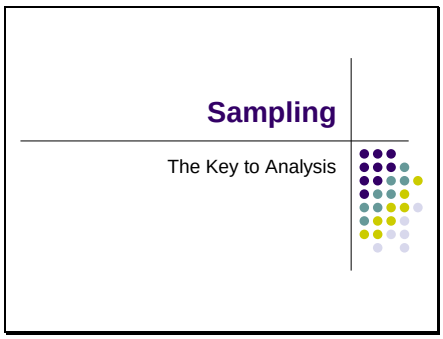
Slide 1



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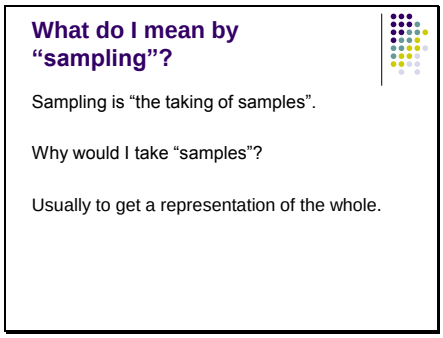

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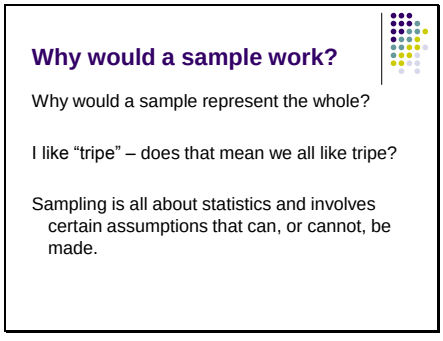


Slide 4

Sampling conditions:

Uniformity: A sample would be representative of a whole if the entire system is completely uniform. E.g. a perfect sphere of pure aluminum

Why did I specify “a perfect sphere” and “pure aluminum”?

A rusty sample would have aluminum oxide on the surface and pure aluminum inside. An imperfectly shaped object might be smooth on one part and rough on another.

Slide 5

Sampling conditions:

Statistically uniform: A sample would be representative of the entire system if it is large enough and random enough to include an “average” of all non-uniformities. E.g. a tablespoon from a glass of Pepsi

Why did I specify “a tablespoon”?

If I took a small enough sample (a single molecule of sugar) it wouldn’t contain all of the components of the whole.

Slide 6

The Blind Men and the Elephant

6 blind men are brought to the zoo and asked to describe an elephant.

The first man goes forward and grabs the elephant’s trunk and says, “An elephant is like a large snake, thick and tubular.”

The second man goes forward and bumps into the elephant’s ribs and says, “An elephant is hard and flat like a brick wall.”

The third man goes forward and grabs the elephant’s tusk and declares, “An elephant is like a great spear.”

Slide 7

The Blind Men and the Elephant

The fourth man goes forward and grabs the elephant's tail and cries, "Why, an elephant is just like a rope, thin and rough and wiry."

The fifth man steps forward and grabs the elephant's ear, declaring, "An elephant is like a fan, thin and flat and flexible."

The sixth man steps up and grabs the elephant's leg and says, "An elephant is like a tree."

Slide 8

A sample must…

…contain enough pieces of the whole to allow a description of the whole.

In the case of the blind men, if you combine all six of them, you might get some sense of the true size and shape of the elephant. But you would need even more information to understand its exact functions and nature.

Slide 9

Polling…

In a democracy (or a capital market as well), we are all familiar with polling (or market research) and its pitfalls.

The same issue applies. If you ask everyone in the country who they would like to be the president, you will get an exact vote total. If you ask 1000 people and scale up, will you get an accurate representation?

Slide 10

Randomness and Distribution

If I ask 1000 people in the city of Chicago who they would like to be President and 935 say “Barack Obama”, will Barack Obama be re-elected?

Only if Chicago is representative of the entire country.

Slide 11

Randomness and Distribution

If I asked1000 women in the city of Chicago whom they would like to be President and 935 said “Oprah Winfrey”, would Oprah Winfrey be the next President?

Only if women in Chicago are representative of the entire country.

Slide 12

Issues for a sample:

Place – is it indicative of only a single place, or of all places, or of some places?

Time – is it indicative of a single time, all times, or just some times?

Slide 13

Place

I have ten 1 gallon jugs in my kitchen. If I test one of them for bacteria and find it is clean, does that mean all 10 are clean?

Of course not, they are spatially isolated from each other.

Slide 14

Time

On my way to work at 6:30 a.m., I go to the Genesee Brewery and grab a sample of effluent and test it for lead and find the sample is clean (<1 ppm). Does that mean there is no lead being dumped from the brewery?

It depends: is the effluent mixed before dumping? Is the plant in operation at 6:30 a.m.?

Slide 15

Testing

Suppose I want to test the water in my dog's kiddie pool. There's 10 gallons of water in it. Would it be better to:

A) Test all 10 gallons.
B) Test 1 gallon 10 times.
C) Test 10 mL 10 times.
D) Test 100 mL once.
E) Dude, it's a dog, who cares?

Slide 16

Testing

Suppose I want to test the water in my dog's kiddie pool. There's 10 gallons of water in it. Would it be better to:

A) Test all 10 gallons. (Is the test infinitely accurate with no random errors?)
B) Test 1 gallon 10 times. (Is the test infinitely accurate with no random errors?)
C) Test 10 mL 10 times. (Does this sample include leaves floating on top, algae clinging to the bottom?)
D) Test 100 mL once. (Does this sample include leaves floating on top, algae clinging to the bottom? Is the test infinitely accurate?)
E) Dude, it's a dog, who cares? (YOU FAIL, GET OUT!)

Slide 17

Main Issues

- **Measurement errors** - multiple samples measured reduce random errors (not systematic errors) and yield more accurate results.
  - This is specific to the required accuracy and the nature of the test procedures/equipment
  - More measurements, lower standard deviation, more accurate result.
- The nature of water systems require assembling **representative samples** of the whole system.
  - This is specific to the nature of the system itself.
  - Complex, dynamic systems require more samples to be taken than small, static systems.

Slide 18

Random vs. Systematic Errors

I weigh myself on my scale and I weigh 175.00 pounds. How accurate is my measurement?

SPOT ON! ☺

Would it help to weigh myself 10 different times and take the average?

Only if the error was "random".

Slide 19

Random vs. Systematic Errors

I weigh myself on my scale 10 times and I weigh 175.00 pounds each time. How accurate is my measurement?

My scale is off by 3 pound every time. ☺ No matter how many times I weigh myself, I don't improve the error. Precise but not accurate.

I weigh myself 10 times and get 175.00, 287.21, 201.37, 243.65, 212.67, 287.33, 193.25, 181.63, 287.59, 180.30 for an average of 225.00 pounds.

Accurate, but not precise.

Slide 20

Standard deviation

Random errors will average out over time. The error is usually measured using the standard deviation:

$$\sigma = \frac{\text{SQRT}\left(\Sigma\{(\text{measurement} - \text{average measure})\}^2\right)}{\text{SQRT}(N-1)}$$

So as N (number of measurements increases), the error decreases – IF THE ERROR IS RANDOM

Slide 21

There are 2 types of sampling:

Samples taken to be tested. (System sampling.)

Number of tests run on each sample. (Test sampling.)

For example, if I'm testing my swimming pool and take a single sample from the swimming pool (1 system sample) but the test I'm running is known to be problematic I may want to run the same identical test 5 times (5 test samples).

Slide 22

Paint the Picture

System sampling – attempting to obtain enough samples to statistically represent the whole system.

Test sampling – attempting to do enough repetitions so that the random errors in the test average out.

Slide 23

The Ideal vs. The Mundane

Ideally…

…we achieve infinite accuracy with multiple testing of the entire system.

Practically…

…cost is always an issue.

Slide 24

The Balance

We need the minimally sufficient sampling and the minimum number of test samples to get the minimally acceptable result.

This is something of an art as well as a science. If you are testing a pond for organic contamination you do not need as accurate a result as you would for drinking water.

Slide 25

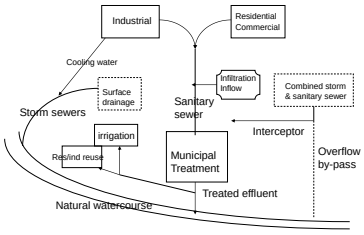
The number of system samples depends on the system.

The number of test samples depends on the test. If I am weighing something on a calibrated scale in a closed room, there is little to be gained from weighing it 10 times. If I am weighing something on a calibrated scale outside in a hurricane…

Slide 26

Wastewater Characteristics

My version of Figure 9-1 on p. 312 of Hammer & Hammer



Slide 27

Testing sites

What you test for depends on what was on the site, near the site, or could have drained into the site.

Hudson River valley – PCB contamination all through it, even though the original dumping was localized at one part of it. The river pollutes everything downstream of it.

Slide 28

2 Types of Systems:

- Static systems - Unchanging in time (limited flow and few inputs). Stratification is possible. Testing at different positions might yield different results for some contaminants based strictly on a static concentration profile (no inputs).
- Dynamic systems - Changing in time (strong flow and/or multiple inputs). Stratification is impossible. There should be no difference based on position unless there is a difference in inputs. The mixing will keep the system homogenous with regard to contaminants.

Slide 29

3 Types of Samples

Grab sample – scoop out a sample with a cup! (or the equivalent. Single sample, single time, single place.

Composite sample – sample is a mixture (composite) of multiple grab samples taken at different TIMES.

Average sample – a collection of grab samples taken from different LOCATIONS. (Consider a soil core sample).

Slide 30

Main Questions:

1. How many samples?
2. From where?
3. How frequently?

These questions are tied to each other and also depend on the type of system and type of contaminant.

Slide 31

A Pond

Suppose you want to test a pond with no obvious water sources or sinks. You want to test for heavy metal contamination.

What do we need to consider? What are some additional questions we need to ask?

Slide 32

Questions you want answered:

1) What's around the site?
2) Water table? Spring?
3) Budget
4) Soil composition

Slide 33

Things to consider:

1. How big is the pond?
   - 300 ft across, 5 ft deep in center
2. How deep is the water table?
   - 8 ft down
3. What's around the site?
   - The site is 10 acres, square in shape. On one side there is a light industrial park, on two of the sides there is existing housing, and on the fourth side is MacGregor's and a convenience store with gas station.

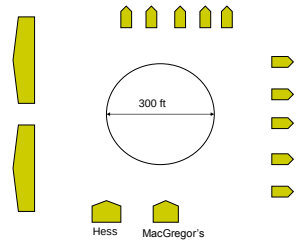
Slide 34

Things to consider:

4. Is there a likely source?
   - industrial park
5. What type of soil?
   - sandy loam

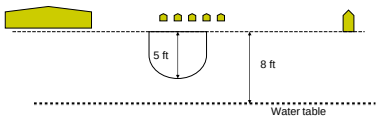
Slide 35

The view from above



Slide 36

The view from MacGregor's



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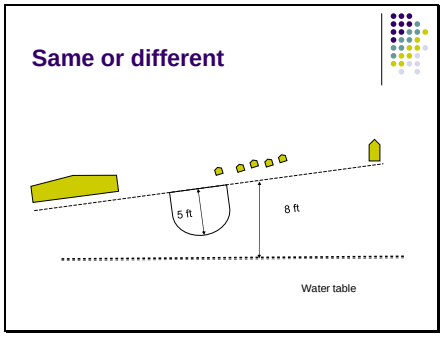

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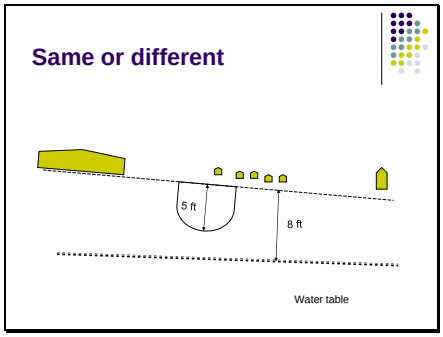

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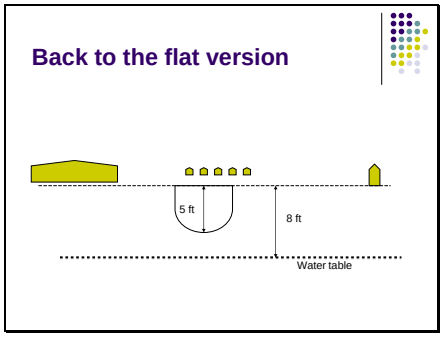


Slide 40

What Picture are we trying to Paint?

CONTAMINATION – YES OR NO?

If there is no contamination, there is no point in looking for the source.

CONTAMINATION – YES!

Where is it coming from?

Slide 41

"Likely testing" – How many samples? From where?

No more than 5 soil core samples per acre, leaning toward the industrial side of the property. In fact you might do 5/acre on that side and diminish to 2/acre by the time you reach the other side.

2 samples from pond, but must include sediment sample. 1 near the shore on the industrial side and 1 in the center.

Slide 42

How frequently would testing be done?

Probably a one-time test when purchasing. There is not active dumping, it is a static situation, so you just want to know what happened before you got there.

Slide 43

A stream

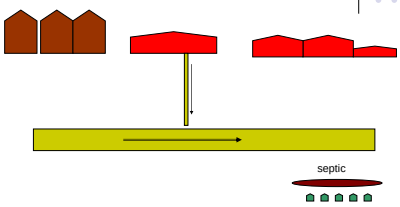
You own a metal-plating company that is situated on the shore of a 15 foot wide stream with moderate flow. You are in the center of a light industrial park with 3 buildings (mostly offices) downstream and 3 manufacturing and light assembly operations up stream.

There are condos 1/4 mile away on the other side of the stream that have a septic system.

You are on a sewer system and have an effluent treatment center with a 5,000 gallon tank. You generate 20,000 gallons of waste water per day.

Slide 44

Picture of this



Slide 45

Testing

Do we need to test the stream itself?

- Probably not. We will make sure we don't pollute it and hope everyone else is doing the same. Of course, if you were buying the site, you'd need soil samples tested.

How would we sample the effluent?

- We are continuously dumping. No single sample will tell us the whole story.

Slide 46

Composite testing

Rather than single samples, you can take a "composite sample". This is a time-averaged sample from a single location.

For example, you would take 10 mL from the effluent every 30 minutes or so, for a 24 hour period. All the individual samples are combined into a single "composite sample" which is then tested.

The result is a time-averaged effluent sample.

Slide 47

How frequently would you test?

A potentially heavy polluter like a metal plating company (they use heavy metals, acids, bases, cyanide and other salts) would probably do their own testing on a daily basis to insure their effluent is safe.

Many water treatment systems do continuous testing of certain things (like pH) all day long and shut off the effluent if they wander out of range.

Slide 48

Sampling is not our main topic

You discuss much more about sampling and systems in your other waste water engineering courses.

We are mostly concerned with the chemistry of the pollutants and the chemistry of the testing for the pollutants. BUT, we do need to keep the sampling issue in the back of our minds. Perfect testing of an imperfect sample gives imperfect results.