



# A Chemistry Laboratory Experiment with Higher Order Cognitive Tasks for Non-Science Majors

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## ABSTRACT

We report the development and results of a water analysis experiment in the course: "Chemistry and Society Laboratory" for non-science majors at Montgomery College, Takoma Park/Silver Spring Campus, Maryland. This experiment complements the topic "The Water We Drink" in the associated lecture course. Students are provided with test kits and analyze a drinking fountain water sample for some common chemical elements (ions) as well as for the pH and "hardness" of the sample. Students are then provided with an "unknown" and analyze the "unknown" water sample using the same test procedures. In this experiment all students are (unknowingly) provided with the same "unknown" water sample and class results for the analyses are tabulated and displayed. The concepts of "averages", "error estimates", and "accuracy and precision" are introduced and easily understood. Each student analysis result will differ, although all the "unknown" samples are identical. Students are then provided with a copy of an annual "Water Report" from the City of Rockville, Maryland and a similar report from the District of Columbia. Comparisons and evaluations of the reports are made and recommendations for improvements including corrections and omissions are developed. We report the results of the evaluations for the 2006 reports.

## METHODS

### The Water Experiment (Abridged Version)

#### Collection and Analysis of Water Samples

Water sources:

- Drinking Fountain water
- Water sample given to the class in the laboratory

Five parts to experiment:

- Sample Collection/ Preparation
- Chemical Analyses of the Sample
- Reporting the Results
- Estimating the Error
- Evaluating a Water Quality Report

### Reporting the Results

Test	Drinking Fountain Water	Unknown Water Sample
pH		
Calcium Ion (ppm)		
Copper Ion (ppm)		
Total Hardness (ppm)		

## RESULTS OF STUDENT EVALUATION OF WATER QUALITY REPORTS

DATA FROM THE REPORT	CITY OF ROCKVILLE, MD	WASHINGTON, D.C.
CLARITY OF TABLES	NO RECOMMENDATION	A "VIOLATION" COLUMN (YES - NO) NEEDS TO BE ADDED
SAMPLING	REPORTED ANALYSES ARE CLEAR AND EASY TO UNDERSTAND	THE 90 <sup>TH</sup> PERCENTILE ANALYSIS NOT DEFINED. THE REPORT NEEDS SOME SIMPLIFICATION. EPA LIMITS NEED TO BE RECORDED IN A MANNER CONSISTENT WITH THE FORMAT USED IN THE REPORT
TIME AND FREQUENCY OF SAMPLING	FAILS TO SPECIFY DATE OR A FREQUENCY FOR SAMPLING	THE REPORT IS NOT USEFUL TO DETERMINE IF THE WATER IS SAFE TO DRINK TODAY AS THE ANALYSES ARE FOR THE YEAR 2006
ERRORS	REPORT FOR 2006 IS MISLEADING SINCE SOME OF THE ANALYSES WERE PERFORMED IN MAY 2007	REPORTED ANALYSES ARE QUESTIONABLE SINCE MANY OF THE REPORTED VALUES SHOW A VIOLATION OF EPA LIMITS.
OTHER	OTHER KNOWN CONTAMINANTS IN THE WATER NOT REPORTED - E.G. STEROIDS	OTHER KNOWN CONTAMINANTS IN THE WATER NOT REPORTED - E.G. STEROIDS

## EXCERPTS FROM WATER QUALITY REPORTS (2,3)

**Water Quality Data Table**  
The table below lists all of the drinking water contaminants that we detected during the calendar year of this report. The presence of contaminants in the water does not necessarily indicate that the water poses a health risk. Please observe notes. The data presented in this table is from testing done in the calendar year of the report. The EPA or the state require us to monitor for certain contaminants less than once per year because the concentrations of these contaminants do not change frequently.

Contaminant	Units	MCL or MCLG	MCL or MCLG	Third results of Year	Range	Range	Sample Year	In this treatment	Typical Source
<b>Organic Chemicals</b>									
Trihalomethanes (THMs) (ppb)	NA	NA	80	36.76	22	62.2	2006	No	By-product of drinking water chlorination
<b>Inorganic Chemicals</b>									
THMs (Total Trihalomethanes) (ppb)	NA	NA	80	63.67	35.5	104.2	2006	No	By-product of drinking water chlorination
Hardness (ppm)	2	2	0.002	NA	NA	NA	2006	No	Discharge of drilling wastes; discharge to from road construction; erosion of natural deposits
Fluoride (ppm)	4	4	0.7	0.1	0.7	0.7	2006	No	Discharge of natural deposits; water additive which promotes strong teeth; discharge from nuclear and uranium facilities
Metals (concentration in micrograms per liter)	10	10	2.8	NA	NA	NA	2006	No	Runoff from highway use; leaching from septic tanks, seepage; erosion of natural deposits

## INTRODUCTION

- Laboratory activities for non-science majors are often focused on "directed discoveries".
- Some laboratory activities may illustrate various techniques or procedures used in analytical, physical, and organic laboratory experiments.
- By contrast a SENCER approach to an activity in the laboratory will help the student to develop critical thinking skills (1) as part of the laboratory experience.

This approach is used for three of the laboratory experiments at Montgomery College:

- Analysis of Campus Soil Samples
- Analysis of Water Samples
- Analysis of Air Samples (A Demonstration)

We report here some details of the Water Experiment

## CONCLUSIONS

- A SIMPLE 3 HOUR WATER ANALYSIS EXPERIMENT MAY BE MODIFIED TO INCLUDE HIGHER ORDER COGNITIVE TASKS WELL WITHIN THE CAPABILITY OF STUDENTS WHO ARE NON-SCIENCE MAJORS
- STUDENT INTEREST LEVEL APPEARS TO INCREASE IN THE LABORATORY WITH THE INCLUSION OF THESE TASKS ( RESULTS FROM STUDENT ASSESSMENT OF LEARNING GAINS)
- IMPROVEMENTS IN THE ANNUAL WATER REPORTS FROM THE CITY OF ROCKVILLE, MARYLAND, AND FROM THE DISTRICT OF COLUMBIA ARE NEEDED

### Water Entering WASA's Distribution System

#### Inorganic Metal

	Units	EPA Limits		DC Drinking Water		Description / Typical Sources of Contaminants
		MCLG	MCL	Highest	Range	
Arsenic	ppb	0	10	0.7	ND to 0.7	Erosion of natural deposits; Runoff from orchards
Barium	ppm	2	2	0.04	0.03 to 0.04	Erosion of natural deposits
Chromium	ppb	100	100	1.3	ND to 1.3	Erosion of natural deposits
Selenium	ppb	50	50	0.7	ND to 0.7	Erosion of natural deposits; discharge from mines
<b>Inorganic Anions</b>						
Fluoride	ppm	4	4	1.2	0.1 to 1.2	Erosion of natural deposits; water additive which promotes strong teeth
Nitrate	ppm	10	10	2.9	0.4 to 2.9	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite	ppm	1	1	0.05	ND to 0.05	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits

## REFERENCES

1. See for example: Peter Facione, "Critical Thinking: What Is It and Why It Counts" [http://www.calpress.com/pdf\\_files/what&why.pdf](http://www.calpress.com/pdf_files/what&why.pdf) 1998) California Academic Press
2. <http://www.rockvillemd.gov/residents/DrinkingWater2007.pdf>
3. <http://www.dcwasa.com/news/publications.cfm>