Soil contamination associated with illegal burn piles in West Haven, Vermont

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Introduction

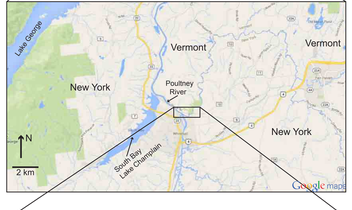
The Nature Conservancy owns and manages the Helen W. Buckner Memorial Preserve in West Haven, Vermont. The 4010-acre preserve has one of the highest levels of biodiversity in the state. It is located on the border of New York State, bounded to the south by the Poultney River and on the west by the South Bay of Lake Champlain. According to the Buckner Preserve website (http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/vermont/placesweprotect/helen-w-buckner-preserve-at-bald-mountain.xml):

> "[The preserve] is home to 11 uncommon or rare-in-Vermont animal species, 18 species of rare or uncommon plants and 10 distinct plant community types. Peregrine falcons nest on the cliffs of Bald Mountain and the preserve includes floodplain and upland forest, marsh habitat, three miles of undeveloped Lake Champlain shoreline, and wetlands along the Poultney River."

The Poultney River bordering the preserve also contains diverse populations of native mussels and other aquatic organisms. The first section (approximately 400 m) of the access road to the preserve (Galick Road) closely follows the Poultney River. Along the banks of the river, and also farther along Galick Road, are several illegal garbage dumps and burn piles. The garbage dumps contain household trash, construction debris, junked furniture, obsolete electronics, plastics and metal. Observation of the burn piles indicates that these materials are regularly set on fire.

This preliminary study involved sampling the burn piles and surrounding soil to determine which elements, particularly heavy metals, may have elevated concentrations in this area, and what the source of these elements might be.

Site Location



Items observed in burn piles

Particle board
Plywood
Electronics
Batteries
Kitchen cabinets
Cans
Window blinds
Cardboard boxes
Plastic (e.g. packaging, tubing, PVC)
Metal (e.g. nails, wire, scrap)

Sampling

One sample (FYS Oct 2011) was a grab sample collected in October, 2011, as part of an unrelated study. It was taken off the top of a burn pile located approximately where Burn Pile 1 is now. This burn pile contained partially-burned but still recognizable electronics components, as well as household garbage and construction debris such as plywood. The other samples were taken in November, 2013, by participants in Castleton State College's Hydrogeology class.

Burn Pile 1 appears to be the most "active" burn pile, with unburned and partially burned material piled on top of previously burned material. Two samples were taken from the top of the burned material. Sample WH-11-13-1 is dark-colored, coherent material, and sample WH-11-13-3 is loose ashy material. We also dug a hole into the pile and sampled burned material 15 cm down from the surface (WH-11-13-2).

Two samples of soil were taken from a spot halfway between Burn Pile 1 and the Poultney River, approximately 5 m from each. Sample WH-11-13-6 is a surface sample, and sample WH-11-13-7 is from 15 cm below the surface.

Burn Pile 2 is located approximately 30 m south of Burn Pile 1, along the river bank. A core of Burn Pile 2 (approximately 20 cm long) was obtained using a hollow-stem hand auger. Sample WH-11-13-11A is the bottom third of the core, sample WH-13-11-11B is the middle third, and sample WH-11-13-11C is the top third (surface). Sample WH-11-13-12 was obtained from the bottom of a small cut bank near the edge of the river, just below Burn Pile 2.

Between Burn Piles 1 and 2 was a heavily rutted section, presumably the result of people driving four-wheel-drive vehicles along the river bank. This rutted section contains pools of oily, dark-colored water. Another 20-cm core was obtained here. Sample WH-11-13-10A is the bottom third of the core, and sample WH-11-13-10C is the top third (surface).

Burn Pile 3 is located a few hundred meters west of Burn Pile 1, along Galick Road. This burn pile had little unburned material. Samples WH-11-13-14 and WH-11-13-15 are both from the surface of this burn pile. The surface of this burn pile had a bluish color. Sample WH-11-13-16 was obtained from 10 cm down, in a hole that we dug into the pile.

Methods

Each sample was stirred to mix it and an aliquot of approximately 10 g was measured into a small sealable plastic Whirl-Pak bag. Geochemical analysis (INAA and ICP) for forty-nine elements was performed by ActLabs, Inc. (Ontario, Canada). The results are given in Table 1 (which also includes the detection limit for each element).

Table 1: Concentration of selected elements in burn piles and soil samples

Analyte Symbol		Au	Ag	Cu	Cd	Mo	Pb	Ni	Zn	Si	Al	As	Ba	Be	Bi	Br	Ca	Co	Cr	Cs	Eu	Fe	Hf	Hg	In	K	Li	Mg	Mn	Na	P	Rb	Sb	Sc	Se	Sr	Ta	Ti	Th	U	V	W	Y	La	Ce	Nd	Sm	Sn	Tb	Yb	Lu	Mass
Unit Symbol		ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	%	ppm	%	ppm	%	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	g
Detection Limit		2	0.3	1	0.3	1	3	1	1	0.01	0.01	0.5	50	1	2	0.5	0.01	1	2	1	0.2	0.01	1	1	5	0.01	1	0.01	1	0.01	0.001	16	0.1	0.1	3	1	0.5	0.01	0.2	0.5	2	1	1	0.5	3	5	0.1	0.01	0.5	0.2	0.05	0.05	0.1	0.05	
Analysis Method	Sample description	INAA	INAA / TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA / TD-ICP	INAA / TD-ICP	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
WH-11-13-1	Burn pile 1 surface	66	1.5	920	2.3	12	> 5000	100	12000	0.46	2.79	460	740	< 1	2	24.4	10.3	86	1230	< 1	< 0.2	18.2	< 1	< 1	< 5	1.00	12	1.01	2170	0.41	0.283	< 16	51.7	3.1	< 3	616	< 0.5	0.7	2.4	< 0.5	32	< 1	5	16.6	23	< 5	2	< 0.01	< 0.5	< 0.2	< 0.05	1.09	1.09
WH-11-13-2	Burn pile 1: 8" down	< 2	0.3	7450	0.5	2	2360	36	1170	0.07	6.46	19.2	630	2	< 2	< 0.5	3.14	20	120	< 1	0.9	3.13	9	< 1	< 5	1.1	33	1.48	555	0.98	0.095	< 15	21.1	9.1	< 3	145	< 0.5	0.36	5.8	5.5	105	< 1	19	32.1	56	33	4.9	< 0.01	< 0.5	2	0.33	1.81	1.81
WH-11-13-3	Burn pile 1: ash	18	1.2	875	0.6	8	1300	26	10700	0.73	3.06	280	1970	< 1	< 2	31.6	23.3	138	1020	< 1	< 0.2	2.56	3	< 1	< 5	1.98	13	1.85	1030	0.42	0.435	< 15	44.9	2.8	< 3	1260	< 0.5	0.12	3.3	< 0.5	21	< 1	4	14.4	17	< 5	1.5	< 0.01	< 0.5	< 0.2	< 0.05	1	1
WH-11-13-6	Soil between burn pile 1 and river: surface	37	< 0.3	247	0.4	< 1	167	23	408	0.04	4.96	87.4	400	1	< 2	< 0.5	3.43	10	196	3	1.1	2.61	9	< 1	< 5	1.2	25	1.13	781	0.84	0.081	< 15	4.4	7.5	< 3	148	< 0.5	0.38	5.4	1.4	47	< 1	14	34.1	60	23	6.1	< 0.01	< 0.5	2.9	0.37	1.82	1.82
WH-11-13-7	Soil between burn pile 1 and river: 6" down	< 2	0.4	111	0.3	< 1	87	27	228	0.05	5.79	20.8	540	2	< 2	< 0.5	2.05	10	86	< 1	1.1	2.72	10	< 1	< 5	1.31	30	1.14	711	0.88	0.064	< 15	1.7	8.7	< 3	120	< 0.5	0.22	5.8	2.7	38	< 1	16	39.4	72	34	6.8	< 0.01	< 0.5	2.9	0.51	1.65	1.65
WH-11-13-9	Soil from woods >100 feet from burn pile	< 2	< 0.3	330	0.3	< 1	45	174	155	0.04	5.84	2.1	380	2	< 2	2.9	2.12	13	86	< 1	1.1	2.8	10	< 1	< 5	1.37	30	1.32	718	0.87	0.076	81	1.1	9	< 3	119	< 0.5	0.21	6.1	2.9	45	< 1	17	36.7	73	27	6.6	< 0.01	< 0.5	2.9	0.33	1.61	1.61
WH-11-13-10A	Core taken in oily rut: bottom 1/3 of core	< 2	< 0.3	19	< 0.3	< 1	29	32	77	0.02	6.56	5.8	< 50	2	< 2	< 0.5	1.85	13	74	< 1	1.1	3.36	7	< 1	< 5	1.46	36	1.27	1070	0.88	0.058	92	0.7	9.6	< 3	109	< 0.5	0.17	7.8	4.3	34	< 1	17	40.6	71	41	6.6	< 0.01	< 0.5	3.1	0.41	1.61	1.61
WH-11-13-10C	Core taken in oily rut: top 1/3 of core	< 2	< 0.3	21	< 0.3	< 1	17	28	85	0.02	5.47	4.2	340	1	< 2	< 0.5	1.44	8	43	< 1	1	2.53	14	< 1	< 5	1.28	27	1.03	758	0.85	0.06	< 15	< 0.1	7.4	< 3	98	< 0.5	0.17	7.2	3.9	23	< 1	15	40.4	71	44	7.1	< 0.01	< 0.5	3	0.43	2.13	2.13
WH-11-13-11A	Burn pile 2: bottom 1/3 of core	< 2	< 0.3	16	< 0.3	< 1	17	30	84	0.02	5.91	8.9	440	2	< 2	< 0.5	1.09	14	66	3	1.3	2.92	12	< 1	< 5	1.11	32	1	799	0.87	0.058	< 15	0.7	9.5	< 3	98	< 0.5	0.19	8.4	< 0.5	32	< 1	16	43.5	73	37	7.3	< 0.01	< 0.5	3.1	0.5	1.82	1.82
WH-11-13-11B	Burn pile 2: middle 1/3 of core	< 2	0.3	21	< 0.3	< 1	23	26	141	0.03	7.62	8.3	420	1	< 2	< 0.5	1.47	11	54	< 1	1.1	3.18	9	< 1	< 5	0.77	36	1.06	878	0.91	0.074	37	0.9	8	< 3	111	< 0.5	0.45	7.2	1.6	38	< 1	21	39.8	82	46	7	< 0.01	< 0.5	2.8	0.37	1.82	1.82
WH-11-13-11C	Burn pile 2: surface	< 2	< 0.3	211	0.4	< 1	196	20	494	0.08	4.99	34.4	530	< 1	< 2	2.6	8.66	9	103	< 1	0.9	2.34	11	< 1	< 5	1.13	22	1.49	1590	0.74	0.131	< 15	3.1	6.6	< 3	404	< 0.5	0.13	7.8	< 0.5	46	< 1	11	36.9	68	17	6.7	< 0.01	< 0.5	2.5	0.4	1.02	1.02
WH-11-13-12	Riverbank below burn pile 2	< 2	< 0.3	15	< 0.3	< 1	16	26	68	0.02	6.26	2.2	400	2	< 2	< 0.5	1.65	12	51	< 1	1.2	3.26	12	< 1	< 5	1.21	31	1.23	699	0.93	0.06	76	0.4	8.7	< 3	103	< 0.5	0.29	7.4	1.5	46	< 1	16	45.8	100	30	8.6	< 0.01	< 0.5	3.6	0.48	1.53	1.53
WH-11-13-14	Burn pile 3 surface	19	1.1	204	0.6	< 1	61	26	313	0.22	10.2	4.8	380	1	< 2	7.6	17.9	8	64	4	< 0.2	0.86	< 1	< 1	< 5	0.61	44	0.97	322	0.95	0.042	< 15	5.3	5.5	< 3	203	< 0.5	0.28	6.7	0.7	21	< 1	7	22.5	50	9	3	< 0.01	< 0.5	< 0.2	0.1	0.925	0.925
WH-11-13-15	Burn pile 3: surface	152	0.3	175	1.2	1	122	29	467	0.14	5.06	58.8	520	< 1	< 2	7	5.07	11	117	4	< 0.2	1.69	5	< 1	< 5	1.06	20	0.89	497	0.56	0.1	102	2.7	5.9	< 3	148	< 0.5	0.31	6.3	2.2	37	< 1	13	24.1	54	15	4.6	< 0.01	< 0.5	1.2	0.34	0.937	0.937
WH-11-13-16	Burn pile 3: 3" down	< 2	< 0.3	74	< 0.3	< 1	22	39	240	0.04	7.95	4.3	450	2	< 2	4.1	2.04	17	112	< 1	1.6	4.98	14	< 1	< 5	1.46	28	1.51	685	1.09	0.06	< 15	1	13.5	< 3	157	< 0.5	0.21	7.2	< 0.5	58	< 1	29	41.8	85	37	8.3	< 0.01	< 0.5	3.6	0.4	1.82	1.82
FYS Oct 2011	Top of burn pile (=same location as burn pile 1)	239	17.8	> 10000	1.5	< 1	4040	218	2590	0.28	2.98	58.7	< 50	< 1	< 2	19900	9.03	18	217	< 1	< 0.2	3.03	19	< 1	< 5	2.65	1.55	1710	1.68	0.074	< 15	5210	4.1	< 3	3150	< 0.5	0.33	< 0.2	< 0.5	40	< 1	24	28.4	114	88	1.9	< 0.01	< 0.5	< 0.2	< 0.05	1.05	1.05

Natural abundance of selected elements in soil:

	range	average
Au	3 - 6	5 ppb
Cu	2 - 100	30 ppm
Pb	2 - 200	10 ppm
Ni	5 - 500	40 ppm
Zn	10 - 300	50 ppm
As	1.5 - 10	5 ppm
Ba	100 - 3000	430 ppm
Br	1 - 10	5 ppm
Cs	0.01 - 28	1 %
Cr	1 - 1000	100 ppm
Fe	0.01 - >10	2.5 %
Mn	20 - 3000	600 ppm
Sr	50 - 1000	200 ppm

Results

The garbage burn piles contain elevated concentrations of many heavy metals and other elements, particularly at the recently-burned surface of the piles. The most pronounced maximum concentrations are:

	Burn Pile 1	Old Burn Pile 1 (sampled in 2011)	Burn Pile 2	Burn Pile 3
Au:	68 ppb	239 ppb	< 2 ppb	152 ppb
Cu:	7480 ppm	> 10,000 ppm	211 ppm	204 ppm
Pb:	> 5000 ppm	4040 ppm	196 ppm	122 ppm
Ni:	100 ppm	218 ppm	30 ppm	29 ppm
Zn:	12500 ppm	2590 ppm	494 ppm	467 ppm
As:	460 ppm	59 ppm	34 ppm	57 ppm
Ba:	7480 ppm	< 50 ppm	530 ppm	520 ppm
Br:	32 ppm	19900 ppm	3 ppm	8 ppm
Ca:	23 %	9 %	9 %	18 %
Cr:	1230 ppm	217 ppm	66 ppm	117 ppm
Fe:	18 %	3 %	3 %	5 %
Mn:	2170 ppm	2 ppm	1590 ppm	685 ppm
Sb:	52 ppm	4 ppm	1 ppm	5 ppm

Old Burn Pile 1 contained the highest concentrations of Au, Cu, Ni and Br. The current Burn Pile 1 contains the highest concentrations of Pb, Pb, Zn, As, Ba, Ca, Cr, Fe, Mn and Sb.

The samples taken between Burn Pile 1 and the Poultney River (both the surface sample and the sample taken at 15 cm depth) contain elevated concentrations of Cu, Pb, Zn, As and Cr.

The sample taken in a wooded area approximately 30 m from Burn Pile 1 contains elevated concentrations of Cu, Ni and Zn.

The sample taken from a small cut bank below Burn Pile 2 and the samples taken in the "oily rut" contain much lower concentrations of heavy metals than the burn piles.

Potential sources of heavy metals and other elements of interest in burn pile materials (observed or inferred):

Au: Electronics, circuitry, appliances
Cu: Electrical and electronic equipment, plumbing supplies, wood preservative (CCA)*
Pb: Lead paint (pre-1978), solder, vinyl window blinds, cathode ray tubes, some PVC plastic
Ni: Stainless steel alloys, cell phones, batteries, electronics
Zn: Galvanized metal, furniture/cabinet hardware (e.g. screws), cans, batteries, some PVC
As: Wood preservative (CCA), semiconductors, batteries, copper/lead alloys
Ba: Vacuum tube manufacture, alloys, spark plugs, solder
Br: Flame retardants (polybrominated diphenyl esters; for plastics, electronics, mattresses, textiles)
Ca: Cement, quicklime, slaked lime, white paint, wallboard, plaster
Cr: Wood preservative (chromic acid, chromate salts, CCA), fire extinguishers, oils/lubricants
Fe: Scrap metal, nails, hardware, cans
Mn: Steel alloy, batteries
Sr: Color television picture tubes, zinc refining, magnets

* CCA = chromated copper arsenate; used as a fungicide/insecticide in pressure-treated lumber, plywood, particle board, and other manufactured wood products

Discussion

The elevated concentrations of heavy metals and other elements in and near the burn piles are the result of the illegal burning of construction debris, household garbage, electronics, and other refuse. Some elements have their highest concentrations at the top of the burn piles, while others have a higher concentration below the surface. This may be due to several factors:

1. The element was more concentrated in older material that was burned at some time before the current surface material was burned.
2. The element is mobile, and leaches downward with percolating surface water.

The correlation of chromium and arsenic suggests that chromated arsenates (e.g. CCA, chromated copper arsenate) used as wood preservatives in pressure-treated lumber, plywood, particle board and other manufactured wood products, was present in the burn piles. The poor correlation between chromium and iron suggests that the chromium is not coming from steel alloy refuse. See graphs on near right.

Krook et al. (2006) have shown that particle board made from recovered wood may contain elevated concentrations of some or all of: As, Cd, Cr, Cu, Ni, Pb, Zn, Hg.

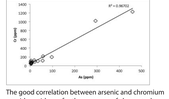
The sample taken in the woods was intended to provide "background" concentration levels. However, the elevated concentrations of many elements, particularly Cu, Ni and Zn, indicate that this soil has also been contaminated due to the burning of trash nearby. The surface ash from Burn Pile 1 (Sample WH-11-13-3) contains heavy metal concentrations that are very similar to those found in garbage incinerator fly ash (e.g. Remond et al., 2002), indicating that heavy metals can become airborne when refuse is burned. (This is true even at the lower temperatures of open burn piles.) This would explain the elevated levels of some metals away from the burn piles.

Old Burn Pile 1 has concentrations of target elements consistent with the burning of electronics. Metals used in circuitry (for wiring and soldering) are Au, Ag, Cu, Pb, Ni and Zn. Br likely comes from the brominated flame retardants commonly used in plastics. (More than 70% of electronic appliances are made with brominated flame retardants; http://www.bromine-info.org/en/Bromine-and-Fire-Safety). Partially burned circuit boards and other computer components were observed on this burn pile. See graph on far right.

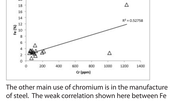
The "oily rut" did not contain particularly elevated concentrations of heavy metals or other target elements, suggesting that only airborne particles may have reached this area. However, the presence of oily substances suggests that the area is likely contaminated by organic compounds; this may prove to be a valuable subject of a future study.

Leaching of soluble metals and other target elements by percolating rainwater will allow the dispersion of these elements away from the burn piles, and likely towards the Poultney River.

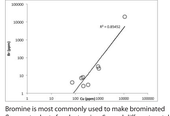
We hope that future work in this area will include a study of the freshwater mussels and other benthic organisms that live in the Poultney River just below the burn piles, so see if the heavy metals being released from the burn piles are having an adverse effect on aquatic organisms.



The good correlation between arsenic and chromium provides evidence for the presence of chromated arsenate wood preservative (in plywood, particle board and pressure-treated lumber).



The other main use of chromium is in the manufacture of steel. The weak correlation shown here between Fe and Cr suggests that steel is not the source of chromium in the burn piles.



Bromine is most commonly used to make brominated flame retardants for electronics. Several different metals are commonly used in electronics (for circuit boards and wiring), and so should correlate with bromine if electronics have been burned. The correlation shown here between bromine and copper supports this idea.

Acknowledgments

Funding for this project comes from Castleton State College. Literature research and data analysis was done by members of Castleton's Spring 2014 Geochemistry class, and is gratefully acknowledged:

Au: Alex Clodgo; Cu: Chelsea Dimick; Pb: Connor Kelley; Ni: Ashley Breen; Zn: George Grant; As: Tim Marshall; Br: Michael Ely; Ca: Tyler Robtoy; Cr: Flo Keyes; Al: Jack Limauro; Mn: Adam Boshart; Sr: Tom Stockwell; Ce: Catie Wielgasz.

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