

The Undergraduate Component of the Arsenic Project

Julian Tyson

Department of Chemistry, University of
Massachusetts Amherst
MA 01003

tyson@chem.umass.edu

Analytical chemistry: Application of chemical principles for the determination of the chemical composition of materials.

Provision of reliable information that is useful in the context of the problem.

A science that (a) underpins the progress of many scientific disciplines, and (b) impacts many aspects of our daily lives (e.g. clinical analysis of blood, of food and beverages).

Is it safe? what species? what concentrations? where did it go?

Graduate Student Activities

Improved procedures for the determination of arsenic compounds in waters, soils, plants and other biological systems.

Improved against the usual criteria: cost, speed, accuracy, precision, multi-analyte capability, detection limit, selectivity, sensitivity, signal-to-noise ratio, cost effectiveness,

Both at "high-tech" end
(HPLC with plasma source emission or mass spectrometry)

and at the "low tech" end
(naked-eye/digital camera detection).

Broader Impacts:

Elementary and Middle Schools.

Undergraduates:

1. First-years
2. Independent studies
3. REU

Website

International Visits

Background to "The Arsenic Project"

Mandal and Suzuki, "Arsenic around the world" *Talanta*, 2002, **58**, 201-235.

As, element 33, a mono-isotopic (75) metalloid, named for the yellow pigment orpiment (Latin arsenicum), probably isolated in 1250 by Albert Magnus.

It is widely distributed in all environments. 20th most abundant in earth's crust, 14th in seawater and it is claimed the 12th in the body (but this must be wrong). Concn. in rocks: 2 mg kg⁻¹, slightly higher in soils, sea water 8 µg L⁻¹. But there is a huge range.

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Mandal and Suzuki, "Arsenic around the world" *Talanta*, 2002, **58**, 201-235.

Uses: embalming, insecticides, herbicides, desiccant (cotton production), wood preservation, feed additive, medicine, poison, bullets, electronics, glass, paints, wallpapers and ceramics.

Our quality of life is affected by the extent to which we can (a) minimize the harmful effects of naturally occurring chemicals, (b) exploit the beneficial effects of chemicals with which we choose to interact.

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analytical chemistry

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7088
Gas-Phase
Chemiluminescence-
Based Analyzer for
Waterborne Arsenic

7071
On-Line Drug Metabolism in
CE: Glucuronidation Using Rat
Liver Microsomes

7078
Visualizing Ion
Electromigration during
Isotachophoretic Separations
with Capillary ITP-NMR

<http://pubs.acs.org/ac> 

Background to "The Arsenic Project"

The US FOOD and Drug Administration (FDA) considers **130 $\mu\text{g}/\text{person}/\text{day}$** from all sources to be a tolerable daily intake of arsenic and the US Environmental Protection Agency (EPA) has set the maximum contaminant level in **drinking water at 10 $\mu\text{g}/\text{L}$** .

Intake of **70 to 300 mg** of arsenic trioxide may be **fatal**. Death typically occurs between 12 to 48 hours but can occur within one hour.



Recent studies estimate that 2-100 children per million exposed to PTW during early childhood may develop lung or bladder cancer later in life as a result of this exposure
Consumer Product Safety Commission (2003)



Good intentions gone awry. Villagers drill a tubewell in Bangladesh (left). Encouraged as a solution to pathogenic contamination of surface waters, such wells have resulted in exposure of millions to arsenic, leading to the need for alternative water sources (above).

- Abnormal levels exist in:
Argentina, Australia, Bangladesh, Chile, China, Hungary, India, Mexico, Mongolia, Peru, Thailand and the United States of America
- Adverse health effects documented in:
Bangladesh, China, India (West Bengal), Mongolia and the United States of America
- Arsenic in drinking-water will cause 200,000 - 270,000 deaths per year predicted from cancer in Bangladesh alone.

Arsenic contaminated water revealed in 1993

4.5 million tube wells

Arsenic contamination in 20% of those tested

Current arsenic-related research in the Tyson group.

Fate of arsenic leached from CCA pressure-treated wood.

Bio-oriented topics

Study of the transformations of arsenic compounds by microorganisms.

Study of the uptake of arsenic by plants.

Study of the *in vivo* interaction of arsenic and selenium (plants and humans/models)

Graduate Student Activities

Secondary Topics

Mapping of As distribution in local communities

soil, surface & ground water

PTW, pesticide & herbicide application (past and present), chicken farming, cemetery leachate

Removal of arsenic from drinking water

Solid-phase extraction, adsorption, ion-exchange, chelation, waste biomass, zero-valent iron, live biota

Biomarkers of arsenic exposure

Hair, nails, and earthworms

Broader Impacts:

Undergraduates:

1. First-years
2. Independent studies
3. REU

Agenda is to get them interested in research.
So that they will seek out another experience.
Will maintain an interest in science and not drop out.
Will go on to graduate school.

Trying to create an authentic research experience.

An authentic research experience?

Takes place over a significant time period gives students the opportunity:

to become familiar with the relevant big picture, detailed background, and previous work

to conduct a series of experiments in which designs of the later ones are based on the outcomes of earlier ones

to draw conclusions, summarize the findings, make suggestions for further work

to create a written document containing the material of interest to the broader community.

An authentic research experience?

Relatively inexperienced and **unskilled workers work alongside the more experienced** and knowledgeable workers, from whom they can obtain guidance and information as needed.

Participants are part of an **active community of scholars** who regularly come together to discuss their interests, findings, and to examine critically relevant new knowledge in the field.

Participants take some responsibility for, and have some say in, the **formulation of goals** and **experiment design**.

The undergraduate component of the arsenic project

One-credit, semester-long, honors colloquium.

Now involves: First-years in Chem 121H and Chem 122H.
Juniors in Chem 315 (fall), Chem 312 (spring)

Students recruited following visit (by me) to classrooms.

Each group: one grad (or me), 1 or 2 Chem 312/5 students and 2-3 Chem 121/2 students.

No change to freshman labs. Set up a small lab in former Gen. Chem. balance room. Students also use my research lab.

Participants

Semester	No. of groups	General Chem.	Upper level	Total	Cum Total
Fall 04	6	17	6	23	23
Spring 05	10	25	17	42	65
Fall 05	11	60	12	72	137
Spring 06	11	36	9	45	182
Fall 06	8	35	12	47	229
Spring 07	6	23	6	29	258
Fall 07	7	17	9	26	284
Spring 08	8	23	1	24	308
Totals	67	236	72	308	

What does this piece of the As project look like?

FALL 2007	Time at the weekend (weeks) from start.	Week of	Activity	What's due? (to Prof. Tyson by e-mail)	Group #	Adviser	Background Topic: What do we know about . . .	Technique: With particular reference to the determination of arsenic
	0.5	4-Sep	Recruit and register		1	Prince Amoako	How organisms convert toxic forms of arsenic into non-toxic forms	Inductively coupled plasma techniques
	1.5	10-Sep	Recruit and register		2	Elena Dodova	How much arsenic we eat in our food in the US?	HPLC with element specific detection
	2.5	17-Sep	Project Kick-off meeting 9/19		3	Maura Mahar	Arsenic in drinking water in the US and around the world	Field test kits based on the Gutzeit reaction
	3.5	19-Sep	Work on background		4	James Kearns	The use of arsenic in herbicides and pesticides	Solution spectrophotometry
	4.5	1-Oct	Work on background Progress meeting 10/3		5	James Kearns	The removal of arsenic from contaminated drinking water by inorganic adsorbents.	Anodic stripping voltammetry
	5.5	8-Oct	Work on background Work on how to measure.		6	Julian Tyson	The removal of arsenic from contaminated drinking water by material of biological origin	Atomic absorption spectrometry
	6.5	15-Oct	Work on how to measure, Progress meeting 10/17	Brief report on participation: 10/21 Background and how to measure As: midnight 10/21	7	Julian Tyson	CCA pressure-treated wood as a source of arsenic contamination in the US	Atomic fluorescence spectrometry
	7.5	22-Oct	Work on proposal				The background material should be about 500 words and contain 7-10 links to websites of relevance. The measurement technique or procedure should be about 500 words and contain at least one diagram and 2 links to relevant websites	
	8.5	29-Oct	Work on proposal. Each group measures 2n samples. Last day to drop with W: 10/29.					
	9.5	5-Nov	Work on proposal Progress meeting 11/7	Proposal: midnight 11/12			The proposal should be about 750 words long.	
	10.5	12-Nov	Work on project					
	11.5	19-Nov	Work on project					
	12.5	26-Nov	Work on project					
	13.5	3-Dec	Work on project					
	14.0 on 12/14	10-Dec	Project meeting 12/12. Work on project. Last classes 12/14 Work on reports					
	15.5	17-Dec	Work on reports	Project report. Report on group participation. Report on value of experience: midnight 12/21				

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4-Sep	0.5	Recruit and register	
10-Sep	1.5	Recruit and register	
17-Sep	2.5	Project Kick-off meeting 9/19	
19-Sep	3.5	Work on background	
1-Oct	4.5	Work on background Progress meeting 10/3	
8-Oct	5.5	Work on background Work on how to measure.	
15-Oct	6.5	Work on how to measure, Progress meeting 10/17	Brief report on participation: 10/21 Background and how to measure As: midnight 10/21
22-Oct	7.5	Work on proposal	
29-Oct		Work on proposal. Each group measures 2n samples Last day to drop with W: 10/29.	
	8.5		

5-Nov	9.5	Work on proposal Progress meeting 11/7	Proposal: midnight 11/12
12-Nov	10.5	Work on project	
19-Nov	11.5	Work on project	
26-Nov	12.5	Work on project	
3-Dec	13.5	Work on project	
10-Dec	14.0 on 12/14	Project meeting 12/12. Work on project. Last classes 12/14 Work on reports	
17-Dec	15.5	Work on reports	Project report. Report on group participation. Report on value of experience: midnight 12/21

Further information about these activities is provided at the website: <http://courses.umass.edu/chemh01/>

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1	Prince Amoako	How organisms convert toxic forms of arsenic into non-toxic forms	Inductively coupled plasma techniques
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5	James Kearns	The removal of arsenic from contaminated drinking water by inorganic adsorbents.	Anodic stripping voltammetry
6	Julian Tyson	The removal of arsenic from contaminated drinking water by material of biological origin	Atomic absorption spectrometry
7	Julian Tyson	CCA pressure-treated wood as a source of arsenic contamination in the US	Atomic fluorescence spectrometry

Student Activities in "The Arsenic Project"

Final reports from spring semester 2006.

1. Removal of Arsenic from Drinking Water: Chemical Means: Arsenic Removal by Iron Precipitation in Alkaline Solutions
2. Arsenic (III) Removal from Water via Coagulation with an Iron Species
3. Measurement of Arsenic in Hair and Nails
4. Spectrophotometric Determination of Arsenic in Water: Flow injection molybdenum blue method
5. Spectrophotometric Determination of Arsenic in Plants: The Molybdenum Blue Method

6. Spectrophotometric Determination of Arsenic in Pressure-Treated Wood: Silver diethyldithiocarbamate method

7. Determination of arsenic in wood by inductively coupled plasma mass spectrometry using oxalic acid extraction: the mapping of copper chromated arsenate wood on the University of Massachusetts Amherst Campus

8. Metabolism of Arsenic in *E. Coli*

9. Analyzing the spatial distribution of arsenic in soil using the Hatch Test Kit and soil from the Amherst area

10. Effectiveness of Solvents in the Removal of Arsenic from Soil

11. Evaluating and Improving a Commercial Test Kit for the Determination of Arsenic in Drinking Water

Evaluation?

Of students: based on production of deliverables (background paper, proposal, report) and questionnaire

Participation: students send a confidential e-mail to me describing the effort and contribution by themselves and the other members of the group.

Most students received an A, some NR, one or two B

Evaluation? Responses by students to my questionnaire.

Upper numbers in each box are for Chem 111 (n = 53-58, most questions have 57 or 58 responses).

Numbers are the percentage of respondents. Lower numbers are for Chem 122H (n = 28 - 33, most questions have 32 or 33 responses).

Chem 111 in the fall 2005.

Chem 122H in the spring 2006.

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Evaluation? Percentages of responses

As a result of participating in the arsenic project,	Strongly agree	agree	neutral	disagree	Strongly disagree
I know more about the environmental chemistry of arsenic	57 61	40 39	2 0	2 0	0 0
I have a better appreciation of the importance of chemical analysis	58 61	39 38	3 0	0 0	0 0
I understand how difficult it can be to make reliable measurements of chemical composition	73 72	24 28	3 0	0 0	0 0
I have a better understanding of how scientific progress is made	54 51	40 45	4 4	2 0	0 0
I have a better understanding of why scientists need to study chemistry	52 58	41 33	7 6	0 3	0 0
I am more interested in chemistry than I was at the start of the semester	36 18	41 36	21 33	2 3	0 0
I am more likely to seek out another opportunity to do research	41 70	45 21	9 9	5 0	0 0
I am more interested in becoming a graduate student	21 18	30 36	33 33	14 3	2 0
I am considering majoring in chemistry	2 10	21 17	33 23	35 40	9 10
I feel more confident about my abilities as a scientist.	15 22	60 53	23 22	2 3	0 0

As a result of participating in the arsenic project,	Strongly agree	agree	neutral	disagree	Strongly disagree
My interpersonal skills have improved	17 22	57 44	22 25	3 3	0 0
My time-management skills have improved	14 24	32 35	46 38	9 3	0 0
My writing skills have improved	7 19	28 28	53 41	12 12	0
My oral communication skills have improved.	7 23	37 35	54 35	4 7	0 0
My ability to do chemical calculations has improved	28 24	36 36	28 30	9 6	0 3
My ability to design experiments has improved	28 26	51 55	21 19	0 0	0 0
My abilities to find relevant information about chemical topics have improved.	41 68	55 26	3 6	0 0	0 0
I feel more confident in carrying out experimental work	38 43	52 53	10 4	0 0	0 0
I did better in my regular 111/121/315 class	9 15	21 15	51 52	14 15	5 3

Comments about the format.	SA	A	N	D	SD
It was useful to have a Chem. 315 student in the group	61	20	17	2	0
	44	19	26	7	4
It was useful to have a graduate student mentor/adviser.	84	12	2	0	2
	94	6	0	0	0
The project should be incorporated into the regular lab experience	14	45	32	7	2
	19	23	35	23	0
The regular lab should be available on a drop-in basis (like the CRC).	23	24	42	11	0
	19	38	31	6	6
There was too much direction from Prof. Tyson	0	0	18	59	23
	0	10	13	47	30
There was not enough structure to the project.	0	7	15	62	16
	7	3	30	33	27
There were too many people in my group	0	4	14	64	18
	7	3	10	43	37
The difficulties in scheduling meetings spoiled the whole experience	2	9	31	44	16
	0	18	18	36	28

Suggestions for the future	SA	A	N	D	SD
Prof. Tyson should not to run this program again	4 0	0 0	2 3	23 26	74 71
Some way should be found to make the program part of the regular curriculum	3 6	26 16	36 29	33 48	2 0
The one-credit independent study format is just fine	23 29	39 52	30 10	9 10	0 0
Even if the format were the same, I would encourage Chem 111 students to participate, as the benefits outweigh the problems	50 48	38 42	12 10	0 0	0 0
More credits should be given for the activity	26 29	37 29	30 29	4 12	4 0
I would like to participate again in a leadership role	10 23	41 30	36 37	12 10	0 0

Evaluation: the faculty instructor perspective

It can be done: 300 UG (230 first-years) impacted.

Useful rather than useless.

Increased number of independent study UG in my group.

May have impacted the number of chemistry majors.

Scheduling is major problem.

Graduate students are an integral component.

Challenge is to find ways to sustain.

Evaluation: the faculty instructor perspective

Challenges

- (1) With graduate students?
- (2) Embed in regular curriculum: drop-in lab with TAs?
- (3) Can senior UG act as mentors?
- (4) Can independent study UG act as mentors?
- (5) how to provide analytical support?
- (6) Developments on campus may help. New ISB coming on-line fall 2009. Dean is aggressively pushing curriculum revision to meet this deadline.

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NSF CHE-072527 "Discovery Corps Fellowship: Integrating the "bio" into the environmental biogeochemistry of the arsenic project" Aug 07 - July 09

