the letter(s) on the answer sheet. Use the key below to answer #1-12:

A. sulfur dioxide (SO2) D. ozone

B. nitrous oxides (NOx) E. particulates

C. carbon monoxide (CO) F. volatile organic compounds

For each of the descriptions below, indicate those pollutants to which the description applies.

Letters may be used more than once and there may be multiple answers for each question. *Include all answers that apply.*

* 1. produced directly as a result of fossil fuel burning
	2. a yellow-brown gas that contributes to photochemical smog
	3. a colorless and odorless gas that readily binds to hemoglobin
	4. a colorless and odorless gas that causes direct damage to lungs
	5. contributes to acid deposition
	6. pollutant most commonly associated with coal-fired electrical generation
	7. a secondary pollutant
	8. the only air pollutant that has not declined dramatically in the U.S. since 1970
	9. combines with water to form sulfuric acid
	10. airborne lead and asbestos are examples
	11. proposed as the primary cause of .nuclear winter.
	12. blocks UV-B radiation in stratosphere

**Multiple Choice (2 points each):** Select the most appropriate answer and place the letter on the answer sheet.

1. What chemical is missing in the reaction below?

VOC’s + \_\_\_\_\_\_ + sunlight 🡪 photochemicals

A. SO2 D. NOx

B. O3 E. UV-B

C. CO2

1. Acidification of most midwestern (e.g. Indiana, Iowa, Nebraska) lakes is generally not expected

because:

A. coal-fired electric plants are intentionally located far from these lakes

B. the bedrock there has a powerful buffering effect

C. electricity is generated by technologies other than coal-burning

D. this region has strict air quality regulations

E. there are no mountain ranges in this region

1. You collect rainwater from a rain gauge in downtown Portland over several days and measure the pH of that water to vary from 5.6 - 5.8. What conclusion do you draw from this measurement?

A. this measurement falls within the normal pH range for rainwater

B. this measurement suggests acid precipitation

C. the water is unusually basic

D. the sample contains excessive hydrogen ions

E. none of the above

1. What observation is the direct result of the following chemical reaction?

H2O + CO2 🡪 HCO3 - + H+

A. the death of aquatic animals such as fish and amphibians

B. the natural acidity of rainwater

C. the accumulation of ozone at low elevations

D. the release of alpha particles

1. Radon has a half-life of about 4 days. Twelve days after a sample of radon gas is emitted into

a sealed room, \_\_\_\_\_\_\_\_ of the original amount remains.

A. 1/2 D. 1/3

B. 1/8 E. 1/12

C. 1/16

1. Radon gas is considered to be a threat to human health because it:

A. causes lung cancer D. binds with hemoglobin

B. causes birth defects E. causes skin cancer

C. damages the immune system

1. Which of the following waste management options probably has the greatest negative impact on air quality?

A. composting D. recycling

B. source reduction E. incineration

C. landfilling

1. The major component of municipal solid waste in the U.S. is:

A. yard and food waste D. plastic

B. paper E. construction debris

C. glass

1. In a secure landfill for hazardous waste, an impermeable clay cap is often used to:

A. prevent infiltration of surface water

B. prevent leakage of leachate into underlying groundwater

C. monitor surrounding soil for possible contamination

D. collect leachate for removal and treatment

1. In the spring 1991, 610 oil wells in Kuwait were ignited, burning about 4.6 million barrels per day for several weeks. As a result of this event, each of the following occurred except:

A. a decline in average temperatures in Kuwait for several weeks

B. 75-80% blockage of solar radiation for several days

C. severe acid rain deposition in Kuwait

D. a small but measurable decline in global temperatures

1. Although lichens have been used to evaluate a number of components of air pollution, their most common use to date has been to detect harmful levels of:

A. nitrous oxide D. sulfur dioxide

B. hydrogen sulfide E. particulates

C. methane

1. Natural phenomena, as well as human-produced pollutants contribute to poor air quality in the Los Angeles area. Which of the following natural phenomena probably does not contribute to air pollution in LA?

A. mountain ranges D. temperature inversions

B. chimney effect E. volcanic eruptions

C. westerly wind direction

1. What is the main reason that ozone depletion will continue to occur for at least several decades, even if all production, use and emission of ozone depleting chemicals were stopped today?

A. once in the stratosphere, these chemicals can never be removed

B. developing countries will never agree to the ban

C. some ozone depleting chemicals have a long residence time

D. natural production of ozone depleting chemicals will continue

E. none of the above

1. The Antarctic ozone hole occurs in early spring; why does this phenomenon largely disappear later in the spring and summer?

A. there is more evaporation of water, which also blocks UV radiation

B. warmer temperatures increase the production of ozone

C. the sun heats up the air over Antarctica breaking up the polar vortex and stratospheric clouds

D. the input of UV radiation is reduced

E. anthropogenic emissions of ozone increase

1. Monitoring wells on modern sanitary landfills are designed to:

A. capture methane gas

B. detect the movement of leachate into the soil or aquifer

C. pump leachate out of the landfill

D. pump air into the landfill to increase aerobic decomposition

E. prevent the release of carbon monoxide gas from the landfill

1. The ozone problem results in excessive amounts of \_\_\_\_\_\_\_\_ reaching the surface of the Earth.

A. UV-A D. UV-D

B. UV-B E. UV-E

C. UV-C

1. When ultraviolet (UV) radiation contacts ozone in the atmosphere:

A. UV is reflected back into space and the ozone becomes CO2

B. UV is converted into heat and the ozone becomes O2 and O

C. UV is converted into light and the ozone becomes monatomic oxygen

D. UV is converted into infrared radiation and the ozone becomes water vapor

E. UV is scattered and the ozone remains unchanged

1. The ozone problem is sometimes described as an “ozone distribution problem”. What is meant by this statement?

A. ozone is accumulating over tropical and temperate areas but declining over the poles

B. ozone is accumulating in the stratosphere but declining in the troposphere

C. CFC’s are accumulating in the troposphere while ozone is declining in the stratosphere

D. ozone is declining in the stratosphere but accumulating in the troposphere

E. ozone is declining in the stratosphere but ultraviolet radiation is increasing in the Troposphere

1. Which of the following statements best describes the significance of the chemical reaction below?

ClO + O 🡪 Cl + O2

A. ozone is being chemically broken down as a result of this reaction

B. ozone is being generated as a result of this reaction

C. chlorine is being produced which can cause further breakdown of ozone

D. chlorine is being produced which can absorb UV-B radiation

E. oxygen is being produced which can form additional ozone

1. All of the following chemicals have been proposed as replacements for CFC’s except:

A. methane D. propane

B. HCFC’s E. HFC’s

C. helium

1. There is evidence to support all of the following consequences of increased ultraviolet radiation except:

A. the decline of amphibian populations

B. the decline of primary production in marine ecosystems

C. the increase of melanomas in humans

D. the increase in lung cancer rates in humans

Questions 34-36 refer to the incomplete reaction below:

\_\_\_\_\_\_\_ + O3 🡪 ClO + O2

1. What is the missing element in the reaction above? (Fill in)
2. What is the source of the missing element in the reaction above?

A. CFC.s C. ozone

B. methane D. propane

1. The reaction above, when completed, is best described as the reaction that causes:

A. ozone depletion D. the production of ozone

B. global warming E. the absorption of UV radiation

C. AIDS

1. A short video describing current research on lichens in forest canopies was shown in lab.

Preliminary results from this research suggest that lichens normally found only in old-growth forests die when transplanted to younger stands.

A. True B. False

1. Heap leach mining allows mining companies to extract gold from ore that contains only tiny amounts of gold. What chemical is used in this process?

A. sulfur dioxide D. ozone

B. cyanide E. sulfuric acid

C. radon

1. The Mining Act of 1872 allows for the purchase of federal lands by private mining companies at levels far below current market value.

A. True B. False

1. You are using a spectrophotometer to measure the amount of methylene blue in a dilute solution of lead chloride. What should you use as your “blank”?

A. distilled water C. methylene blue

B. lead chloride D. any of the above could be used

**Essay Question - #41 - 42 (10 points)** - Answer **one** (and only one) of the following questions on a blank sheet of paper.

1. Describe the difference between “ozone depletion” and the “greenhouse effect”. In what ways are these two global phenomena connected?
2. Describe the effects of acid rain on terrestrial ecosystems.

**Analysis - 10 points**

1. You are hired by the Environmental Protection Agency to evaluate the effects of a major industrial park on air quality in a large metropolitan area. The industrial park contains several factories suspected of releasing a variety of pollutants. Since your budget is limited and you lack the funds to purchase expensive air monitoring equipment, you have decided to use lichens as indicators of air quality.

Before you can begin field studies, however, you must decide which species are the best indicators of air quality. To do this, you evaluate the degree to which various metallic ions are absorbed by 3 species of lichens that occur locally. Since you have successfully completed Cudmore’s *Environmental Science* course you already know how to conduct such experiments using cation exchange between metallic ions and methylene blue. You measure the degree of cation uptake by each lichen species using spectrophotometry and you obtain the following data:



You also generate a “standard curve” for methylene blue using known concentrations of methylene blue:



Answer the following questions using the information above:

* Use the data above to generate a graph that illustrates the amount of lead (Pb++) absorbed by each of the three lichen species. Graph paper will be provided. *Hint: Use methylene blue concentration as an indirect measure of lead absorbed. Also, graph only the data for lead, not all cations.*
* Of the three lichen species you have examined, which one appears to be the best candidate for a bioindicator of air pollution? Explain your answer.
* What is the function of the “distilled water” in this experiment?
* The use of leaded gasoline was phased out from the early 1980’s to the present time. Describe the changes in the relative amounts of each of these lichen species that might be expected as a result of this policy.

**Extra Credit (5 Points)** - Answer the following question as completely as possible on the blank sheet.

1. Integrated waste management (IWM) has been proposed as a sustainable approach to solid waste management. List and briefly describe the most important components of IWM in order of their priority.

Environmental Science III

Final Exam (correlates with pages 165-171 in PDF file and book)

**Final Exam**

**Multiple Choice (2 points each):** Select the most appropriate answer and place the letter on the answer sheet.

1. An economic policy of “free-market environmental regulation” attempts to assign “true costs” to consumer products or services.

A. True B. False

1. In Oregon, the sprawl of residential and industrial areas around cities is limited by establishing a(n) \_\_\_\_\_\_\_\_ (fill-in).
2. According to your text, land-use planning is most directly in conflict with which of the following?

A. agricultural use of the land D. rights of property owners

B. urban uses of the land E. maintaining esthetic value

C. uncontrolled development

1. Agricultural uses and \_\_\_\_\_\_\_\_ have similar land requirements; therefore, most farmland that is currently being converted into non-farm use goes into this land use (fill-in).
2. Which of the following phrases best describes a “rhizosphere”?

A. a fungus associated with the root of a tree

B. a root that is in the shape of a ball

C. an oxygen rich zone that surrounds a root

D. the above-ground portion of a wetland plant

1. Oregon’s Land Use Policy was established in 1973 during Tom McCall’s term as governor. This policy represents a fundamental shift in responsibility for land use planning from the \_\_\_\_\_\_\_\_ to the \_\_\_\_\_\_\_\_ level.

A. local, state C. county, local

B. state, local D. local, federal

1. One of the reasons that modern civilization has had large impacts on the environment is that civilization has tended to put value on the environment only for \_\_\_\_\_\_\_\_ reasons.

A. esthetic C. ecological

B. moral D. utilitarian

1. The “land ethic” as proposed by Aldo Leopold affirms the right of all resources to continued existence. This ethic was largely designed to change the prevalent view of natural resources and the environment as:

A. commodities D. wilderness

B. objects of fear E. inexhaustible supplies

C. a fruitful garden

1. In the current U.S. economic system, commercial enterprises maximize profits by paying \_\_\_\_\_\_\_\_ costs and ignoring \_\_\_\_\_\_\_\_.

A. indirect; direct costs D. intangible; externalities

B. direct; externalities E. mandatory; supply and demand

C. direct; the discount factor

1. The “Tragedy of the Commons” explains why individuals don’t always act in such a way as preserves the environment. At its core, the principle states that:

A. individuals are interested in the short-term, not the long term

B. benefits go to the individual; costs go to society as a whole

C. common land is valued less highly than private land

D. governments don’t do enough to instill environmental values

E. people would rather clean up environmental degradation that prevent it in the first place

1. In an analysis of the total costs of developing a new coal mine, which of the following would be considered an externality?

A. the market price of coal

B. the cost of diesel fuel to run mining machinery

C. the cost of operating a public relations center at the mine

D. damage from acid rain downwind of coal-fired utilities

E. the cost of treating and disposing of mining tailings

1. A person living in the United States who never intends to visit China may nevertheless be willing to pay a certain amount of money to preserve Giant panda populations. When circumstances like this occur, the commodity (in this case, the panda) is said to have \_\_\_\_\_\_\_\_\_ value. (Fill-in)
2. Who is best known for the statement: “Visit our state of excitement again and again, but for heaven’s sake, don’t move here to live”?

A. Ron Wyden D. John Kitzhaber

B. Tom McCall E. Bob Straub

C. Mark Hatfield

1. A wetland mitigation site in San Diego Bay has failed to meet one of its performance standards - to create nesting habitat for the light-footed clapper rail. What ecological factor has been the primary cause for this failure?

A. an introduced predator D. low nitrogen levels in soil

B. lack of water E. toxic pollutants

C. growth of invasive wetland plants

1. Which of the following groups is most likely to have made the following statement?

“The land use system has become very rigid, very inflexible, and very unreasonable... The objective

has become not protecting prime farmland, but prohibiting living in the country”

A. 1000 Friends of Oregon D. American Civil Liberties Union

B. Oregonians in Action E. National Wildlife Federation

C. Earth First!

1. There have been a number of efforts in recent years to assign value to ecosystem goods and services. In this analysis, which of the following ecosystems has the greatest value when expressed as “$ per acre”?

A. open ocean D. wetlands

B. coastal ecosystems E. Cudmore Forest

C. grasslands

**Questions #17 - 25 pertain to the “Constructed Wetlands Lab”:**

1. Name one process that took place in the constructed wetlands that resulted in improved water quality (fill in).
2. The “rotten egg” odor associated with polluted water is caused by hydrogen sulfide. Some groups reported this odor in their tanks and it was also detected in the control tank. What does the production of hydrogen sulfide indicate?

A. decomposition by anaerobic bacteria

B. a rapid increase in photosynthesis by algae

C. nitrogen fixation by bacteria

D. the consumption of algae by copepods and other aquatic invertebrates

1. Assuming that the constructed wetlands were effective in the treatment of agricultural wastewater, which of the following statements makes the most sense?

A. *Chlamydomonas* appeared in samples from both test and control tanks throughout the study

B. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in the control tank

C. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in the test tanks

D. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in both

1. What is the primary difference between the “control” tank and “test” tanks?

A. Test tank measurements were taken by students, control tank measurements were taken by the instructor

B. Test tanks contain a wetland, control tank does not

C. There were six test tanks and only one control tank

D. Wastewater in control tank was more concentrated than wastewater in test tanks

E. Control tank was exposed to greater solar radiation than test tanks

**Identification (one point each) #21-25**

In a brief phrase or single sentence, describe what each of the following look like. Please answer on

blank sheet.

1. *Chlamydomonas*
2. Tailed frog tadpole
3. *Pteranarces* stonefly
4. Spectrophotometer
5. End point of dissolved oxygen test

**Matching (one point each) #26-30 (Each letter is used once)**

1. Pacific giant salamander A. Most closely associated with large decaying logs
2. Tailed frog B. Preferred habitat is the splash zone along streams
3. Dunn’s salamander C. One of very few of its kind that practices internal fertilization
4. Rough skinned newt D. The major predator of small western Cascades streams
5. Oregon slender salamander E. A generalist species found in old growth forests as well as a

number of other habitats

**Analysis - (20 points)**

1. The following graphs were generated from data collected by a hypothetical *Environmental Science* class in Portland. Students conducted a study of the constructed wetlands that was identical to ours - six constructed wetlands were used as models to study the effectiveness of wetlands in the treatment of agricultural wastewater. Agricultural wastewater (400 g fertilizer/300 gallons water) was added to each tank and water quality was measured at approximately one week intervals. A control tank contained only this wastewater and whatever algae and bacteria that decided to call this “home”.

For each graph, describe the **major trends** that appear in the data. Then, explain **your interpretation** of these trends and their **significance**. Answer on a blank sheet.

1. **Dissolved Oxygen Measurements**

****

**B. pH Measurements**

****

**C. Phosphate Measurements**



**D. Describe modifications to the experimental design in the Constructed Wetlands Lab that would be required to answer the following question:**

“What is the maximum capacity of these constructed wetlands to treat agricultural wastewater?”

**E. Select one (and only one) of the parameters below and generate a graph or table that would support the following statement:**

“Constructed wetlands are an effective way to treat agricultural wastewater.”

Algal concentration

Turbidity

Algal species

Odor

**Short Answer - (5 points each) The following questions (#32 and #33) relate to the H.J.**

**Andrews Field Trip. Please answer both on the blank sheet.**

1. Describe the relationship between the following terms:

**flourescene - macroinvertebrate - stream flow - stream ecology**

1. Describe the relationship between the following terms:

**log decomposition - forest management - respiration - terrestrial amphibians**

**Essay - (20 points) - #34-36** Choose **one** (and only one) of the following questions and answer as completely as possible on a blank sheet of paper. Use specific information from text readings, supplemental readings, videotapes, class discussions and laboratories where appropriate.

1. Describe in detail how “wetland mitigation” works. What changes in the current process would you offer to make this a more “ecologically sound” practice? Explain the benefits of these changes.
2. The “free-market” has recently been proposed as an alternative to “command and control” mechanisms for environmental regulation. Describe in detail two specific examples of attempts to “protect the environment with the power of the market.”
3. What are the various goals of “land-use planning”? How has Oregon addressed these land use goals through its land use planning legislation? How would Oregon be different today if these land use laws had not been adopted?

**EXTRA CREDIT - 5 Points**

1. When we first entered Lookout Creek Old Growth Trail at H.J. Andrews Experimental Forest, I asked you to do something I had never before tried with a class. Explain this experience and describe the impact that this course had on it (if any).