Sable Island Fog Chemistry project

Sable Island Preservation Trust
Atlantic Coastal Action Program
2003-2004

Introduction:

Sable Island has a long history of involvement in a variety of atmospheric research and measurement projects.

This project was intended to measure toxic compounds in fog including organics and heavy metals in order to understand gas-droplet partitioning of air toxics, evaluate long-range transport of these substances, and quantify what impact they may have on Sable Island.

The transport of these substances to a remote island like Sable has relevance for other parts of the Maritimes, and provides data that may be used to evaluate regional effects.

In this project, it was hoped to perform three types of chemical analysis on the fog water:

1. Heavy metals including mercury
2. Organochlorines and PCB's
3. Polycyclic Aromatic Hydrocarbons (PAH), and

Background

Airborne emissions of pollutants result from a wide variety of human activities including mining, industrial processes, and transportation. Many of these emissions are further transformed by chemical reactions in the air.

These toxic materials can be transported long distances, crossing international boundaries, and deposited by "dry deposition" where they simply 'fall from the sky'. As well, these pollutants can be washed out of the air by precipitation. Fog also is an efficient transporter of pollutants, particularly the stable advection fogs characteristic of Sable Island in the late spring and summer.

Pollutants can damage vegetation by affecting their growth and survival, and contaminate soil and water. For pollutants that are bio-accumulators, increasing pollutant burdens in vegetation are transferred into wildlife.

Heavy Metals

The amount of accumulation of heavy metals in plants depends on factors such as pH, organic content, the particular species of plant, and the particular heavy metal. Some metals deposited from the air affect soil concentration, but not the concentration measured in plants, but others affect both. There are many factors at play, but fog and precipitation analysis can show the incoming burden and efficiency of dispersal.

Mercury is a special case. It's emitted to the atmosphere from both human and natural sources. The greatest emissions come from fossil-fuel power plants, especially coal, although waste incinerators are also a large source. Biological processes change the elemental forms of mercury to an organic form called methylmercury which accumulates in the food chain.

Organochlorine compounds and PCB's

These compounds are resistant to breakdown, and can also accumulate in animal tissues. Even at low concentrations they can have toxic effects, particularly over long exposure periods.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons or PAHs result from the incomplete combustion of wood, fossil fuels and other organic substances. Many of these compounds are carcinogens but harmful effects depend on concentration, duration of exposure, and individual response.

Equipment and methods:

Fog:
The Fog Collector is a 'harp' design, and consists of a nylon frame with more than 300 nylon strings oriented vertically. Fog water condenses on the strings and runs into a collection bottle in the lower base.


Photo by Sable Island Green Horse Society

In 2003, one collector was deployed in the instrument compound at the Sable Island station.

It's common to have zero visibility fog to the edge of the island, with daytime-heating thinning out the fog in the center of the island. In the first year of the project, the location of the instrument compound at the main station meant that minor daytime heating could thin the fog so that even though the visibility was poor, the water content of the fog was much reduced.

In 2004, the sampler location was moved to the south side of the island. Since part of this project includes collecting samples for organic compounds, two additional collectors of similar design were constructed from stainless steel.

The collector was prepared for sampling when thick fog was occurring with a visibility of less than one kilometer, and was forecast to continue for more than six hours. As well, the wind direction was required to be from a direction away from the station.

Preparation involved washing the collector with distilled, deionized water (DDI water) until the washings had a conductivity of less than 4 umho/cm. A sample bottle was similarly cleaned and placed in the collection chamber.

The collector was placed on the sampling pole, and left to collect fog water as long as conditions remained within the protocol specification. If the fog thinned out to have a visibility greater than one kilometer, of if precipitation began, the collector was covered with a plastic bag until the fog thickened or precipitation ended.

A ‘sampling gazebo’ was constructed from recycled untreated and unpainted plywood to shelter the collector from precipitation.

Precipitation:
As there are periods of the year where conditions make fog infrequent, a goal was to also collect precipitation samples and do the same analysis. MSC provided two Sangamo Automatic Precipitation Collectors, refurbished and operational, but still more than 20 years old.

Samples were collected every Tuesday morning, using a WMO protocol which required similar cleanliness standards as the fog collector.

Sampling:

As expected, there were a number of times when the weather forecast either incorrectly predicted the fog would end, and consequently the collector was not deployed, or it incorrectly predicted the fog would continue, but it ended shortly after the collector was deployed, and before a usable sample volume could be retained.

The collector was deployed 109 times. Forty-seven deployments had to be aborted when the fog ended before a usable sample of fog water could be collected. In the remaining 62 deployments, sample volumes were successfully collected.

Fifty samples (including field blanks) were submitted for analysis to the Environmental Quality Lab in Moncton, New Brunswick.

Analysis and Results:

Equipment problems and a heavy workload delayed analysis of the samples at the Environmental Quality Lab.

A major complication was the burden of sea-salt in the samples. EQL had to develop techniques to remove the salt before the analysis for pollutants could be done.

Many samples have not been analyzed yet, although EQL hopes to have them finished shortly.

The returned results are displayed in the tables.

Table	Results received
1	Heavy metals
2	PAH
3	Organochlorine Pesticides
4	PCB congeners

Computation of back trajectories, calculation of pollutant loadings with source region, estimates of transport losses, and comparison with mainland samples must wait until the sample analysis is completed.

Table 1: Sample analysis for heavy metals.

		Sample 2003-01 22-May-03	2003-02 22-May-03	2003-03 27-May-03	2003-04 4-Jul-03
Metals					
ALUMINUM EXTRACTABLE - ICP/MS	UG/L	35.5	53.2	11.9	25.6
ANTIMONY EXTRACTABLE - ICP/MS	UG/L	0.1	<0.1	<0.1	<0.1
ARSENIC EXTRACTABLE - ICP/MS	UG/L	1.1	1.9	0.6	1.1
BARIUM EXTRACTABLE - ICP/MS	UG/L	5.8	4.1	2.1	1.9
BERYLLIUM EXTRACTABLE - ICP/MS	UG/L	<0.1	<0.1	<0.1	<0.1
	UG/L	0.2	0.5	0.2	0.3
CADMIUM EXTRACTABLE - ICP/MS	UG/L	14.5	9	3.5	2
CHROMIUM EXTRACTABLE - ICP/MS	UG/L	0.4	0.6	0.2	0.1
COBALT EXTRACTABLE - ICP/MS	UG/L	5.1	6	3.3	6.3
COPPER EXTRACTABLE - ICP/MS	MG/L	0.16	0.19	0.07	0.1
IRON EXTRACTABLE - ICP/MS	UG/L	5.5	4.2	1.9	2.2
LEAD EXTRACTABLE - ICP/MS	UG/L	14.4	18.1	7	3.4
MANGANESE EXTRACTABLE - ICP/MS	UG/L	0.3	0.3	0.1	0.2
MOLYBDENUM EXTRACTABLE - ICP/MS	UG/L	28	44	19.4	7.5
NICKEL EXTRACTABLE - ICP/MS	UG/L	50.5	27.1	24.3	82.2
STRONTIUM EXTRACTABLE - ICP/MS	UG/L	1.2	2.5	1.2	1.9
TITANIUM EXTRACTABLE - ICP/MS	UG/L	1.9	3.6	1.5	1.5
VANADIUM EXTRACTABLE - ICP/MS	UG/L	32.8	63.6	22.7	40.6
ZINC EXTRACTABLE - ICP/MS	UG/L	<0.1	<0.1	<0.1	<0.1
SILVER EXTRACTABLE - ICP/MS					

Table 1 (cont'd): Sample analysis for heavy metals.

Metals	2003-05 5-Jul-03	2003-06 6-Jul-03	2003-07 7-Aug-03	2003-08 7-Aug-03	2003-09 7-Aug-03
ALUMINUM EXTRACTABLE - ICP/MS	43.1	5.8	7.9	68.7	17.4
ANTIMONY EXTRACTABLE - ICP/MS	0.1	<0.1	<0.5	<0.5	<0.5
ARSENIC EXTRACTABLE - ICP/MS	<0.5	<0.5	<0.3	0.9	0.4
BARIUM EXTRACTABLE - ICP/MS	7	1.3	4.1	5.2	2.7
BERYLLIUM EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.4	<0.4	<0.4
CADMIUM EXTRACTABLE - ICP/MS	0.6	<0.1	<0.2	<0.2	<0.2
CHROMIUM EXTRACTABLE - ICP/MS	6.8	0.8	1.5	9.5	4.3
COBALT EXTRACTABLE - ICP/MS	0.3	<0.1	<0.4	0.7	<0.4
COPPER EXTRACTABLE - ICP/MS	10.1	6.7	6.8	21.7	9.1
IRON EXTRACTABLE - ICP/MS	0.1	0	<0.05	0.19	<0.05
LEAD EXTRACTABLE - ICP/MS	6.2	1.9	0.7	3.6	1.1
MANGANESE EXTRACTABLE - ICP/MS	357.8	5.5	5.8	19.1	7
MOLYBDENUM EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.7	<0.7	<0.7
NICKEL EXTRACTABLE - ICP/MS	16.8	3.4	9.9	66.2	18.3
STRONTIUM EXTRACTABLE - ICP/MS	12.5	2.4	3.9	38.1	13.1
TITANIUM EXTRACTABLE - ICP/MS	0.7	0.3	<0.3	1.9	0.5
VANADIUM EXTRACTABLE - ICP/MS	1	0.8	<0.5	1.4	<0.5
ZINC EXTRACTABLE - ICP/MS	436.3	17.7	14.8	19.8	18.2
SILVER EXTRACTABLE - ICP/MS	<0.1	<0.1	<4.5	<4.5	<4.5

Table 1 (cont'd): Sample analysis for heavy metals.

	SIS. 9-Aug-03	2003-11 12-Sep-03	# 0405 8-Jul-04	P0401 30-Jun-04	P0404 30-Jun-04
Metals					
ALUMINUM EXTRACTABLE - ICP/MS	17.5	14.6	24.1	21.6	6.3
ANTIMONY EXTRACTABLE - ICP/MS	<0.5	0.1	<0.1	0.2	<0.1
ARSENIC EXTRACTABLE - ICP/MS	0.5	0.4	0.9	0.3	<0.1
BARIUM EXTRACTABLE - ICP/MS	2.4	2.6	3.5	1.9	0.8
BERYLLIUM EXTRACTABLE - ICP/MS	<0.4	<0.1	<0.1	<0.1	<0.1
CADMIUM EXTRACTABLE - ICP/MS	<0.2	<0.1	0.2	0.3	<0.1
CHROMIUM EXTRACTABLE - ICP/MS	4.4	1.5	1.1	0.9	0.5
COBALT EXTRACTABLE - ICP/MS	<0.4	0.5	0.4	13.2	0.1
COPPER EXTRACTABLE - ICP/MS	9.3	8.6	9.6	50.5	4
IRON EXTRACTABLE - ICP/MS	<0.05	<0.02	0.03	0.02	<0.02
LEAD EXTRACTABLE - ICP/MS	1.6	0.8	0.6	2.5	1
MANGANESE EXTRACTABLE - ICP/MS	10.4	15.3	12.1	2.4	1
MOLYBDENUM EXTRACTABLE - ICP/MS	<0.7	0.1	0.1	<0.1	<0.1
NICKEL EXTRACTABLE - ICP/MS	20.3	39.2	24.3	5.2	1.8
STRONTIUM EXTRACTABLE - ICP/MS	19.4	14.3	78.2	1.2	2
TITANIUM EXTRACTABLE - ICP/MS	<0.3	0.2	1.6	0.1	<0.1
VANADIUM EXTRACTABLE - ICP/MS	0.9	0.7	0.9	0.9	0.6
ZINC EXTRACTABLE - ICP/MS	17.8	16.9	19.9	53.1	5.9
SILVER EXTRACTABLE - ICP/MS	<4.5	<0.1	<0.1	<0.1	<0.1

Table 1 (cont'd): Sample analysis for heavy metals.

	P0406 17-Aug-04	P0407 31-Aug-04	P0409 7-Sep-04	P0412 21-Sep-04
Metals				
ALUMINUM EXTRACTABLE - ICP/MS	12.9	5.1	2	3.9
ANTIMONY EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.1	<0.1
ARSENIC EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.1	0.6
BARIUM EXTRACTABLE - ICP/MS	0.9	0.3	0.2	0.5
BERYLLIUM EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.1	<0.1
CADMIUM EXTRACTABLE - ICP/MS				
CHROMIUM EXTRACTABLE - ICP/MS	0.2	<0.1	<0.1	<0.1
COBALT EXTRACTABLE - ICP/MS	1	<0.4	<0.4	<0.4
COPPER EXTRACTABLE - ICP/MS	0.3	<0.1	<0.1	<0.1
IRON EXTRACTABLE - ICP/MS	9.5	2.6	0.7	1.2
LEAD EXTRACTABLE - ICP/MS	<0.02	<0.02	<0.02	<0.02
MANGANESE EXTRACTABLE - ICP/MS	1.6	1.1	0.5	0.6
MOLYBDENUM EXTRACTABLE - ICP/MS	2.1	0.3	0.3	1.3
NICKEL EXTRACTABLE - ICP/MS	<0.1	<0.1	<0.1	<0.1
STRONTIUM EXTRACTABLE - ICP/MS	6.3	0.3	0.2	0.8
TITANIUM EXTRACTABLE - ICP/MS	2.6	0.6	0.9	52.3
VANADIUM EXTRACTABLE - ICP/MS	0.1	<0.1	<0.1	0.3
ZINC EXTRACTABLE - ICP/MS	0.2	0.1	<0.1	0.9
SILVER EXTRACTABLE - ICP/MS	5.6	4.9	1.7	2.6
	<0.1	<0.1	<0.1	<0.1

Table 2: Sample analysis for PAH.

		7-Aug-03	13-Aug-04	8-Jul-04	19-Jul-04
Poly Aromatic Hydrocarbons (PAH's)					
NAPHTHALENE	UG/L	<0.04	<0.040	<0.040	<0.040
ACENAPHTHYLENE	UG/L	<0.02	<0.02	<0.02	<0.02
ACENAPHTHENE	UG/L	<0.04	<0.040	<0.040	<0.040
FLUORENE	UG/L	<0.03	<0.030	<0.030	<0.030
PHENANTHRENE	UG/L	0.02	0.006	<0.010	0.009
ANTHRACENE	UG/L	<0.02	0.008	<0.020	0.012
FLUORANTHENE	UG/L	<0.01	0.011	<0.010	0.019
PYRENE	UG/L	<0.02	0.006	<0.020	<0.020
BENZ(A)ANTHRACENE	UG/L	<0.02	<0.020	<0.020	<0.020
CHRYSENE	UG/L	<0.01	0.004	<0.012	<0.012
BENZO(B)FLUORANTHENE	UG/L	<0.03	<0.030	<0.030	<0.030
BENZO(K)FLUORANTHENE	UG/L	<0.02	<0.02	<0.02	<0.02
BENZO(A)PYRENE	UG/L	<0.02	<0.020	<0.020	<0.020
INDEN0(1,2,3-C,D)PYRENE	UG/L	<0.04	<0.040	<0.040	<0.040
DIBENZ(A,H)ANTHRACENE	UG/L	<0.04	<0.040	<0.040	<0.040
BENZO(G,H,I)PERYLENE	UG/L	<0.04	<0.040	<0.040	<0.040

Table 3: Sample analysis for Organochlorines.

Organochlorine Pesticides (OC's)		7-Aug-03	13-Aug-04	8-Jul-04	19-Jul-04
ALDRIN	NG/L	<9	<2	<2	<2
ALPHA-BENZENEHEXACHLORIDE	NG/L	<14	4	<9	<9
ALPHA-CHLORDANE	NG/L	<8	<8	<8	<8
GAMMA-CHLORDANE	NG/L	<11	<11	<11	<11
O,P'-DDD	NG/L	<11	<11	<11	<11
P,P'-DDD	NG/L	<9	<9	<9	<9
O,P'-DDE	NG/L	<6	<6	<6	<6
P,P'-DDE	NG/L	<10	<10	<10	<10
O,P'-DDT	NG/L	<7	<7	<7	<7
P,P'-DDT	NG/L	<9	<9	<9	<9
DIELDRIN	NG/L	<7	<7	<7	<7
ALPHA-ENDOSULFAN	NG/L	<42	<42	<42	<42
BETA-ENDOSULFAN	NG/L	<6	<6	<6	<6
ENDRIN	NG/L	<10	<10	<10	<10
HEPTACHLOR EPOXIDE	NG/L	<9	<9	<9	<9
GAMMA-BENZENEHEXACHLORIDE	NG/L	<4	<4	<4	<4
P,P'-METHOXYCHLOR	NG/L	<13	<13	<13	<13
MIREX	NG/L	<12	<12	<12	<12

Table 4: Sample analysis for PCB congeners

PCB Congeners		7-Aug-03	13-Aug-04	8-Jul-04	19-Jul-04
2,4'-DICHLOROBIPHENYL (PCB 8) IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',5-TRICHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,4,4'-TRICHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,4,5-TRICHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,5'-TETRACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',4,6-TETRACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',5,5'-TETRACHLORIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,3',4,4'-TETRACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
3,3',4,4'-TETRACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,4,5'-PENTACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',4,5,5'-PENTACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,3,3',4,4'-PENTACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,3',4,4',5-PENTACHLRBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,3',4,4'-HEXCHLRBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,4,4',5'-HEXCHLRBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',4,4',5,5'-HEXCHLRBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,3',4,4',5-HEPCHLRBIPHNL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,4,4',5,5'-HEPCHLRBIPHNL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,4',5,5',6-HEPCHLRBIPHNL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,3',4,4',5,6-OCTCHLRBIPHNL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
2,2',3,3',4,4',5,5',6-NONCHLRBIPHN/WATER	NG/L	<10.0	<10.0	<10.0	<10.0
DECACHLOROBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
3,3',4,4',5,5'-HEXCHLRBIPHENL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0
3,3',4,4',5-PENTACHLORBIPHENYL IN WATER	NG/L	<10.0	<10.0	<10.0	<10.0