29 January 2013

Dear Senators and Representatives of Illinois:

I write on behalf of many concerned Illinois citizens who fear passage this year of a weak, ineffectual bill providing legislative approval for horizontal, hydraulic fracturing (hydrofracking) in Illinois. This potentially dangerous drilling technology entails a number of risks everywhere, and the risk is much greater for the Illinois shale field due to its distinctive geology and geochemistry. These serious and credible risks call for exacting and thorough examination. Here is an executive "summary" of some of our more pressing concerns.

1. Illinois shale is too close to groundwater or too heavily faulted to permit safe use of hydrofracking.

The sine qua non of safe fracking is a thick layer of impermeable cap rock to prevent the migration of methane (and possibly fracking byproducts) into shallow groundwater. Both the International Energy Agency and a panel of German experts, who were funded and provided with data by ExxonMobil, state that a distance of at least 1,000 meters (3,280 feet) should separate the top of the shale field from the land surface.[1] They also call for a ban on hydrofracking and the deep-injection of flowback and produced water in "areas characterized by critical underground stress or by severe tectonic upheavals".[2]

Most of the Illinois New Albany shale field lies only 500 to 2,500 feet, or 152 to 610 meters, beneath the surface.[3] As Table 1 shows, *Illinois or New Albany shale is closer to the surface than any other shale field in the United States*. "Shallow fracking," namely drilling lateral wells less than 1,000 meters from the surface, is risky drilling in a "danger zone." In addition, the deeper area in the southeast corner of the state -- which most likely is the sweet spot for shale gas extraction in the state -- is part of the now active Wabash Valley seismic zone (See Figure A1 for a map of the Wabash Valley seismic zone).

Table 1. Measurement Data in Feet for United States Shale Gas Basins[3]

Basin (State)	Barnett (TX)	Fayetteville (AK)	Haynesville (TX, LA)	Marcellus (NY, PA,WV)	Woodford (TX)	Antrim (MI)	New Albany (IL, IN, KY)
Depth	6,500 - 8,500	1,000 - 7,000	10,500 - 13,500	4,000 - 8,500	6,000 - 11,000	600- 2,200	500 - 2,000
Net Pay	100-600	20-200	200-300	50-200	120-220	70-120	50-100
Rock Column Thickness: H_2O to Shale Top	5,300 - 7,300	500 - 6,500	10,100 - 13,100	2,125 - 7,650	5,600 - 10,600	300- 1,900	100-1,600
Produced H_2O Barrels H_2O / Day	NA	NA	NA	NA	NA	5-500	5-500

The Wabash Valley Fault has been seismically active with three magnitude 5 earthquakes in the last 20 years. Seismologists at Washington University, St. Louis believe that the next big earthquake "will come out of Illinois".[4] In addition, shale in the Wabash Valley is characterized by "complex faulting" and "extensive fracturing of rocks." It also contains the Cottage Grove, Rend Lake, Shawneetown and Fluorspar Faults.[5]

In sum, it will be highly risky to frack in SE Illinois because it is a heavily faulted and seismically active area.

Adoption of a 1,000 meter danger zone will not always protect surface water from contamination, especially in areas where after the fact study reveals past seismic activity or lots of naturally fractured rock. Two reports appearing in the *Proceedings of the National Academy of Sciences,* found highly elevated levels of methane in private water wells -- levels so high that they could cause fires, explosions, or asphyixiation.[6] Isotope analysis traced the origins of the methane back to the Marcellus Shale Formation which lay at least 1,100 meters below

the wells. A third study found traces of brine, radioactive nuclides, such as radium, and thermogenic methane in other private water wells. These three contaminants bore the "distinctive geochemical footprint" of the Marcellus Shale Formation, in this case located 1,200 to 2,500 meters below the wells. The investigators in this study concluded that the most likely explanation involved rock fractures, caused by past seismic activity, with the rock fractures creating pathways connecting deep shale formations to shallow aquifers.[7]

All in all, these studies provide additional support for (1) a 1,000 meter (3,200 foot) danger zone, namely the distance separating the ground surface from the top of the shale formation, and (2) an outright ban on fracking in seismically active or heavily faulted or fractured geologic formations.

2. Methane & frack byproducts can bleed into aquifers and groundwater from our unplugged oil wells.

There are 32,100 operating oil and gas wells in Illinois and another 110,000^{+} "non-active" wells.[8] Among the latter, the Illinois Division of Oil & Gas lists 4,500 "orphaned" or "abandoned" wells that are leaking oil and need to be plugged with cement. Unfortunately, the Plugging and Restoration Fund has only enough money to plug 500 wells per year, so the orphans on the current list will not be safely decommissioned until 2021.[9]

How many of the remaining 105,000 wells are sufficiently plugged to withstand "kicks"[10] from nearby fracking activity? A "kick" involves the high pressure intrusion of gas, water, or fluid from a frack job into an adjacent well and can lead to a blowout through an unplugged well. Does the IDNR even know the physical locations of all of these 105,000 wells, or will the state have to conduct aerial reconnaissance to locate unplugged or deteriorating wells that were abandoned before Illinois began regulating the industry?

These are not idle questions; the quickest and most common way for methane and toxic fracking byproducts to infiltrate groundwater -- and for methane, an extremely potent greenhouse gas, to leak into the atmosphere -- is through new wells that are inadequately cased or cemented or through old abandoned wells that are leaking or unplugged.[11] On this issue gas industry representatives and environmentalists agree.

Results from Halliburton experiments in Kentucky's segment of the New Albany Shale shed more light on this issue. Their trials with nitrogen as a frack fluid -- the fluid that will most likely be used in Illinois -- produced an "unexpected" outcome: hydraulically induced fractures with nitrogen were connecting with natural or preexisting faults and fractures that extended "out of zone," i.e., outside the shale formation and into adjacent rock.[12] This should not have been surprising because the pressure required to shatter New Albany Shale is greater than the pressure required to shatter the rock above the shale.[13]

The Halliburton experiment in New Albany Shale, along with the studies cited above, present flashing red lights for Illinois. Their message is clear: our groundwater supplies will be placed under grave danger of contamination if horizontal hydrofracking is allowed in Illinois. *"Out of zone" fracture networks will have a high probability of creating pathways to many of our non-active wells, and those pathways will permit the movement of methane and fracking byproducts into our water and air.*

3. Radioactive, toxic, hypersaline produced water.

Black marine shales are "notable for their high radioactivity" with typical averages of about 20 parts per million (ppm) of uranium.[14] Black shales in Illinois average a bit higher, 29 ppm[15], and a few samples register at 140 to 170 ppm.[16] Illinois shale registers at the higher end of the uranium-bearing shale spectrum.

This fact is critically important given the dangerous levels of radioactivity established through lab tests for shale gas brine in Pennsylvania, West Virginia, and New York. Hundreds of lab tests of Marcellus brine find radium^{-226} levels in wastewater that average several hundred to over 1,000 times above the EPA maximum contaminant level for drinking water.[17]

Given the "anomalously high radioactivity"[18] of New Albany shale, we can expect an unknown but potentially significant percentage of Illinois shale wells to generate produced water with dangerously elevated radioactive levels along with a blend of other toxic elements released from the shale. As Table 1 indicates, Illinois will have lots of produced water, and the level of radioactivity will increase across time: less radioactive at first but

increasing as production continues.[19] In sum, we are talking about large-scale generation of produced water from shale operations in Illinois, and a lot of that water will be toxic and radioactive.

The gas industry will most likely seek legislative definition of shale gas produced water as "nonhazardous," a designation giving it legal license to pump radioactive brine down Class II injection wells in Illinois. Radioactive brine is already being pumped down injection wells in Ohio,[20] so we can expect the gas industry to push for this cheap and dangerous method of disposal here as well.

Without statutory exemption, the Illinois Low-Level Radioactive Waste Management Act (420ILSC20), would prohibit the gas industry from disposing of radioactive waste in Class II injection wells. As the EPA notes:

> "Deep-well injection is not commonly used [for disposal of low-level radioactivity] and is specifically prohibited in the states of Wisconsin and Illinois. Because of its potential adverse impact on groundwater aquifers, EPA uses its authority under the Safe Drinking Water Act to control and also discourage this practice."[21]

Illinois does not allow nuclear power plants, industries, hospitals, research facilities, water treatment plants, etc., to dispose of low-level radioactivity in a reckless manner. *Why then should an Illinois version of the Halliburton Loophole be ceded to the gas industry? Why would they be allowed to dump nuclear waste in an uncontrolled manner when we prevent nuclear power plants from doing the same? How would one explain this exemption to Illinois voters?*

Please note that produced water can also contain high levels of other toxic elements. The most common toxic elements in Illinois shale samples (parts per million) are barium (520), manganese (300), vanadium (220), zinc (200), lead (43) and arsenic (34). Table A1 lists the adverse health effects of these toxic elements.

4. The debt-laden, profitless, financially troubled status of shale gas companies.

The shale gas industry is promoted as a financial bonanza for the state,[22] and one of the most common assertions in industry-sponsored reports and newspaper articles is that hydrofracking makes the extraction of shale gas "economically viable." If that is true, why are shale gas companies so financially troubled? The data in Table 2, taken from Yahoo Finance on January 7, 2013 (e.g., http://finance.yahoo.com/q?s=XCO&ql=1), list 15 companies with moderate to heavy involvement in shale gas extraction. I chose a number of smaller "pure play" companies specializing in shale gas to help isolate and highlight the economics of the shale gas industry.

Table 2. Natural Gas Companies 2012Q3 Financial Statistics

Company	Ticker	Market Cap.	Profit Margin %	EPS ($)	Debt (B$)	Cash ratio	Debt/ Equity	Levered Cash Flow (M$)
Exco	XCO	1,480	- 225.2	-6.03	1.85	1.70	436	-205
Ultra	UPL	2,830	-182.2	-10.30	2.16	0.43		-389
Quicksilver	KWK	489	-182.0	-8.02	2.17	1.39		-516
Forest Oil	FST	818	-156.7	-8.62	2.09	0.32	862	-558
PetroQuest	PQ	327	-73.4	-1.75	0.18	0.53	165	-65
Encana	ECA	14,870	-51.0	-4.17	7.76	2.07	141	-358
Penn Virginia	PVA	280	-24.9	-1.70	0.68	0.76	85	-170
Goodrich	GDP	367	-16.8	-1.02	0.57	0.48	419	-61
Comstock	CRK	738	-15.8	-1.52	1.24	0.44	122	- 622
Southwestern	SWN	11,710	-13.6	-1.06	1.70	1.11	52	-973
SM Energy	SM	3,620	-7.2	-1.67	1.33	0.65	90	-789
Bill Barrett	BBG	848	-7.0	-1.09	1.33	0.73	113	-517

Chesapeake	CHK	11,360	-5.2	-1.20	16.46	0.56	93	- 12,800
Range	RRC	10,380	-3.3	-0.27	2.85	0.50	125	-1,030
Atlas Energy	ATLS	1,850	-3.1	-0.91	1.01	0.68	52	-239

All have bloody red balance sheets. Not one has positive cash flow; most have cash ratios that threaten their ability to cover payroll and other business expenses, such as royalty payments.[23] Not one has made a profit in years, all have negative earnings per share, and all are cash consuming machines that have piled up large amounts of debt thus threatening a complete loss of shareholder equity.[24]

Why are shale gas companies so troubled financially? Because shale gas production costs exceed the natural gas market price by a factor of at least two. The February 2013 contract for natural gas, as of 1/9/2013, is $3.15 per million BTUs (see http://www.bloomberg.com/energy/) whereas the production cost for shale gas runs between $4 and $8 /MMBTU depending on which shale field is considered, whether the production occurs in a "sweet spot" or less productive parts of a field, and whether one is considering only production versus full costs.[25]

Normally, businesses would reduce production drastically under these circumstances, but most shale gas companies have been ensnarled in a web of contractual obligations forcing them to continue drilling. Drilling rig and pipeline contracts (with stiff penalties for cancelations), joint venture agreements and partnerships, which usually stipulate production volumes, loans with variable production payments tied to discounted cash flow create pressure for upfront production, and "use or lose" leases stipulate deadlines to begin drilling. These arrangements locked companies into drilling even when it was financially irrational to do so.

Companies holding leases in areas with high proportions of natural gas liquids (ethane, propane, butane) or shale oil, such as the Eagle Ford play, are abandoning dry natural gas production areas. As a result, the number of operating rigs in the Barnett and Haynesville shale plays -- predominantly dry gas areas -- have dropped by over 70% and gas-related employment has plummeted. Adam Durvney, in an Nov 25, 2012 article in the *Shreveport Times* explains what has happened in the Shreveport area:

> "Oil and gas firms fled the Haynesville Shale, one of the world's largest natural gas deposits and a major driver of the northwest Louisiana economy, in droves this year as natural gas prices reached record lows. Economic activity associated with drilling fell to bare-bones staffing and proved a major blow to local economies."[26]

The boom/bust cycle of natural gas, in short, is a surefire method for spreading eventual economic misery to areas under its influence. Two other considerations are more pressing:

1) Shale gas companies are in such deep financial trouble that they cannot afford to follow even weak, inadequate regulation. *Any regulations Illinois legislators pass will most likely be violated.* Regulations actually designed to safeguard our water, and the property rights of citizens living in a fracking zone, along with a very substantial and indispensable increase in regulatory staff to ensure compliance, will be tenaciously opposed by the shale gas industry because they cannot even afford to comply with even weak regulations.

2) When (not if) these companies cause significant environmental and economic damage in Illinois, small shale gas companies will lack the financial resources -- if they are not already bankrupt -- to make good on successful lawsuits. *And this industry will spawn a litigator's paradise.*

In sum, the financial condition of these companies is so precarious that they could be likened to a swarm of wayward summer bugs in search of a windshield.

My recommendation? Let some other state play windshield for this industry.

There are other important issues -- air pollution, violations of 5th and 14th Amendment Constitutional liberties and property rights of non-consenting citizens living in a frack zone, and the misallocation of scarce capital to a

dying industry (fossil fuels) instead of investing in the energy sources of the future (renewables) -- but this "summary" has gone on too long. I can only hope, then, that I have made a strong and credible case for banning fracking in Illinois.

Sincerely yours,

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Illinois State University

Notes

[1] International Energy Agency. 2012. *Golden Rules for a Golden Age of Gas: Special Report on Unconventional Gas.* Pp. 37, 44-45. http://www.iea.org/publications/freepublications/publication/WEO2012_GoldenRulesReport-1.pdf

Ewen, C. D. Borchardt, S. Richter, and R. Hammerbacher. 2012 (March). *Hydrofracking Risk Assessment: Study concerning the Safety and Environmental Compatibility of Hydrofracking for Natural Gas Production from Unconventional Sources.*

http://dialog-erdgasundfrac.de/sites/dialog-erdgasundfrac.de/files/Ex_HydrofrackingRiskAssessment_120611.pdf

Shale Gas Information Platform. 2012 (October 7). "Safe distance between hydraulic fractures and groundwater." http://www.shale-gas-information-platform.org/areas/news/detail/article/safe-distance-between-hydraulic-fractures-and-groundwater.html

This standard is informed by a growing and extensive body of evidence on the height of hydraulically induced fractures. See: Davies, Richard J. et al. 2012 (April). "Hydraulic Fractures: How Far Can They Go?" *Marine and Petroleum Geology* http://www.dur.ac.uk/resources/dei/JMPG_1575.pdf And:

Maxwell, Shawn. 2011 (November). "Hydraulic Fracture Height Growth." *CSEG Recorder*. https://www.cseg.ca/publications/recorder/2011/11nov/Nov2011-Hydraulic_Fracture_Height_Growth.pdf

A 1,000 meter offset has also been recommended in two horizontal, ground-surface settings. First, Osborn and his associates recommend baseline water well testing within 1,000 meters of a site that will be fracked (Jackson, Robert B., et al. 2011. "Research and policy recommendations for hydraulic fracturing and shale -gas extraction." Center on Global Change: Duke University. http://www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf). They make this recommendation because of the significant methane contamination of surface drinking water they found in samples from residential wells located within 1,000 meters of fracking operations. See reference #6.

Second, the British Columbia Oil & Gas Commission recommends well operators notify each other when fracturing is to take place within 1,000 meters of either an existing well or one currently being drilled because of 18 reported instances of "kicks" between a frack job and an adjacent well. A "kick" involves the high pressure intrusion of gas, water, or fluid into the non-fracked well. Such pressure spikes can cause blowouts if not managed by venting or the resort to other pressure reducing measures. With classic British-inspired understatement, the Commission notes "fracture propagation via large-scale hydraulic fracturing operations has proven difficult to predict," and "may result in fracture lengths that exceed initial design expectations." (BC Oil and Gas. 2010. "Safety Advisory: Communication During Fracture Simulation." http://www.bcogc.ca/node/5806/download).

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[9] IDNR No Date. "Program Description: PRF Program." http://dnr.state.il.us/mines/dog/program_prf.htm

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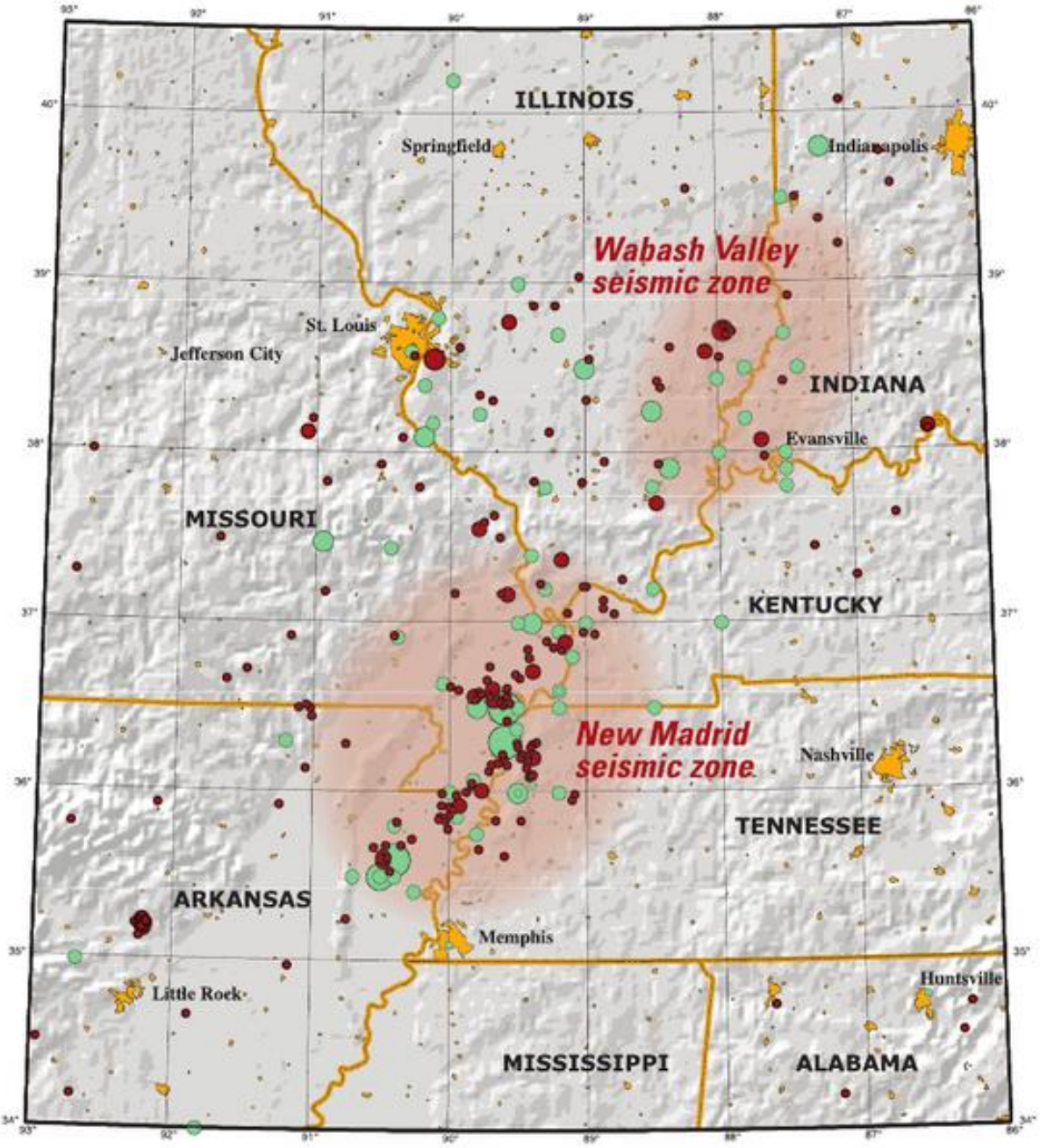
Figure A1 Map of Wabash Valley and New Madrid seismic zones



Source: USGS 2002. Earthquake Hazard in the Heartland. http://pubs.usgs.gov/fs/fs-131-02/fs-131-02.pdf
Red circles = earthquakes 1974 to 2002; Green circles = before 1974

Table A1. Some Elements Found in Illinois Black Shale and Their Health Effects

Sym	Element / PPM: Mean, Min-Max	Wikipedia Synopsis of Some Health Effects
Ba	Barium 520, 330-6,800	"Soluble barium compounds are poisonous due to release of the soluble barium ion, and therefore have been used as rodenticides. At high doses, barium affects the nervous system, causing cardiac irregularities, tremors, weakness, anxiety, dyspnea and paralysis. Other target organs for water-soluble barium compounds are eyes, immune system, heart, respiratory system, and skin. They affect the body strongly, causing, for example, blindness and sensitization."
Mn	Manganese 300, 100-820	Waterborne manganese has a greater bioavailability than dietary manganese. A 2010 study suggests higher levels of exposure to manganese in drinking water is associated with increased intellectual impairment and reduced intelligence quotients in school-age children. Long-term exposure to naturally occurring manganese in shower water may put up to 8.7 million Americans at risk.
Vn	Vanadium 220, 110-650	All vanadium compounds should be considered toxic. The National Institute for Occupational Safety and Health (NIOSH) has recommended that 35 mg/m^3 of vanadium be considered immediately dangerous to life and health. This is the exposure level of a chemical that is likely to cause permanent health problems or death. Vanadium and vanadium compounds result primarily in adverse effects on the respiratory system. Other effects have been reported after oral or inhalation exposures on blood parameters, on liver, on neurological development in rats, and other organs.
Zn	Zinc 200, 30-3,600	Zinc is an essential requirement for good health, but excess zinc can be harmful. Excessive absorption of zinc suppresses copper and iron absorption. The free zinc ion in solution is highly toxic to plants, invertebrates, and even vertebrate fish. The Free Ion Activity Model is well-established in the literature, and shows that just micromolar amounts of the free ion kills some organisms. A recent example showed 6 micromolar killing 93% of all *Daphnia* in water.
Pb	Lead 43, 9-230	Lead is highly poisonous, affecting almost every organ and system in the body. The main target is the nervous system, both in adults and children. Long-term exposure of adults can result in decreased performance in some tests that measure functions of the nervous system and (especially soluble salts) can cause nephropathy, and colic-like abdominal pains. Exposure to high lead levels can severely damage the brain and kidneys in adults or children and ultimately cause death. High levels of exposure may cause miscarriage. Lead also damages nervous connections (especially in young children) and causes blood and brain disorders. Lead poisoning typically results from ingestion of food or water contaminated with lead, It is rapidly absorbed into the bloodstream and is believed to have adverse effects on the central nervous system, cardiovascular system, kidneys, and immune system
As	Arsenic 34, 10-230	Arsenic is notoriously poisonous to multicellular life. Arsenic contamination of groundwater is a problem that affects millions of people across the world. Increased levels of skin cancer have been associated with arsenic exposure in Wisconsin, even at levels below the 10 part per billion drinking water standard, although this link has not been proven. Epidemiological studies have suggested a correlation between chronic consumption of drinking water contaminated with arsenic and the incidence of all leading causes of mortality. The literature provides reason to believe arsenic exposure is causative in the pathogenesis of diabetes. A post mortem in an arsenic poisoning death reveals brick-red-colored mucosa, owing to severe hemorrhage.

Source: Wikipedia: Go to periodic table at http://en.wikipedia.org/wiki/Periodic_table. Click on element in table for details on toxicity. Parts per million values are found in Frost et al. (1985), Table 9, p. 23.