DOC. 533

SAULT COLLEGE OF APPLIED ARTS & TECHNOLOGY

SAULT STE. MARIE, ONTARIO

COURSE OUTLINE

COURSE TITLE: WATER POLLUTION

CODE NO.: BIO 129-4 SEMESTERS: II, V

PROGRAM: WATER RESOURCES/ENVIRONMENTAL ENGINEERING/ PULP & PAPER TECHNOLOGY

AUTHOR: H. ROBBINS

DATE: OCT. 1996 PREVIOUS OUTLINE DATED: DEC. 1995

APPROVED: _____ Oct-6/96
DEAN DATE

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PREREQUISITE: AQUATIC BIOLOGY 125-3

I. PHILOSOPHY/GOALS:

This is a course designed to provide an introduction to the biological effects of water pollution and to ways of detecting, describing and quantifying these effects in the field and the laboratory. Types and sources of pollution, sampling strategies and legislation governing water quality will be discussed. On successful completion of the course the student will be comfortable in reading and understanding non-scientific literature on various aspects of water pollution and environmental concern. Practical laboratory experiments and student presentations on pollution in the great Lakes supplement the classroom discussion.

II. STUDENT PERFORMANCE OBJECTIVES:

Upon successful completion of this course the student will be able to:

1. Define pollution and discuss its complexity in aquatic ecosystems.
2. Describe and discuss the physical, biological and ecological relationships in lentic versus lotic environments.
3. List and discuss the categories of water pollution and the impact on aquatic systems of various types of pollutants. Demonstrate and explain through a lab experiement, respiration rates, photosynthesis rate and net productivity in a closed vessel.
4. List and discuss the major sources of water pollution.
5. Explain acceptable levels of pollutants, how they are monitored and the significance of abnormal values in natural waters.
6. Outline the procedure for setting up a bioassay and discuss the determination of LC50's, ET50's and toxicity curves. Perform a demonstration bioassay in the lab and explain the significance of the results.
7. Describe the changes in macroinvertebrates, bacteria, algae and fish with increasing eutrophy and explain the use of biological assessment method in monitoring pollution.
8. Demonstrate the use of various biotic and diversity indices to assess water quality.
9. Discuss the objectives and testing procedures of drinking and bathing waters. Perform a standard bacterial plate count in the laboratory.
10. Describe the historical development of the Great Lakes Basin and its significance in leading to today's pollution patterns in the region.
11. Relate the areas of concern in Canadian waters to land-use patterns and industrial activity.
12. Describe the trends in nutrient pollution in the Great Lakes.

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II. STUDENT PERFORMANCE OBJECTIVES:

13. Describe the major exotic species and the impact of their introductions on the Great Lakes ecosystem.
14. Describe the role of atmospheric deposition in Great Lakes pollution.
15. Describe the trends/changes in levels of pollution of toxic substances in the Great Lakes and explain the responses of governments and citizen groups to these.
16. Discuss compliance monitoring and enforcement of environmental laws and regulations to protect water quality in Ontario.
17. Research a topic and make an oral presentation on an environmental contaminant or introduced species.
18. Describe the legal responsibilities/rights of a person working in a field that may affect the environment.
19. Describe the latest trends in environmental risk management.
20. At the end of the course, competently read non-scientific literature on the subject of water pollution.
21. Using appropriate sampling and testing equipment perform and report on a winter lake survey. Explain the significance and probable reasons for the conditions observed. Relate these to the quantity and quality of life present.

III. TOPICS TO BE COVERED:

WEEK

1 * UNIT 1 POLLUTION AND ECOLOGICAL RELATIONSHIPS

- scope and purpose of this course
- pollution and types of pollutants
- ecological relationships
  - ecosystems
  - food chains
- ecological efficiency and energy transfer
- nutrient cycling
- ecological pyramids
- bioaccumulation and biomagnification

LAB#1 RESPIRATION, PHOTOSYNTHESIS AND NET PRODUCTION IN A CLOSED SYSTEM

* Units correspond to those in the Study Guide.

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III. TOPICS TO BE COVERED:

WEEK

2-3 UNIT 2 FRESHWATER SYSTEMS

- natural factors affecting aquatic ecosystems
- characteristics of water
  - polarity
  - dissociation coefficient
  - density
  - specific heat
  - viscosity
  - surface tension
- limnology
- lentic systems
  - aging and types of lakes
  - light penetration and primary production
  - temperature zonation
  - annual oxygen profile
  - carbon dioxide and nutrient levels
- lotic systems
  - fluctuations in flow
  - light penetration and primary production
  - temperature patterns
  - oxygen and carbon dioxide levels
  - nutrient levels

4 TERM TEST #1

4 LAB #2 WINTER LAKE SURVEY

4-6 UNIT 3 TYPES AND SOURCES OF POLLUTANTS

- the complexity of pollution
- plant/animal nutrients
  - nitrogen
  - phosphorous
  - biochemical/chemical oxygen demand
- acids
  - acid deposition
  - acid mine drainage
- heavy metals
  - mercury, lead, cadmium, aluminum

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III. TOPICS TO BE COVERED:

WEEK

4-6 UNIT 3 TYPES AND SOURCES OF POLLUTANTS (continued)

- radioactivity
- petroleum products
- artificial compounds
    - pesticides
    - herbicides
    - fungicides
    - insecticides
    - synthetic industrial contaminants
- thermal pollution
- exotic species
- removal of renewable and non-renewable resources
- physical alteration
- pathogenic materials

7-8 UNIT 4 THE MONITORING OF POLLUTION - PHYSICOCHEMICAL MEASUREMENTS AND TOXICOLOGY

- establishing a basis of comparison
- physicochemical measurements
    - dissolved oxygen
    - temperature
    - total suspended solids
    - total dissolved solids
    - alkalinity
    - hardness
    - hydrogen ion concentration (pH)
    - free carbon dioxide
    - metals
    - nutrients
- water quality indicators
- environmental toxicology
    - degree of toxicity
    - bioassays
- student presentation on a selected pollutant

7 LAB #3 BIOASSAY

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III. TOPICS TO BE COVERED:

WEEK

9-10 UNIT 5 THE MONITORING OF POLLUTION-POPULATIONS AND ECOSYSTEMS

- biomonitoring
- biological assessment of water quality
  - sampling procedures
  - sampling design
  - choice of organisms
    - fish
    - macrophytes
    - algae and blue-greens
    - macro-invertebrates
      - biotic indices
      - diversity indices
    - bacteria

9 LAB #4 STANDARD BACTERIAL PLATE COUNT

10 TERM TEST #2

11-14 UNIT 6 THE GREAT LAKES - SUMMARY OF A CASE STUDY

Additional Reference: Toxic Chemicals in the Great Lakes and Associated Effects

- The Great Lakes Basin
  - historical overview
  - present patterns of land use
  - legacy of pollutants
    - toxic chemicals
    - nutrient pollution
    - metals
    - radioactivity
    - petroleum
    - thermal pollution
    - exotic species
    - physical change
    - pathogens
  - trends in discharge levels
    - agriculture
    - ground water supplies
    - pulp and paper
    - metal processing/finishing
    - chemical industries
    - power generation
    - atmospheric deposition
    - sediment loadings

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11-14 UNIT 6 THE GREAT LAKES - SUMMARY OF A CASE STUDY (cont'd)

- government action and policy
  - early government actions
  - public involvement

11-12 LABS 5-6 STUDENT PRESENTATIONS

15 UNIT 7 INTRODUCTION TO LEGAL RESPONSIBILITIES AND LATEST TRENDS IN WATER POLLUTION

- Legal Responsibilities
  - MOEE
  - legislation and regulations
  - legal responsibilities/rights of employees and citizens
  - environmental risk management
- trends in Water pollution

16 TERM TEST #3

NOTE: SCHEDULE SUBJECT TO CHANGE

IV. EVALUATION METHODS:

Oral Presentation:	10 marks	85% and over	- A+
Participation and lab reports:	40 marks	76%	- A
Term Tests (3):	50 marks	68%	- B
		60%	- C
	100 marks	Under 60%	- R

Students with a final grade of less than 60% will receive an "R" grade. All students must complete the oral presentation and each of the lab reports satisfactorily for a passing grade. Late assignments will receive a deduction of 10% per day late. Most lab reports will be due 10 days after the lab.

Students must complete the first and fifth lab reports on their own. The first report must be satisfactorily done before the student will be permitted to join a group for the 2nd, 3rd and 4th labs. These students who have not done so will be put in a group for experimental purposes but must write up their own reports. In other words each student must demonstrate their individual ability to write up an experiment in proper report format before being permitted to join a group.

ATTENDANCE:

Students are expected to participate actively in the course discussions. Lab attendance is compulsory. Students missing labs without documented reason run the risk of repeating the course.

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V. REQUIRED STUDENT RESOURCES: (from Campus Bookstore)

BOOKS:

1. Water Pollution - Theory, B10123 Study Guide 1996
2. Environment Canada, Department of Fisheries and Oceans and Health and Welfare Canada, 1991. Toxic Chemicals in the Great Lakes and Associated Effects - Synopsis. Government of Canada, Ottawa, 51 p.

OPTIONAL PURCHASES:

Andrews, W.A. (ed.) 1972. A Guide to the Study of Environmental Pollution. Prentice-Hall Inc., Englewood Cliffs. 260 p.

Colborn, Theodora E. et al 1990. Great Lakes, Great Legacy? The Conservation Foundation and the Institute for Research on Public Policy, Washington and Ottawa, 301 p.

Laws, E.A. 1993. Aquatic Pollution: An Introductory Text. 2nd Edition. John Wiley & Sons Inc., Toronto. 611 pages.

Mason, C.F., 1981. Biology of Freshwater Pollution. Longman Group Ltd., New York.

VI. ADDITIONAL RESOURCE MATERIAL AVAILABLE IN THE COLLEGE LIBRARY:

Adams, S. Marshall (ed.) 1990. Biological Indicators of Stress in Fish. American Fisheries Society Symposium 8. AFS. Bethesda, Maryland QL 639.1B55 1990

Alabaster, J.S. and R. Lloyd. 1982 Water Criteria for Freshwater Fish (2nd Edition). Butterworth's Inc., Yarmouth MA.

*American Public Health Association, American Water Works Association, and Water Pollution Control Federation, 1975, Standard Methods for the Examination of Water and Wastewater. 14th ed. Am. Publ. Health Assoc., Washington, D.C.

*American Society for Testing and Materials. 1977. Bacterial Indicators - Health Hazards Associated with Water. ASTM, Phil.

*American Society for Testing and Material. 1977. Aquatic Toxicology and Hazard Evaluation. ASTM, Philadelphia.

Ashworth, W. 1989. The Late, Great Lakes: An Environmental History. Collins Publ., Stockton, California. QH 545.A1 A57 1989

Black, John A. 1977. Water Pollution Technology. Reston Publishing Company, Inc. Virginia.

Brewer, Richard. 1979. Principles of Ecology. Saunders, Philadelphia

Brown, Lester Russell. 1988. State of the Word: A Worldwatch Institution Report on Progress Toward a Sustainable Society. W. W. Norton, New York

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VI. ADDITIONAL RESOURCE MATERIAL - 2

Burns, Noel M. 1985. Erie: The Lake that Survived. Rowman & Allanheld Pub., Totowa, N.J.

*Cairns, John Jr. 1982. Biological Monitoring in Water Pollution. Pergamon.

Cairns, V.W., Hodson, Peter V. and Nriagu, J.O. 1984. Contaminant Effects on Fisheries. John Wiley & Sons, New York.

Chant, D. A. 1970. Pollution Probe. New Press, Toronto.

Colborn, Theodora E. 1990. Great Lakes, Great Legacy? Conservation Foundation and Institute for Research on Public Policy in Canada. Halifax, N.S. TD 181.G73 G73 1990

Delwiche, C.C. 1981. Denitrification, Nitrification and Atmospheric Nitrous Oxide. Wiley, New York

Edmondson, W. T. (1969). Eutrophication in North America. In - Eutrophication - Causes, Consequences, Correctives. pp. 124-49.
tional Academy of Sciences, Washington.

Environment Canada 1986. From Cradle to Grave. A Management Approach to Chemicals. Ministry of Supply & Services Ottawa. TD 196.C45T38 1986

Environmental Protection Agency. 198_. Water Quality Criteria. E.P.A. R3-73-033. Washington, D.C.

*Environmental Studies Board. 1983. Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation. Acid Deposition: Atmospheric Processes in Eastern North America. National Academy Press, Washington, D.C.

Evans, M. S. (ed). 1988. Toxic Contaminants and Ecosystem Health: A Great Lakes Focus. John Wiley and Sons, N.Y. TD180.A38V.21

Freeman, A.M., Robert Haveman and Allen Kneese. 1984. The Economics of Environmental Policy. R.E. Krieger Publishing Co.,
Inc., Florida

*Goldman, Charles R. and A. J. Horne. 1983. Limnology. McGraw-Hill, Toronto.

*Gordon, Malcolm S. 1982. Animal Physiology: Principles and Adaptations (4th edition). MacMillan Publishing Co., Inc. New York.

Gore, James A. 1985. The Restoration of Rivers and Streams: Theories and Experience.
tterworth Publishing Co., Boston

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ADDITIONAL RESOURCE MATERIAL – 3

Hammer, Mark J., 1986. Water and Wastewater Technology. John Wiley and Son Inc., New York.

Heath, Alan G. 1987. Water Pollution and Fish Physiology. CRC Press Inc., Boca Raton, Florida. SH174.H43 1987

*Hoar, W. S. 1983. General and Comparative Physiology (3rd Edition). Prentice–Hall, Inc., New Jersey.

Hoar, W. S., and D.J. Randall, (eds.). 1979. Fish Physiology. Vol.7: Locomotion Academic Press, Inc., London.

*Hoar, W.S., D.J. Randall and J.R. Brett (eds). 1979. Fish Physiology. Vol.8: Bioenergetics and Growth. Academic Press, Inc., London.

Hocutt, Charles H. and Jay R. Stauffer Jr. (eds). 1980. Biological Monitoring of Fish. Lexington Books, Lexington, Mass.

Huntley, R.V. and R.Z. Rivers (eds). 1986. Proceedings of the Acid Rain Evaluation Seminar. Dept. of Fisheries and Oceans, Ottawa.

*Hynes, H. B. N. 1970. The Ecology of Running Waters. University Toronto Press, Toronto.

_____. 1974. The Biology of Polluted Waters. University Toronto Press, Toronto.

Isom, Billy G., S.D. Dennis, J.M. Bates. 1986. Impact of Acid Rain and Deposition on Aquatic Biological System. ASTM, Philadelphia.

Johnson, Raymond E. 1982. Acid Rain/Fisheries: Proceedings of an International Symposium on Acidic Precipitation and Fishery Impacts in Northeastern North America, Cornell University, Ithaca, New York, August 2–5, 1981. American Fisheries Assoc., Bethesda, Md.

Kimball, John W. 1978. Biology. 4th Ed. Addison–Wesley, Don Mils, Toronto.

*Krenkel, P.A. and Parker, F.L. 1973. Nation Symposium on Thermal Pollution Proceedings: Biological Aspects of Thermal Pollution.

*Larkin, P.A. 1974. Freshwater Pollution Canadian Style. McGill–Queen's University Press, Montreal.

*Laws, Edward A. 1993. Aquatic Pollution – An Introductory Text. 2nd Ed. John Wiley and Sons, Toronto.

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ADDITIONAL RESOURCE MATERIAL - 4

Mason, C. F. 1981. Biology of Freshwater Pollution. Longman.

McKane, L. and Kandel J., 1985. Micro-Biology Essentials and Applications. McGraw-Hill Book Co., Toronto.

*McNeely, R. N., V. P. Neimanis and L. Dwyer. 1979. Water Quality Sourcebook Guide to Water Quality Parameters. Environment Canada, Inland Waters Directorate, Water Quality Branch, Ottawa.

McPhee, John 1989. The Control of Nature. Strauss, Farrar and Giroux, N.Y.

Minns, Charles Kenneth 1986. Project Quinte: point-source phosphorus control and ecosystem response in the Bay of Quinte, Lake Ontario. Cdn. Special Publicaiton of Fisheries and Aquatic Sciences. Dept. of Fisheries & Oceans, Ottawa TD227.06 P73

Misener, A. D. and G. Daniel (eds.) 1982. Decisions for the Great Lakes. Great Lakes Tomorrow, Hiram, Ohio.

Morgan, James and Werner Stum. 1981. Aquatic Chemistry: An Introduction Emphasizing hemical Equilibrium in Natural Waters. Wiley, New York

Murty, A.S. 1986. Toxicity of Pesticides to Fish. CRC Press. Bocaratoni, FLA.

*National Research Council of Canada. 1985. TFM and Bayer 73: Lampricides in the Equatic Environment. Pub. No. NRCC 22488, Ottawa.

Owen, O.S. 1985. Natural Resources Conservation - An Ecological Approach. MacMillan, New York

Palmer, C. Mervin. 1980. Algae and Water Pollution. Castle House Publications, Ltd., England.

Pavoni, J.L., 1977. Handbook of Water Quality Management Planning. Van Nostrand Reinhold Co., Litton Educaitonal Publishing Inc., New York.

Pickering, A.D. 1981. Stress and Fish. Academic Press, San Diego, California. QL639.1 S74 1981

Rand, Gary M and Sam, R. 1985. Fundaments of Aquatic Toxicology; Methods and Applications. Hemisphere Publications, Washington.

*Reid, George K. 1961. Ecology of Inland Waters and Estuaries. Van Nostrand Reinhold Co., Toronto.

Ruttner, F. 1963. Fundamentals of Limnology. University of Toronto Press, Toronto.

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ADDITIONAL RESOURCE MATERIAL - 5

Salle, A.J., 1967, Fundamental Principles of Bacteriology. 6th edition, McGraw-Hill Book Co., Toronto.

Schmidtke, N. W. 1986. Toxic Contamination in Large Lakes. World Conference on Large Lakes. Lewis Publishers QH545.W3 W67 1986

Shubert, Elliot L. 1984. Algae as Ecological Indicators. Academic Press, San Diego, California. QK 565.A46 1984

*Smith, R. L. 1974. Ecology and Field Biology. Harper and Row Publishers, New York.

*Sprague, J. B. 1973. The ABC's of pollution bioassay using fish. Biological Methods for the Assessment of Water Quality, ASTM STP 528, American Society for Testing and Materials, 1973, pp. 6-30.
(Reprint available)

Suffet, Irwin H. 1977. Fate of Pollutants in the Air and Water Environments. Wiley, New York.

Tinsley, Ian J. 1979. Chemical Concepts in Pollution Behaviour. Wiley Interscience, New York.

Tourbier, J. and R. W. Pierson, Jr. (eds.). 1976. Biological Control of Water Pollution. University of Pennsylvania Press, Inc., PA.

Tu, Anthony T. (ed). 1982. Survey of Comtemporary Toxicology, Vol. 2. Wiley, New York.

Vallentyne, J. R. 1974. The Algae Bowl. Lakes and Man. Canada Department of the Environment, Fish and Marine Service, Misc. Spec. Pub. No. 22: 186 pp.

Viessman, W.Jr. and M.J. Hammer. 1985 Water Supply and Pollution Control. Harper and Row, Publishers, New York.

Wagner R. H., 1971. Environment and Man. Norton, New York.

Warren, C. E. 1971. Biology and Water Pollution Control. Saunders, Philadelphia.

Wetzel, Robert G. 1983. Limnology (2nd Edition). Saunders. College Publishing, Toronto.

Wetzel, R. G., and G. E. Likens, 1979. Limnological Analyses. Saunders, Philadelphia.

*Wilber, Charles G. 1969. The Biological Aspects of Water Pollution. Charles C. Thomas. Illinois.

*Worf, D. L. 1980. Biological Monitoring for Environmental Effects. Lexington Books, San Diego, CA

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PRESENTATION TOPICS

Students are required to deliver an oral presentation of approximately 10 minutes on a scheduled date. Presentations will include visual aids as well as oral material delivered by each student. Term Test #3 will include information from students' presentations. The following topics are available for presentation:

NOTE: Relate your topic to water pollution and select a topic that is not too general. For example "2,4D" would be a suitable topic but "herbicides" would not because it is too general.

1. Mercury
2. Polychlorinated biphenyls (PCB's)
3. Oil
4. Insecticides (DDT, Dieldrin, Toxaphene, Lindane)
5. Absorbable Organic Halogen (AOX)
6. Waste heat, (thermal pollution)
7. Nuclear pollution (radioactive waste)
8. Dioxin (2,3,7,8-TCDD), Furan (2, 3, 7, 8 - TCDF)
9. Herbicides (2,4D; Glyphosphate; Hexazinone)
10. Detergents
11. Acid rain
12. Mirex
13. Water-borne pathogens
14. Food Processing Wastes
15. Alkylated lead
16. Acid mine drainage

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17. Hexachlorobenzene (HCB)
18. Zebra mussels
19. Polynuclear aromatic hydrocarbons (PAHs)
20. Sea lamprey
21. Purple loosestrife

NOTE: INCLUDE IN EACH PRESENTATION:

1. Description of the pollutant.
2. Sources of the pollutant (natural, man-caused).
3. The effect of the pollutant on the aquatic environment (both biotic and abiotic).
4. The water quality guidelines (standards) for the pollutant.
5. Any pertinent incidents* involving the pollutant.
6. Clean up/Controls (if applicable).

*Canadian incidents if possible

Each student is responsible for producing a typed abstract (summary) of information presented, as well as a list of references used. This is to be given to your instructor at least 1 day in advance of your presentation day.

Copies of each presentation summary will be produced (by instructor) for all students, and given to you for distribution to classmates prior to presentation.

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REPORT WRITING

All lab reports should include the following components:

1. Title Page with appropriate information.

2. Introduction/Purpose - a brief statement outlining the background and intent of the exercise. Objectives may be itemized, e.g.

   a) to determine LC_{50} for zinc using rainbow trout
   b) to investigate the relationship between water temperature, pH, alkalinity and the toxicity of zinc to rainbow trout

3. Method/Procedure - a brief outline of how the exercise was conducted. In some instances "Refer to manual" with a few extra notes and comments will suffice. Be sure to include a description of any changes in procedure from that outlined in this manual.

4. Results - a presentation of results, and only results, in an organized format, i.e., TABLE FORMAT. There should be no sentences, no paragraphs--table and figures (graphs) only. Be sure all tables and figures are entitled and numbered and include proper units in the headings. Use your own table format showing raw observations and calculated results.

Table 1 - Physical Characteristics of the Great Lakes

Lake	Area (km^2)	Area of Drainage Basin (km^2)	Average Depth (m)	Volume (km3)	Retention time (yr)
Superior	82,100	127,700	147	12,100	191
Michigan	57,800	118,000	85	4,920	99
Huron	59,600	134,000	59	3,540	22
Erie	25,700	78,000	19	484	2.6
Ontario	18,960	64,030	86	1,640	6

5. Calculations - one example of each different calculation used in presenting the results should appear in this section. Subsequent work using the same calculations should appear in the Appendix. Hence, with the exception of one example calculation, all calculations used to generate data in tables must be shown in the Appendix.These rough calculations in the appendix should be in your own handwriting and not typed. They are there to show that you have checked the calculation yourself.

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6. Discussion and Conclusions - results are interpreted and discussed. Carefully observe data to determine trends and relationships among all parameters measured.

When discussing an experiment, the writer interprets the results (i.e. explains why these results were obtained). This can be done by confirming your results by referring to what other authors have found or by explaining why the results do not follow what was expected, perhaps by speculating on possible sources of error.

Are apparent relationships consistent with established relationships present in literature? In this section, you are responsible for conducting a literature search to compare your findings with that of established authors.

Be sure to refer to your data using table and figure numbers - e.g., a direct linear relationship between white sucker weight and fork length is apparent in Figure 2. This relationship agrees well with that established for white sucker by Smith (1982), Jones (1974) and Brown (1971).

If your findings are not consistent with other studies or theories, offer some explanation for the deviation.

e.g., According to Saunders (1972), the principle component of lake trout stomach samples (n=785) in Round Lake prior to 1965 was lake herring (Coregonus artedii) at 72% by volume. Data from this study, however, indicates rainbow smelt (Osmerus mordax) as the dominant food item in 525 lake trout sampled, averaging 97% of stomach contents by volume (Figures 1 and 2). This change in forage species preference is attributed to the introduction of rainbow smelt in 1969 (Wilson, 1971).

All **questions** posed at the end of a lab exercise should be answered in this section.

N.B. There are several acceptable methods of citing references and referring to your data within the text of your report. **Footnotes are not acceptable. Quotes are not acceptable.**

N.B. Scientific names of species should appear in brackets only **once** after the first time the common name appears in the text.

7. Conclusions should clearly state what you have learned or observed and why. They are usually itemized

8. Sources of Error - itemize all conceivable sources of error.

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9. References Cited

- presented on a separate page at end of report,
- all citations in text of report must be listed alphabetically in this section and conversely all references listed in this section must be cited in the text of the report.

e.g.

1) For paper presented in a journal:

Mason, C. F. and R. J. Bryant. 1974. The structure and diversity of the animal communities in a broad land reed-swamp, J. Zool., 172, 289-309. issue no. page reference

2) For book references:

Hynes, H. B. N., 1970. The Ecology of Running Waters, Liverpool University Press, Liverpool.

3) For paper/chapter presented in publication:

Chapman, D.W. 1978. Production fish populations.
In Ecology of Freshwater Fish Production (S. D. Gerking, ed.). Blackwell. Oxford.

See previous list of references for other examples.

10. Appendix

- present calculations for all values appearing in tables.
- present raw data to back up summarizing results
- the data should not by typed but done by hand.

MAJOR DO'S AND DON'TS

1. Don't use first person in report text, i.e., I, we, our.

2. Do refer to tables and figures by number. Be sure all tables and figures in Results are numbered and entitled.

3. Use correct citation of references.

4. Do not use quotes.

Scientific names of species need only appear once in text of report. They are placed in brackets and underlined after the common name of the species appears for the first time.

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REPORT MARKING - ONE REPORT SUBMITTED PER STUDENT

	SECTION	MARK	MARKING BASED ON
1.	Introduction/ Purpose	10	Conciseness; completeness
2.	Method	5-10	Conciseness; completeness
3.	Results	20	Organization; labels, numbers on tables, figures; neatness; correctness
4.	Calculations and Appendices	10	Correctness, completeness
5.	Discussion and Conclusions	40 (or 45 if method not significant)	Conciseness; organization; reference material used and cited; completeness
6.	Sources of Error and References cited	10	Completeness and accuracy
		TOTAL 100	

N.B. Ten percent (10%) deducted per day for late reports.

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ACRONYMS

ADI	Acceptable Daily Intake: The dose that is anticipated to be without risk to humans when taken daily. It is not assumed that this dose guarantees absolute safety. The determination of the ADI is often based on the application of laboratory animal toxicity data concerning chronic (long-term) doses to the environmental doses to which humans are exposed.
AOC(s)	Areas of Concern: Geographic locations recognized by the International Joint Commission where water, sediment or fish quality are degraded, and the objectives of the Great Lakes Water Quality Agreement of local environmental standards are not being achieved.
BaP	Benzo-a-pyrene
BAT	Best Available Technology/Treatment
BATEA	Best Available Technology/Treatment Economically Achievable
BCF	Bioconcentration Factor; the ratio of the concentration of a particular substance in an organism to concentration in water.
BCT	Best Conventional Technology/Treatment
BEJ	Best Engineering Judgement
BHC	Benzene Hexachloride or Hexachlorocyclohexane. There are three isomers; alpha, beta, and gamma. Gamma-BHC is the insecticide lindane.
BOD	Biochemical Oxygen Demand: The amount of dissolved oxygen consumed during the decomposition of organic nutrients in water during a controlled period and temperature.
BMP	Best Management Practices
BPAC	Binational Public Advisory Committee
BPJ	Best Professional Judgement
BPT	Best Practical Treatment

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CANUSLAK	(related to joint spill agreement)
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COA	Canada-Ontario Agreement Respecting Water Quality in the Great Lakes
COD	Chemical Oxygen Demand: The amount of oxygen required to oxidize completely by chemical reagents the oxidizable compounds in an environmental sample.
CofA	Certificate of Approval
CMR	Critical Materials Register
CSO	Combined Sewer Overflow; combined storm and sanitary sewer systems.
CWA	Clean Water Act
DCB	Dichlorobenzene
DDD	A natural breakdown product of DDT.
DDE	Dichlorodiphenyldichloroethylene. A natural breakdown product DDT.
DDT	Dichlorodiphenyltrichloroethane: A widely used, very persistent chlorinated pesticide (now banned from production and use in many countries).
DFO	Department of Fisheries and Oceans (Canada)
DMR	Discharge Monitoring Report
DOA	Department of Agriculture (Canada)
DOE/EC	Department of Environment/Environment Canada

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EC-50	Effective concentration of a substance producing a defined response in 50% of a test population. The higher the EC-50, the less effective the substance is because it requires more material to elicit the desired response.
EMS	Enforcement Management System
EP	Extraction Procedure
EP/OR	Environmental Protection, Ontario Region, Environment Canada
EPA	United States Environmental Protection Agency
FDA	Food and Drug Administration
GLISP	Great Lakes International Surveillance Plan. It provides monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GlWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.
GLWQA	Great Lakes Water Quality Agreement
HCB	Hexachlorobenzene
HCBD	Hexachlorobutadiene
HCE	Hexachloroethane
HWC	Health and Welfare Canada
IJC	International Joint Commission: A binational organization established in 1909 by the Boundary Waters Treaty. Through the IJC, Canada and the United States cooperatively resolve problems along their common border, including water and air pollution, lake levels, power generation and other issues of mutual concern.
IPP	Industrial Pretreatment Program

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LAMP	Lakewide Management Plan
LC_{50}	Lethal concentration (by volume) of a toxicant or effluent which is lethal to 50% of the test organism over a specified time period. The higher the LC_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
LD_{50}	Lethal dose which is lethal to 50% of the test organism over a specified time period. The higher the LD_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDNR	Michigan Department of Natural Resources
MDPH	Michigan Department of Public Health
MERA	Michigan Environmental Response Act
MISA	Municipal-Industrial Strategy for Abatement: The principal goal of this program is the virtual elimination of toxics discharged from point sources to surface waters in Ontario.
MGD	Million Gallons Per Day
MSP	Michigan State Police
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System; a permit system limiting municipal and industrial discharges, administered by U.S.EPA and the states.
NPDWR	National Primary Drinking Water Regulation
NPS	Nonpoint Source
NSPS	New Source Performance Standards
NTU	Nephelometric Turbidity Unit

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OCS	Octachlorostyrene
OMNR	Ontario Ministry of Natural Resources
OMOE	Ontario Ministry of the Environment/Environment Ontario
PAH	Polynuclear Aromatic Hydrocarbons, also known as Polycyclic Aromatic Hydrocarbons or Polyaromatic Hydrocarbons. Aromatic Hydrocarbons composed of at least 2 fused benzene rings, many of which are potential or suspected carcinogens.
PBB	Polybromated biphenyl; used primarily as a fire retardant.
PCB	Polychlorinated biphenyls; a class of persistent organic chemicals with a potential to bioaccumulate and suspected carcinogens; a family of chemically inert compounds, having the properties of low flammability and volatility and high electric insulation quality. Past applications include use as hydraulic fluids, heat exchange and dielectric fluids; plasticizers for plastics.
PEAS	Pollution Emergency Alert System
pH	The negative power to the base 10 of the hydrogen ion concentration. A measure of acidity or alkalinity of water on a scale from 0 to 14; 7 is neutral; low numbers indicate acidic conditions, high numbers, alkaline.
PL	Public Law
POTW	Publicly Owned Treatment Works
PTS	Persistent Toxic Substance: Any toxic substance with a half-life in water of greater than eight weeks.
PWQO	Provincial Water Quality Objectives
QCB	Pentachlorobenzene
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act

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SDWA	Safe Drinking Water Act
SPCC	Spill Prevention and Control Countermeasure
SPDES	State Pollutant Discharge Elimination System; a state administered permit limiting municipal and industrial dischargers.
STP	Sewage Treatment Plant
TCB	Trichlorobenzene
TCDD	Tetrachlorodiebenzo-p-dioxins
TCDF	Tetrachlorodibenzofurans
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TOTAL DDT	Sum of DDT isomers and metabolites
TTBEL	Treatment Technology-Based Effluent Limitation
UGLCCS	Upper Great Lakes Connecting Channels Study
U.S.EPA	United States Environmental Protection Agency
WHO	World Health Organization
WPCP	Water Pollution Control Plant
WQBEL	Water Quality Based Effluent limits
WQS	Water Quality Standards
WRC	Water Resources Commission
WTP	Water Treatment Plant (for drinking water)
WWTP	Waste Water Treatment Plan

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TERMINOLOGY

ABSORPTION Penetration of one substance into the body of another.

ACCLIMATION Physiological and behavioural adjustments of an organism in response to a change in environment. See also Adaptation.

ACCIMATIZATION Acclimation of a particular species over several generation in response to marked environmental changes.

ACCUMULATION Storage and concentration of a chemical in tissue to an amount higher than intake of the chemical. May also apply to the storage and concentration of a chemical in aquatic sediments to levels above those that are present in the water column.

ACUTE Involving a stimulus severe enough to rapidly induce a response; in bioassay tests, a response observed within 96 hours is typically considered an acute one.

ACUTE TOXICITY Mortality that is produced within a short period of time, usually 24 to 96 hours.

ADAPTATION Change in the structure forms or habits of an organism to better fit changed or existing environmental conditions. See also Acclimation.

ADSORPTION The taking up of one substance at the surface of another.

AEROBIC The condition associated with the presence of free oxygen in the environment.

ALGA(E) Simple one celled or many celled micro-organisms, usually free floating, capable of carrying on photosynthesis in aquatic ecosystems.

ALGICIDE A specific chemical highly toxic to algae. Algicides are often applied to water to control nuisance algal blooms.

ALKALINITY A measurement of acid neutralization or buffering capability of a solution (See pH).

AMBIENT Pertaining to the existing/surrounding environment and its components.

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AMBIENT WATER	The water column or surface water as opposed to groundwater or sediments.
AMPULES	A sealed glass container of known concentration of a substance.
ANADROMOUS	Species which migrate from salt water to fresh water to breed.
ANAEROBE	An organism for whose life processes a complete or nearly complete absence of oxygen is essential.
ANOXIA	The absence of oxygen necessary for sustaining most life. In aquatic ecosystems this refers to the absence of dissolved oxygen in water.
ANTAGONISM	Reduction of the effect of one substance because of the introduction or presence of another substance; e.g. one substance may hinder, or counteract, the toxic influence of another. See also Synergism.
APPLICATION FACTOR	A factor applied to a short-term or acute toxicity test to estimate a concentration of waste that would be safe in a receiving water.
AQUATIC	Living in water.
ASSIMILATION	The absorption, transfer and incorporation of substances (e.g. nutrients by and organism or ecosystem)
ASSIMILATIVE CAPACITY	The ability of a waterbody to transform and/or incorporate substance (e.g. nutrients) by the ecosystem, such that the water quality does not degrade below a predetermined level.
BENTHIC	Of or living on or in the bottom of a water body; benthic region, benthos.
BENTHOS	Bottom dwelling organisms, the benthos comprise: 1) sessile animals such as sponges, some the of the worms and many attached algae; 2) creeping forms such as snails and flatworms, and 3) burrowing forms which include most clams and worms, mayflies and midges.
BIOACCUMULATION	Uptake and retention of environmental substances by an organism from both its environment (i.e. directly from the water) and its food.

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BIOASSAY	A determination of the concentration or dose of a given material necessary to affect a test organism under stated conditions.
BIOCONCENTRATION	The ability of an organism to concentrate substances within its body at concentrations greater than in its surrounding environment or food.
BIOCONCENTRATION FACTOR	The ratio of the measured residue within an organism compared to the residue of the substance in the ambient air, water or soil environment of the organism.
BIOLOGICAL MAGNIFICATION	The concentration of a chemical up the food chain.
BIOMASS	Total dry weight of all organisms in a given area or volume.
BIOMONITORING	The use of organisms to test the toxic effects of substances in effluent discharges as well as the chronic toxicity of low level pollutants in the ambient aquatic environment.
BIOTA	Species of all the plants and animals occurring within a certain area or region.
ARCINOGEN	Cancer causing chemicals or substances.
CHIRONOMID	Any of a family of midges that lack piercing mouth parts.
CHRONIC	Involving a stimulus that lingers or continues for a long period of time, often one/tenth of the life span or more.
CHRONIC TOXICITY	Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal; e.g. inhibits reproduction or growth. These effects are reflected by changes in the productivity and population structure of the community. See also Acute Toxicity.
COMMUNITY	Group of populations of plants and animals in a given place; ecological unit used in a broad sense to include groups of various sizes and degrees of integration.

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CONGENER	A member of the same taxonomic genus as another plant or animal: Also a different configuration or mixture of a specific chemical usually having radical groups attached in numerous potential locations.
CONTAMINANT	A substance foreign to a natural system or present at unnatural concentrations.
CONTAMINATION	The introduction of pathogenic or undesirable micro-organisms, toxic and other deleterious substances which renders potable water, air, soils, or biota unfit for use.
CONTROL ORDER/ REQUIREMENT AND DIRECTION ORDER	Enforceable orders in Ontario.
CONVENTIONAL POLLUTANT	A term which includes nutrients, substances which pollutant consume oxygen upon decomposition, materials which produce an oily sludge deposit, and bacteria. Conventional pollutants include phosphorous, nitrogen, chemical oxygen demand, biochemical oxygen demand, oil and grease, volatile solids, and total and fecal coliform, chlorides, etc.
CRITERIA	Numerical limits of pollutants established to protect specific water uses.
CRITERION, WATER QUALITY	A designated concentration of a constituent based on scientific judgments, that, when not exceeded will protect an organism, a community or organisms, or a prescribed water use with an adequate degree of safety.
CRITICAL LEVEL	See Threshold.
CRITICAL RANGE	In bioassays the range of magnitude of any factor between the maximum level of concentration at which no organisms responds (frequently mortality) to the minimum level or concentration at which all organisms respond under a given set of conditions.
CUMULATIVE	Brought about or increased in strength by successive additions.
CUMULATIVE ACTION	Increasingly severe effects due to either storage or concentration of a substance within the organism.

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DENSITY	Number of individuals in relation to the space.
DETRITUS	A product of disintegration, defecation, destruction, or wearing away.
DIATOM	Any of a class of minute planktonic unicellular or colonial algae with silicified skeletons.
DIOXIN	A group of approximately 75 chemicals of the chlorinated dibenzodioxin family, including 2, 3, 7, 8 – tetrachlorodibenzo-para-dioxin (2, 3, 7, 8 – TCDD) which is generally considered the most toxic form.
DISSOLVED OXYGEN	The amount of oxygen dissolved in water.
DRAINAGE BASIN	A waterway and the land area drained by it.
DREDGE SPOILS	The material removed from the river, lake, or harbor bottom during dredging operations.
DREDGING GUIDELINES	Procedural directions designed to minimize the adverse effects of shoreline and underwater excavation with primary emphasis on the concentrations of toxic materials within the dredge spoils.
ECOSYSTEM	The interacting complex of living organisms and their non-living environment; the biotic community and its abiotic environment.
EFFLUENT	Contaminated waters discharged from facilities to either wastewater sewers or to surface waters.
ENVIRONMENT	All the biotic and abiotic factors that actually affect an individual organism at any point in its life cycle.
EPHEMERAL	A plant that grows, flowers, and dies in a few days.
EPHEMERA	Invertebrates (mayflies) that live as adults only a very short time.
EPILIMNION	The warm, upper layer of water in a lake that occurs during summer stratification.

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EROSION — The wearing away and transportation of soils, rocks and dissolved minerals from the land surface, shorelines, or river bottom by rainfall, running water, wave and current action.

EUTROPHICATION — The process of nutrient enrichment that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process so it can be a cultural process accelerated by an increase of nutrient loading to a waterbody by human activity.

EXOTIC SPECIES — Species that are not native to the Great Lakes and have been intentionally or inadvertently introduced into the system.

FACULTATIVE — Exhibiting a broad life-style which allows it to survive under a broad range of environmental conditions.

FOODCHAIN — The process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels; the dependence for food of organisms upon others in a series, beginning with plants and ending with the largest carnivores.

GOAL — An aim or objective towards which to strive; it may represent an ideal condition that is difficult, if not impossible to attain economically.

GREAT LAKES BASIN ECOSYSTEM — The interacting components of air, land, water and living organisms, including man, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States (from article 1 of the 1978 GLWQ Agreement).

GREAT LAKES WATER QUALITY AGREEMENT (GLWQA) — A joint agreement between Canada and the United States which commits the two countries to develop and implement a plan to restore and maintain the many desirable uses of the waters in the Great Lakes Basin. Originally signed in 1978, the Agreement was amended in 1987.

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GROUNDWATER Water entrained and flowing below the surface which may supply water to wells and springs.

GUIDELINES Any suggestion or rule that guides or directs; i.e. suggested criteria for programs or effluent limitations.

HALF-LIFE The period of time in which a substance loses half of its active characteristics (used specifically in radiological work); the amount of time required for the concentration of a pollutant to decrease to half of the original value through natural decay or decomposition.

HAZARDOUS SUBSTANCES Chemicals considered to be a threat to man in the environment, including substances which (individually) or in combination with other substances) can cause death, disease (including cancer), behavioural abnormalities, genetic mutations, physiological malfunctions or physical deformities.

HYDROLOGIC CYCLE The natural cycle of water on earth, including precipitation as rain and snow, runoff form land, storage in groundwaters, lakes, streams, and oceans, and evaporation and transpiration (from plants) into the atmosphere to complete the cycle.

HYPOLIMNION The cold, dense, lower layer of water in a lake that occurs during summer stratification.

ICHTHYOLOGY A branch of zoology that deals with fishes.

INCIPIENT LC_{50} The level of the toxicant which is lethal for 50% of individuals exposed for periods sufficiently long that acute lethal action has ceased. Synonymous with lethal threshold concentration.

INCIPIENT LETHAL LEVEL That concentration of a contaminant beyond which an organism could no longer survive for an indefinite period of time.

INSECTICIDE Substances or a mixture of substances intended to prevent, destroy or repel insects.

LACUSTRINE Formed in, or growing in lakes.

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LEACHATE — Materials dissolved or suspended in water that percolate through solids such as soils, solid wastes and rock layers.

LETHAL — Involving a stimulus or effect directly causing death.

LIPOPHILIC — Having an affinity for fats or other lipids.

LITTORAL — Productive shallow water zone of lakes, rivers or the seas, with light penetration to the bottom; often occupied by rooted aquatic plants.

LOADINGS — Total mass of pollutant to a water body over a specified time; e.g. tones per year of phosphorus.

MACROPHYTE — A member of the macroscopic plant life (i.e. larger than algae) especially of a body of water.

MACROZOOBENTHOS — The distribution of macrozoobenthos in an aquatic ecosystem is often used as an index of the impacts of contamination on the system.

MALIGNANT — Resistent to treatment, occurring in severe form and frequently fatal.

MASS BALANCE — An approach to evaluating the sources, transport and fate of contaminants entering a water system, as well as their effects on water quality. In a mass balance budget, the amounts of a contaminant entering the system less the amount leaving the system. If inputs exceed outputs, pollutants are accumulating and contaminant levels are rising. Once a mass balance budget has been established for a pollutant of concern, the long-term effects on water quality can be simulated by mathematical modelling and priorities can be set for research and remedial action.

MUTAGEN — Any substance or effect which alters genetic characteristics or produces an inheritable change in the genetic material.

MUTAGENICITY — The ability of a substance to induce a detectable change in genetic material which can be transmitted to progeny, or from one cell generation to another within an individual.

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NONPOINT SOURCE	Source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct, identifiable sources.
NUTRIENT	A chemical that is an essential raw material for the growth and development of organisms.
ORGANOCHLORINE	Chlorinated hydrocarbon pesticides.
PATHOGEN	A disease causing agent such as bacteria, viruses, and parasites.
PERIPHYTON	Organisms that live attached to underwater surfaces.
PERSISTENT TOXIC SUBSTANCES	Any toxic substance with a half-life in water and greater than eight weeks.
PESTICIDE	Any substance used to kill plants, insects, algae, fungi or other organisms; includes herbicides, insecticides, algicides, fungicides.
HENOLICS	Any of a number of compounds with the basic structure of phenol but with substitutions made onto this structure. Phenolics are produced during the coking of coal, the distillation of wood, the operation of gas works and oil refineries, from human and animal wastes, and the microbiological decomposition of organic matter.
PHOTOSYNTHESIS	A process occurring in the cells of green plants and some micro-organisms in which solar energy is transformed into stored chemical energy.
PHYTOPHAGOUS	Feeding on plants.
PHYTOPLANKTON	Minute, microscopic aquatic vegetative life; plant portion of the plankton; the plant community in marine and freshwater situations which floats free in the water and contains many species of algae and diatoms.
POINT SOURCE	A source of pollution that is distinct and identifiable, such as an outfall pipe from an industrial plant.

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POLLUTION (WATER)	Anything causing or inducing objectional conditions in any watercourse and affecting adversely the environment and use or uses to which the water thereof may be put.
POTABLE WATER	Water suitable, on the basis of both health and aesthetic considerations, for drinking or cooking purposes.
PRECAMBRIAN	The earliest era of geological history.
PRIMARY TREATMENT	Mechanical removal of floating or settable solids from wastewater.
PUBLIC	Any person, group, or organization.
RADIONUCLIDE	A radioactive material.
RAPTORS	Birds of prey.
RAW WATER	Surface or groundwater that is available as a source of drinking water, but has not received any treatment.
RESUSPENSION	(of sediment) The remixing of sediment particles and pollutants back into the water by storms, currents, organisms and human activities such as dredging.
RIPARIAN	Living or located on the bank of a natural watercourse.
SCAUP	A diving duck.
SECONDARY TREATMENT	Primary treatment plus bacterial action to remove organic parts of the waste.
SEDIMENT	The fines or soils on the bottom of the rive or lake.
SEICHE	An oscillation in water level form one end of a lake to another due to wind or atmospheric pressure. Most dramatic after an intense but local weather disturbance passes over one end of a large lake.

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SELENIUM	A nonmetallic element that chemically resembles sulfur and is obtained chiefly as a by-product in copper refining, and occurs in allotropic forms of which a gray stable form varies in electrical conductivity with the intensity of its illumination and is used in electronic devices.
SESSILE	An animal that is attached to an object or is fixed in place (e.g. barnacles).
SIGMOID CURVE	S-shaped curve (e.g. the logistic curve)
SLUDGE	The solids removed from waste treatment facilities.
SOLUBILITY	Capability of being dissolved.
STABILITY	Absence of fluctuations in population; ability to withstand perturbations without large changes in composition.
STRATIFICATION	(or layering) The tendency in deep lakes for distinct layers of water to form as a result of vertical change in temperature and therefore, in the density of water.
SUBACUTE	Involving a stimulus below the level that causes death.
SUBCHRONIC	Effects from short-term multiple dosage or exposure; usually means exposure for less than three months.
SUB-LETHAL	Involving a stimulus below the level that causes death.
SUSPENDED SEDIMENTS	Particulate matter suspended in water.
SYNERGISM	The joint action of two or more substances is greater than the sum of the action of each of the individual substances. The improvement in performance is achieved because two agents are working together. See also Antagonism.

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SYNERGISTIC — Interactions of two or more substances or organisms producing a result such that the total effect is greater than the sum of the individual effects.

SYNTHESIS — The production of a substance by the union of elements or simpler compounds.

TAXA — A group of similar organisms.

TAXONOMICALLY — To identify an organism by its structure.

TERATOGEN — A substance that increases the incidence of birth defects.

TERATOGENICITY — The ability of a substance to produce irreversible birth defects, or anatomical or functional disorders as a result of an effect on the developing embryo.

THERMOCLINE — A layer of water in lakes separating cool hypolimnion (lower layer) from the warm epilimnion (surface layer).

THRESHHOLD — The chemical concentration or dose that must be reached before a given reaction occurs.

TOXIC SUBSTANCE — As defined in the Great Lakes Agreement, any substance that adversely affects the health or well being of any living organism.

TOXICITY — Quality, state or degree of the harmful effect resulting from alteration of an environmental factor.

TRANSLOCATION — Movement of chemicals within a plant or animal; usually refers to systemic herbicides and insecticides that are moved from the point of contact on the plant to other regions of the plant.

TROPHIC ACCUMULATION — Passing of a substance through a food chain such that each organism retains all or a portion of the amount in its food and eventually acquires a higher concentration in its flesh than in its food. See also Biological Magnification.

TROPHIC LEVEL — Functional classification of organisms in a community according to feeding relationships; the first trophic level includes green plants, the second level includes herbivores; etc.

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TROPHIC STATUS — A measure of the biological productivity in a body of water. Aquatic ecosystems are characterized as oligotrophic (low productivity), mesotrophic (medium productivity) or eutrophic (high productivity).

TUBIFICID — Of aquatic oligochaete or sludge worms which is tolerant to organically enriched waters.

TURBIDITY — Deficient in clarity of water.

WATER QUALITY OBJECTIVES — Under the Great Lakes Water Quality Agreement, goals set by the Governments of the United States Agreement, goals set by the Governments of the United States and Canada for protection of the uses of the Great Lakes.

WATER QUALITY STANDARD — A criterion or objective for a specific water use standard that is incorporated into enforceable regulations.

WIND SET-UP — A local rise in water levels caused by winds pushing water to one side of a lake. (See Seiche)

ZOOPLANKTON — Microscopic and near microscopic aquatic animals including protozoans, rotifers and crustaceans.

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ppm? ppb? ppt?

"Parts per million", "parts per billion", and even "parts per trillion" have gradually worked their way into commonly accepted usage as expressions of air and water pollutant measurements. But who, other than the experts, really knows what these terms mean? What are the terms of reference? How small is small?

Research chemists recently undertook the challenge of delineating some readily understandable terms of reference. The assignment clearly sparked the group's collective imagination, as the list of comparisons they produced shows.

One part per million:

= one inch in 16 miles;
= one minute in two years;
= one ounce in 31 tons of potato chips;
= one bad apple in 2,000 barrels.

One part per billion:

= one inch in 16,000 miles;
= one second in 32 years;
= a pinch of salt in 10 tons of potato chips;
= one bad apple in 2 million barrels.

One part per trillion:

= one hairsbreadth (blond specified) in a trip around the world;
= one second in 320 centuries;
= one pinch of salt in 10,000 tons of potato chips;
= a drop of vermouth in 250,000 hogsheads of gin; or, getting even more specific;
= one flea in 360 million elephants.

At what point are chemicals perceived? Table salt in water becomes somewhat unpalatable at one part per thousand; swimmers can detect chlorine in a pool at one part per million; and sensitive noses can detect the odour of fuel oil at one part per billion. One part per trillion of anything is not detectable without the use of advanced and costly analytical equipment.

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COMMONLY USED TERMINOLOGY

Measurements & Units

mg/l	=	milligram per litre	=	part per million (ppm)
ug/l	=	microgram per litre	=	part per billion (ppb)
ng/l	=	nanogram per litre	=	part per trillion (ppt)
pg/l	=	picograms per litre	=	part per quadrillion (ppq)
mg/kg	=	milligram per kilogram	=	part per million (ppm)
ug/kg	=	microgram per kilogram	=	part per billion (ppb)
ng/kg	=	nanogram per kilogram	=	part per trillion (ppt)
L/d	=	litre per day		
m^3/d	=	cubic metres per day		
kg/ann (kg/yr)	=	kilograms per year		
t/ann (kg/yr)	=	tonnes per year		
uS/cm	=	microsiemens per centimetre (conductivity)		
mgd	=	millions of gallons per day		
cfs	=	cubic feet per second		