Environmental Water Quality
BAE 452/552

Session 8

Water Quality Criteria, Quality Assurance, Water Quality Monitoring

1

Where are we?

Receiving Water Impacts:

- Physical, chemical, biological characteristics of water
- The oxygen problem
- Eutrophication
- Water quality criteria/standards←
- Water quality monitoring←

2

Water Quality Criteria

- http://www.epa.gov/waterscience/standards
- Then click on 'what are water quality standards?' then 'water quality criteria'

Aquatic life	Nutrient
Human health	Microbial
Biological	Wetland

3

Terminology

- Acute toxicity: exposure of organism to a compound or a mixture of compounds will result in crisis shortly after exposure
- Chronic toxicity: exposure will have a sublethal damaging impact on the organism occurring over a longer period of time up to entire life cycle

4

Terminology

- Lethal toxicity: results in death of organism
- Sublethal toxicity: damaging, but will not result in death
- Cumulative toxicity: effect brought about, or increase effect by successive exposure

5

Quality Assurance

Quality Assurance (QA): set of operating principles that will produce data of known and defensible quality

QA consists of two components:

1. Quality Control
2. Quality Assessment

NOTE: handout posted on web site!

6

Quality Control

1. Certification of operator competency
2. Recovery of known additions
3. Analysis of externally supplied standards
4. Analysis of reagent blanks
5. Calibration with standards
6. Analysis of duplicates
7. Control charts

7

Quality Assessment

Assumptions:

1. All glassware, reagents, instruments meet specifications for quality control
2. A single approved methodology is employed
3. All analytical protocols are performed under daily routine conditions

Includes internal and external control measures

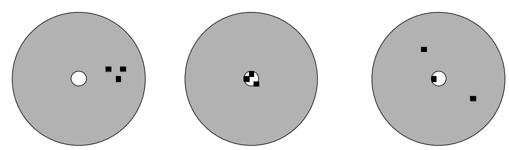
8

Indicators of Data Quality

Precision
Accuracy
Representativeness
Comparability
Completeness
Performance audits
Corrective actions

9

Precision & Accuracy



Good precision Poor accuracy	Good precision Good accuracy	Poor precision Poor accuracy

10

Precision

- Ability to reproduce similar results using replicate observations
- Use actual water samples which cover a range of concentrations and a variety of interfering materials
- A good method of quantification is the determination of the standard deviation

11

Precision (cont'd)

Determination of the standard deviation:

1. 4 separate concentration levels [low [1], intermediate [2], and high [1])
2. 7 replicates for each concentration
3. Two hours of normal lab operations
4. Order: high, low, intermediate (2x)
5. Precision statement should include a range of standard deviations over the range of concentration values

12

Precision (cont'd)

- Standard deviation is √variance:

$$S^2 = \frac{\sum (x - X)^2}{n - 1}$$

where x is observation, X is arithmetic mean, n is number of observations

13

Precision: example

	Source A	Source B	Source C	Source D
Mean	0.059	0.105	0.482	0.621
Standard deviation	0.004	0.005	0.004	0.004

"In a single laboratory, using surface water samples at concentrations of 0.06 to 0.62 mg/L as phosphate-P, the standard deviation was ±0.004"

In this example: very good precision

14

Accuracy

- The degree of difference between observed and known, or actual, or accepted values
- Use spiked samples
- Should be performed on actual water samples, preferably the same as those used for precision determinations
- "correctness of a measurement"

15

Accuracy (cont'd)

- T = X ± E

where T is true value, X is value obtained experimentally, and E is error

- If T = X, measurement is accurate
- If known or true value exists, %recovery or %error can be determined

16

Accuracy (cont'd)

$$\%Recovery = \frac{Experimental \cdot value}{Accepted \cdot value} x100$$

$$\%Error = \frac{Experimental \cdot value - Accepted \cdot value}{Accepted \cdot value} x100$$

where experimental value is from recent assay, and accepted value from standard of known concentration

17

Accuracy (cont'd)

If no accepted value is available:

$$\%Difference = \frac{|\, 1^{st}\, Exp.value - 2^{nd}\, Exp.value \,|}{Average \cdot value} x100$$

18

Accuracy (cont'd)

Steps in determining accuracy:

1. Known amounts should be added to actual samples (spiked samples), 4 separate concentration levels [low [1], intermediate [2], and high [1]), double low concentration, bring intermediate to 75% of high concentration
2. 7 replicates for each concentration
3. Accuracy statement should be reported as the %recovery at the final concentration of the spiked sample. %recovery should be mean of seven replicate results

19

Accuracy: example

	Source A (0.059, added 0.06 mg/L)	Source C (0.482, added 0.30 mg/L)
Mean	0.107	0.740
True value	0.059+0.060=0.119	0.482+0.300=0.782
%Recovery	(0.107/0.119)x100=90	(0.740/0.782)x100=95

"In a single laboratory, using surface water samples at concentrations of 0.110 to 0.740 mg/L as phosphate-P, recoveries were 90% and 95%, respectively"

20

Field Quality Assurance

- Field equipment
- Field logs
- Field quality control samples (field duplicate, trip blank, sample blank, filtration blank)
- Sample custody procedures
- Sample collection and preservation

21

Sample Collection and Preservation

- Volume requirements
- Container type (plastic or glass)
- Preservative (acidification, refrigeration, filtration, darkness)
- Maximum holding time

(see Table 1 in handout posted on web page)

22

Water Quality Monitoring

Information presented from National Handbook of Water Quality Monitoring by NRCS:

http://www.wcc.nrcs.usda.gov/water/quality/common/wqm1.pdf (part 1)

http://www.wcc.nrcs.usda.gov/water/quality/common/nwqh615.pdf (part 2)

23

Water Quality Monitoring

- Includes both surface (streams, lakes, estuaries) and subsurface waters (vadose zone, groundwater)
- It is expensive and should be done well!

24

Monitoring Purposes

- analyze trends
- determine fate and transport
- define critical areas
- assess compliance
- measure effectiveness of conservation practices
- evaluate program effectiveness
- make waste load allocation
- model validation and calibration
- define water quality problem

25

Steps in WQ Monitoring

1. Identify the problem
2. Form objectives
3. Design experiment
4. Select scale
5. Select variables
6. Choose sample type
7. Locate stations
8. Determine frequency
9. Design station
10. Define collection/analysis method
11. Define land use monitoring
12. Design data management

Case study: pages 1-7 to 1-12 in Handbook

26

1.Define WQ Problem

Need to distinguish between a symptom and a problem

- A symptom indicates a problem
- A *problem* requires a solution

Need to write a problem statement in terms of *use impairment* (contact recreation, aesthetics, etc.), and mention *water body*

Need to determine *cause* and *source*

27

1.Define WQ Problem

Example:

"The lack of recreation in St. Albans Bay is because eutrophication caused by excessive phosphorus loading from agricultural sources"

If source is not known:

"The lack of recreation in St. Albans Bay is because of excess nutrients (N or P) from unknown sources"

28

2.Form Objectives

Must address WQ problem

- Monitoring objective: obtaining knowledge about the system
- Management objective: goals of the project that monitoring is intended to assess

29

Forming Monitoring Objectives:

Infinitive verb + object word or phrase + constraints

- To determine, evaluate, assess
- "What?"
- Limit to specified areas

"To determine + the effect of implementing conservation practices + on fecal coliform levels in Long Lake"

30

Forming Management Objectives:

- To reduce, increase, eliminate
- "What?"
- Limit to specified areas

"To reduce + fecal coliform loading + to Long Lake" or

"To implement fecal coliform controls on 75% of the farms in the Long Lake watershed"

31

3. Design Experiment

- Reconnaissance√
- Plot √
- Single watershed √
- Two watersheds √
- Paired watersheds √
- Multiple watersheds X
- Trend station X

32

Reconnaissance

Grab sampling

+ Cheap

– Not necessarily at proper frequency (too much during base flow, too little during peak flow)

33

Plot

Experimental

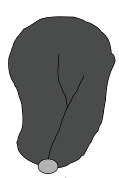
+ Replicates and controls possible

– Difficult to scale up to watershed size

- Analysis of variance

34

Single Watershed



Before – after a practice:

+ Simple design

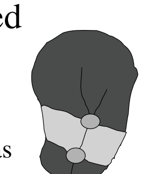
+ Needs one station

– Effect cannot be well separated from other variables such as climate

- T-test for comparison of mean values

35

Single Watershed



Above – below a practice:

+ Climate effects not as important

+ Good for isolation of critical areas

– Results from nested watersheds may not be independent

– Above and below differences due to something else

- T-test of above and below differences, or regression

36

Two Watersheds

One with practice, one without

+ Easy to locate
– Should be avoided because there is no calibration period
– Differences may be due to other factors

37

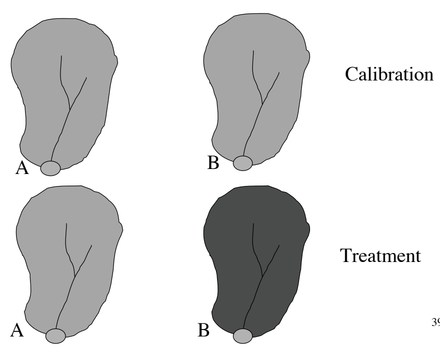
Paired Watersheds

2 watersheds, control and treatment with calibration period

+ Climate variations are statistically controlled
– Variances may not be equal between watersheds
– Costly and time consuming
• Regression and analysis of covariance

38

Paired Watersheds



39

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow				
Vadose zone				
Ground water				
Stream flow				
Lakes				

40

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow		X	X	
Vadose zone				
Ground water				
Stream flow				
Lakes				

41

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow		X	X	
Vadose zone	X	X	X	
Ground water				
Stream flow				
Lakes				

42

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow		X	X	
Vadose zone	X	X	X	
Ground water			X	X
Stream flow				
Lakes				

43

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow		X	X	
Vadose zone	X	X	X	
Ground water			X	X
Stream flow			X	X
Lakes				

44

4.Select Scale of Study

Water body	Point	Plot	Field	Watershed
Overland flow		X	X	
Vadose zone	X	X	X	
Ground water			X	X
Stream flow			X	X
Lakes	X	X	X	X

45

5.Select Variables

- Variable denotes WQ characteristics that exhibit variability such as algae counts, DO, nutrient concentrations)
- Several variables affect selection

46

5.Select Variables

Factors:
- Objective
- System type (lake, stream, soil-water)
- Designated use (DO not for recreation)
- Pollutant source (Ag, urban, mining)
- Cost/difficulty (analysis, handling)
- Water quality problem (eutrophication, turbidity)

47

6.Choose Sample Type

Depends on variability in time and space:
- Seasonal differences
- Trends (climate change)
- Randomness (rain storm location)

48

6.Choose Sample Type

- Grab sample (reconnaissance, pH, bacteria, gases)
- Composite sample (collect at different times and lump together)
- Integrated sample (depth-integrated USGS, EWI method)
- Continuous sample (for transport studies, turbidity sensors, temp sensors, etc.)

49

Composite Sampling

- Time-weighted (collect at fixed time interval): $\overline{C} = \frac{\sum C_i}{n}$
- Inappropriate for mass loading or if Q and C vary (may miss peaks!)

50

Composite Sampling

- Flow-weighted (collect when a specified volume has passed monitoring location)

$$\overline{C} = \frac{\sum (C_i x \Delta Q)}{(n x \Delta Q)}$$

- Need to monitor stream stage and find Q, use automated samplers

51

7.Locate Stations

- See Handbook

52

8.Determine Frequency

- Long: Baseline, Trends, Program effectiveness
- Short: Fate & Transport, Problem definition, Critical areas, BMP effectiveness, Wasteload allocation
- Short to long: model evaluation
- Short to continuous: research

53

9.Design Station

- Discharge stations: Plot, edge-of-field, stream, staff gages, stage recording, stage-discharge (heating in cold climates)
- Concentration sampling: grab samples, passive samplers, automated samplers)
- Precipitation monitoring
- Soil-water sampling
- Biotic sampling
- Sediment sampling

54

10.Define Collection/Analysis Method

- EPA guidelines
- Method in Examination of Water and Wastewater (APHA)
- Quality Assurance

55

11.Define Land Use Monitoring

Methods:

- Personal observation
- Field logs
- Personal interviews
- Remote sensing

How to handle data:

- Storage in spreadsheets, or GIS

56

12.Design Data Management

- Data acquisition (entry sheets, data logger)
- Data storage (digital)
- Data validation (error check)
- Data retrieval (organized well; data base)
- Data manipulation (calculations, sorting, graphing, statistical analysis)
- Data reporting

57