

RISK ASSESSMENT
FOR THE COMBUSTION PRODUCTS OF
METHYLCYCLOPENTADIENYL MANGANESE TRICARBONYL
(MMT)
IN GASOLINE

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Part I – Chapters 1-6; References

Part II – Figures; Tables; Appendix

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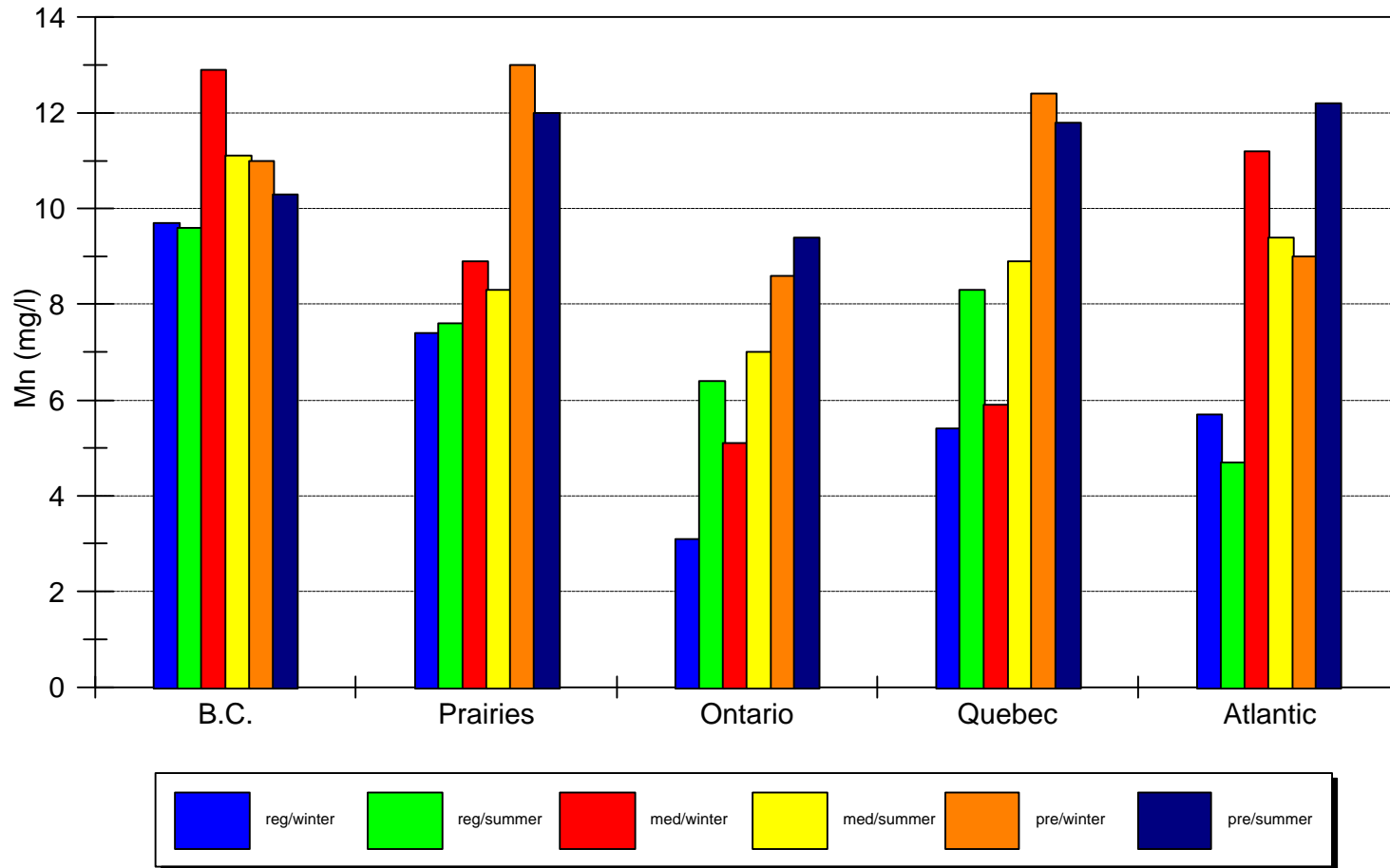
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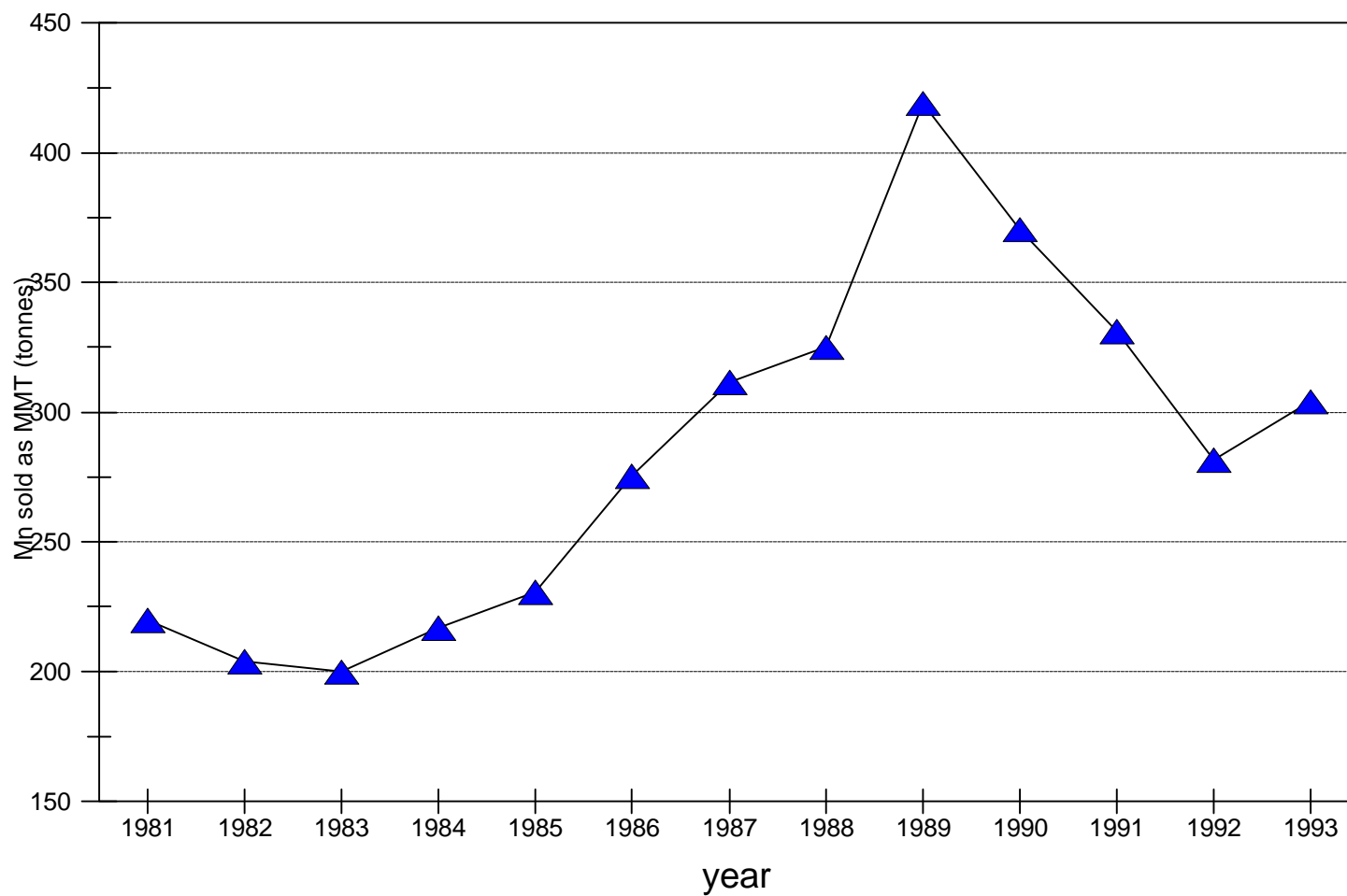
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**Fig.1. Mn in Canadian gasoline in 1993
(regular, medium and premium blends)**

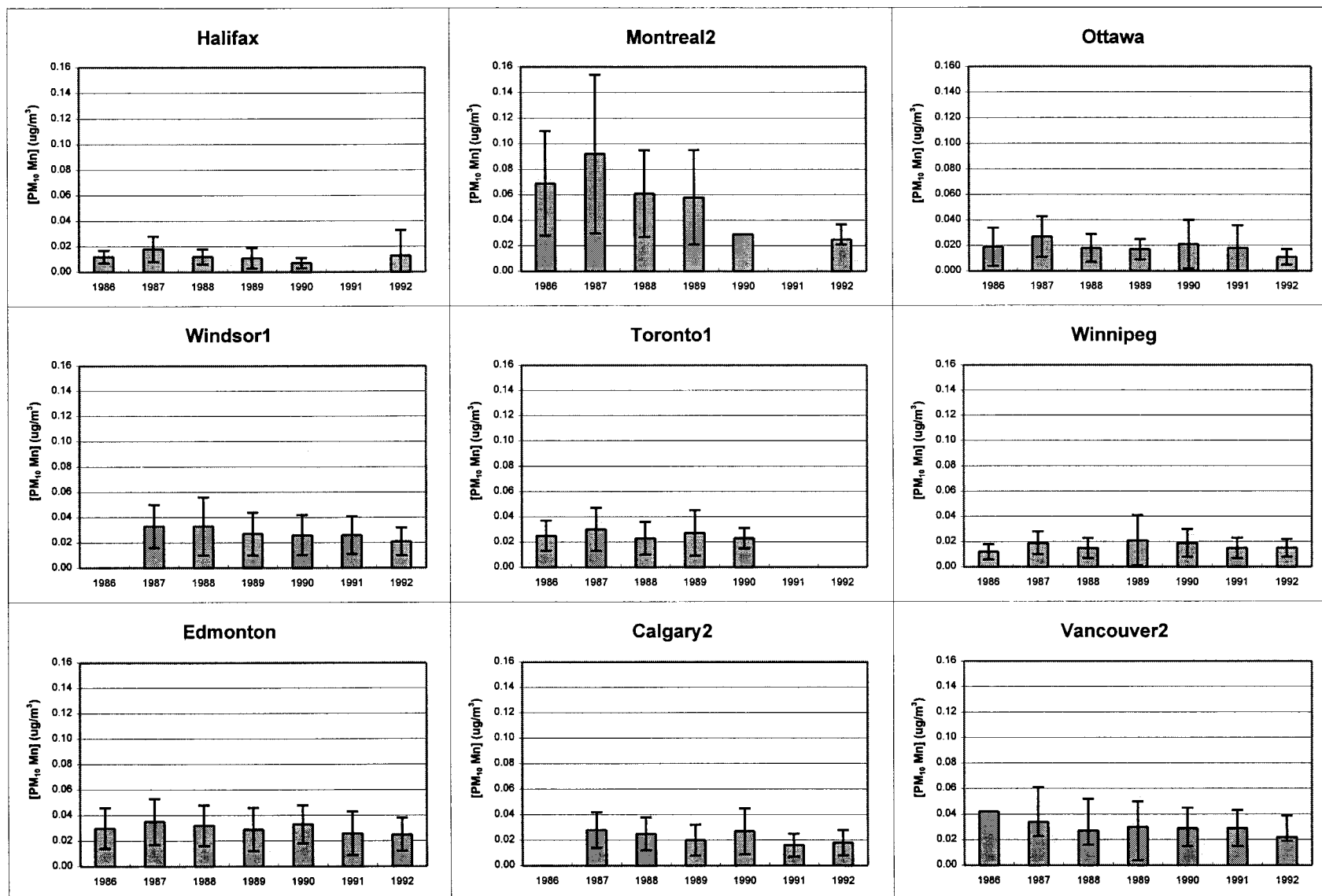


Based on data in CPPI (1994)

Fig.2. Manganese sold as MMT in Canada

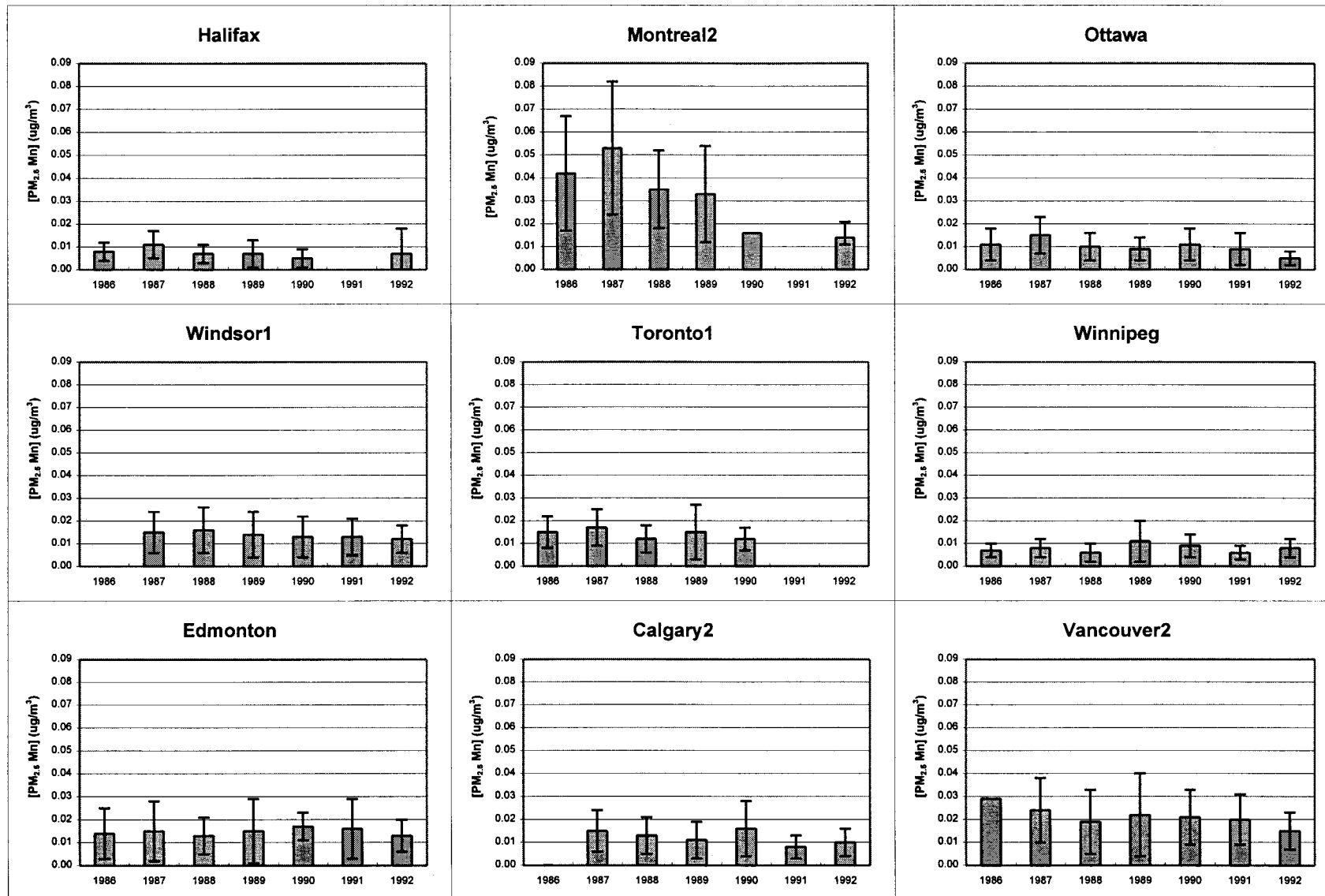
²Data represent Ethyl Corp. sales only (provided by Wilson 1994)

Fig. 3. Trends in ambient PM₁₀ manganese levels in Canadian cities (1986-1992)



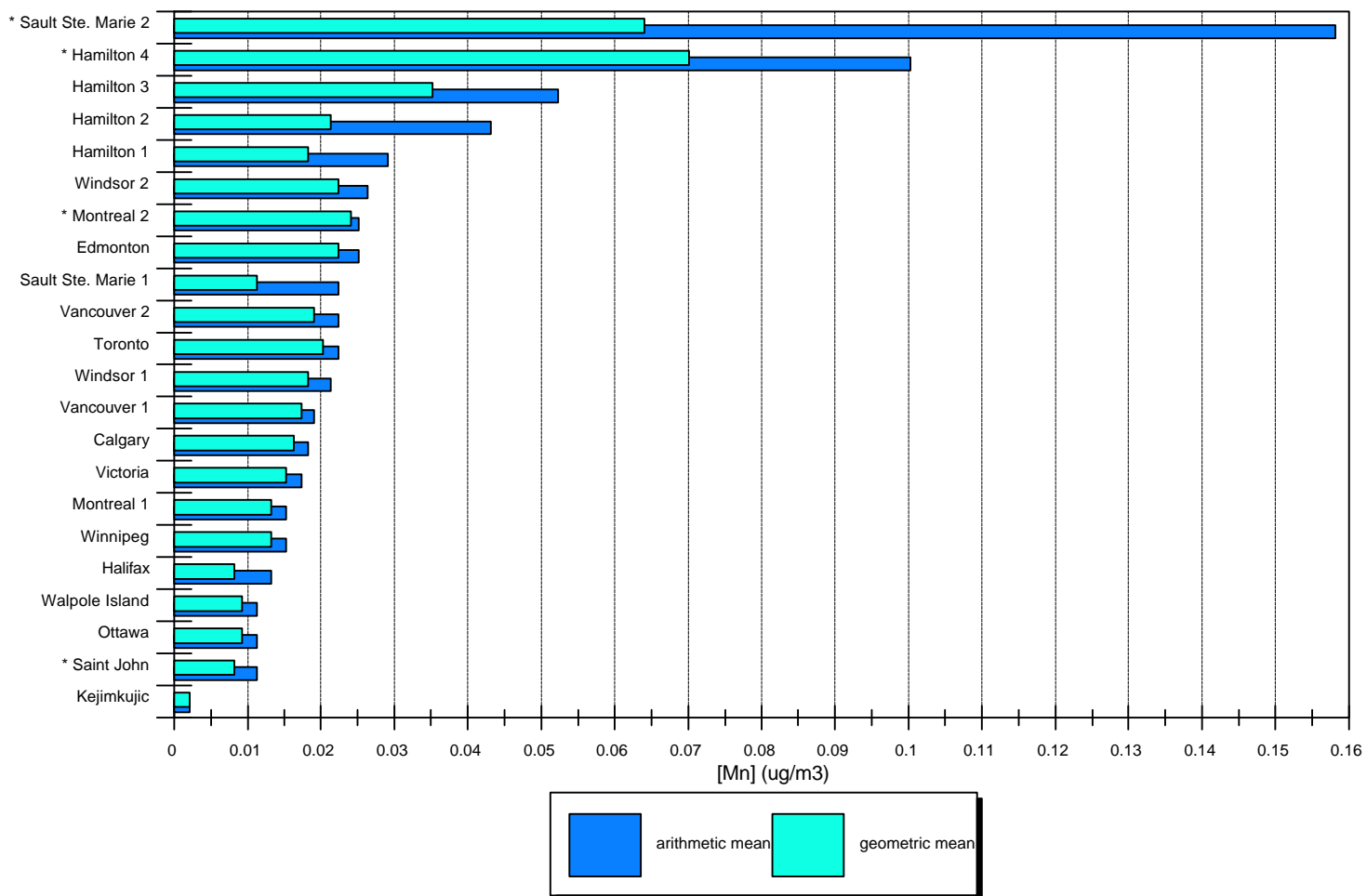
arithmetic mean +/- s.d.: based on original data provided by T. Dann (1994b)

Fig. 4. Trends in ambient PM_{2.5} manganese levels in Canadian cities (1986-1992)



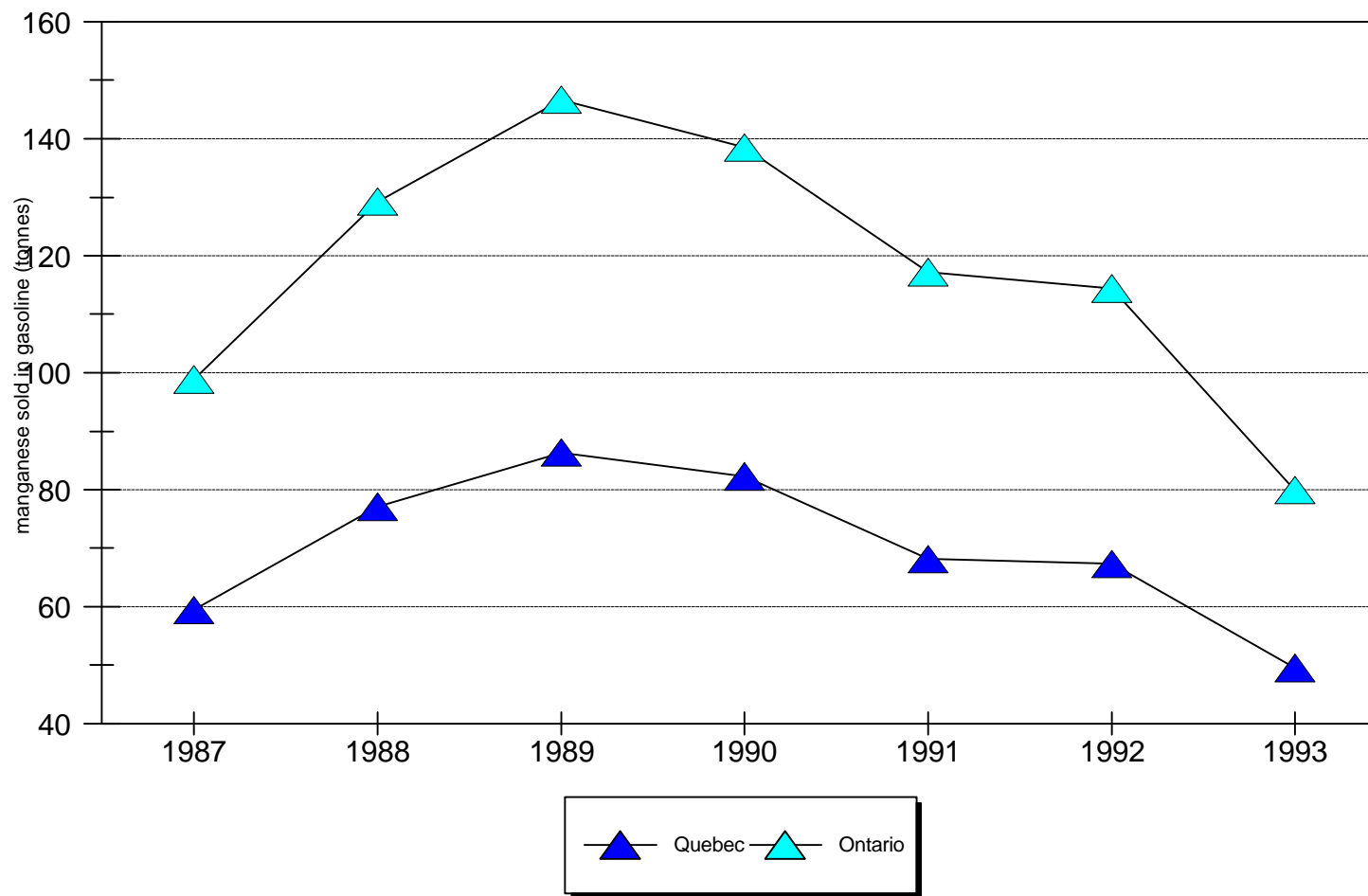
arithmetic mean +/- s.d.: based on original data provided by T. Dann (1994b)

Fig.5. Annual mean PM10 manganese in ambient air (1992)



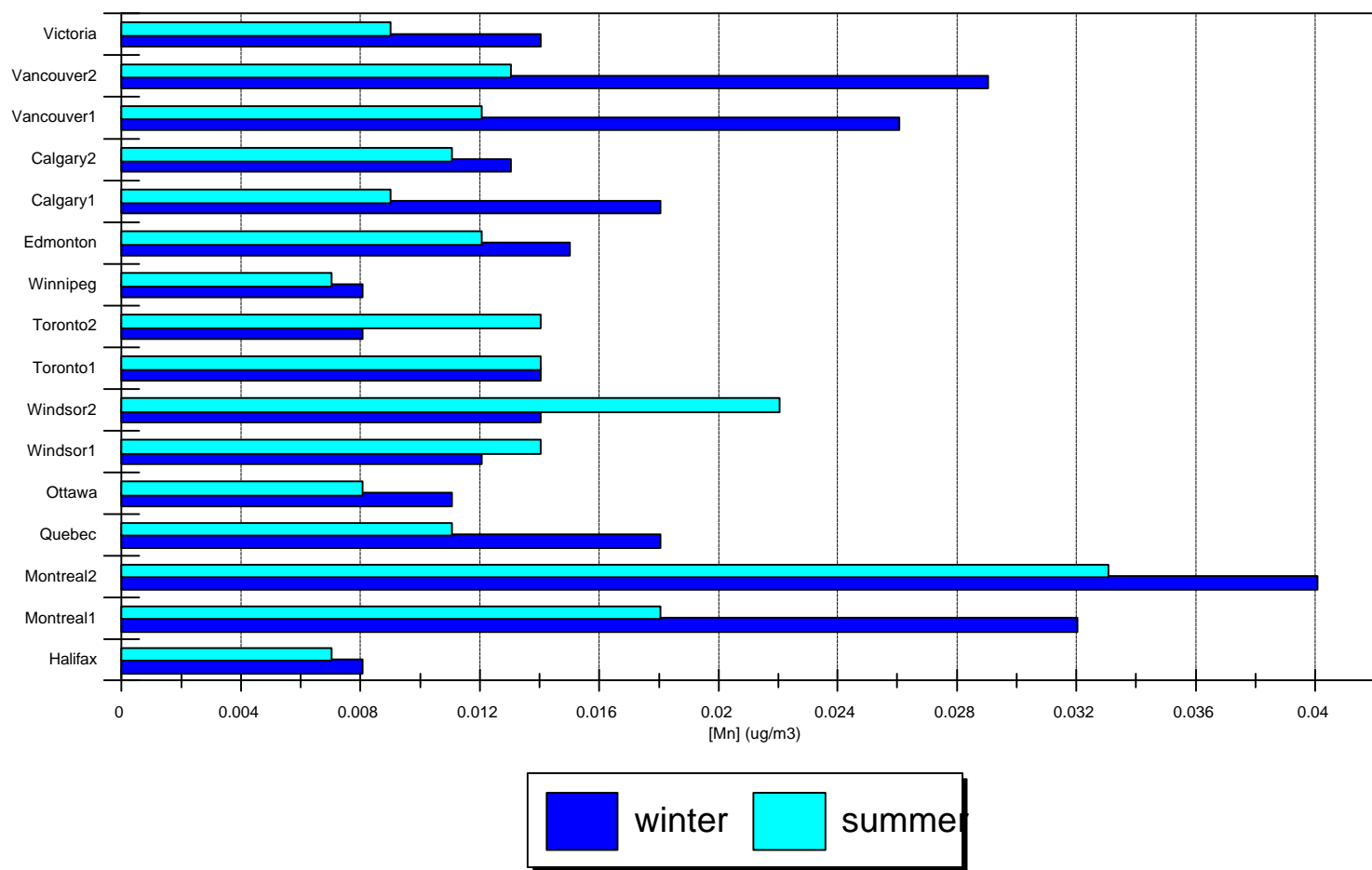
³*=sites used in exposure assessment. Data from OMOEE (1993) and from original data provided by Dann (1994b).

**Fig. 6. Manganese sold as MMT in
unleaded gasoline in Quebec & Ontario**



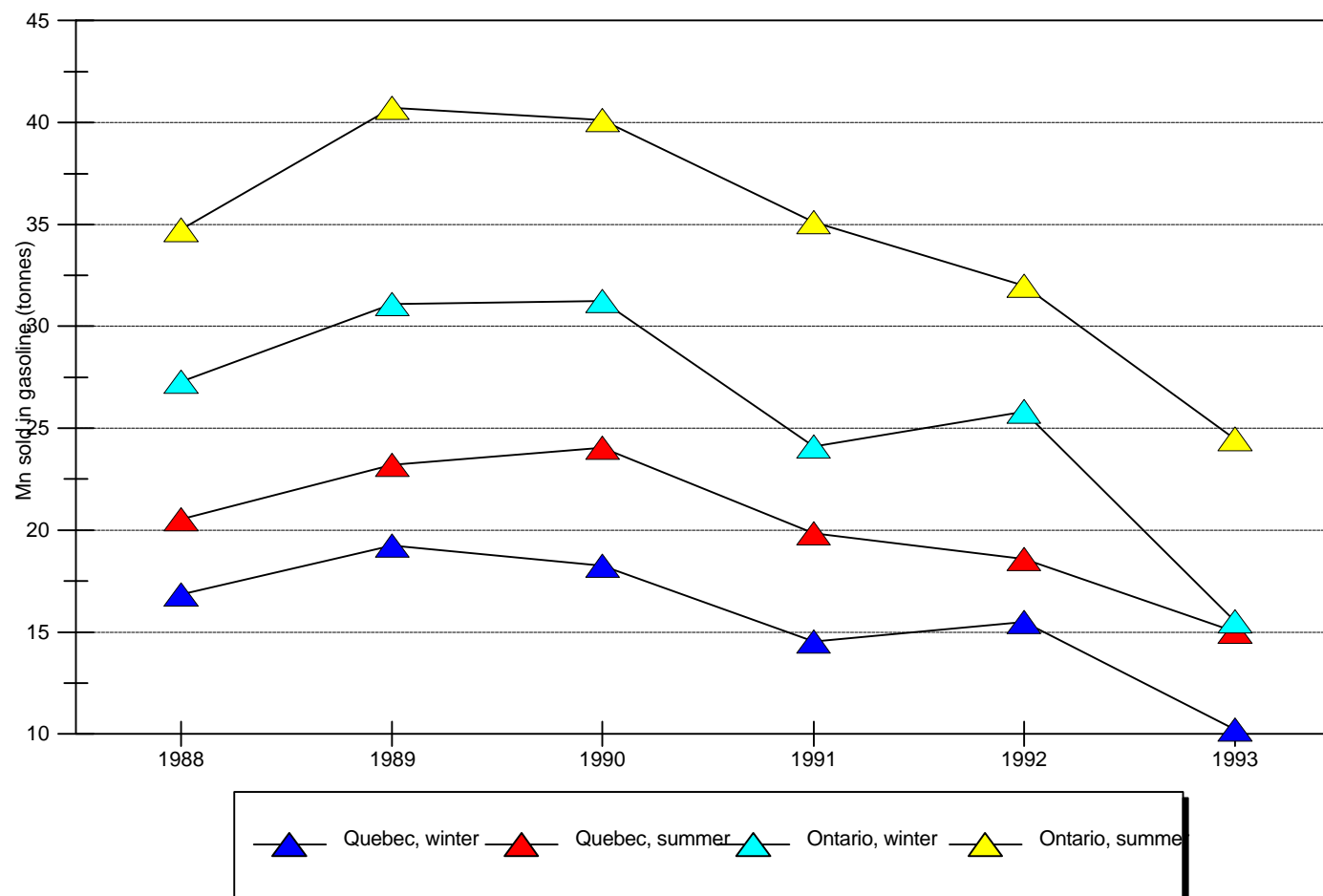
⁴Based on fuel sales including leaded premium fuel

**Fig.7. Annual mean PM2.5 manganese
(1986-1993) in winter and summer**



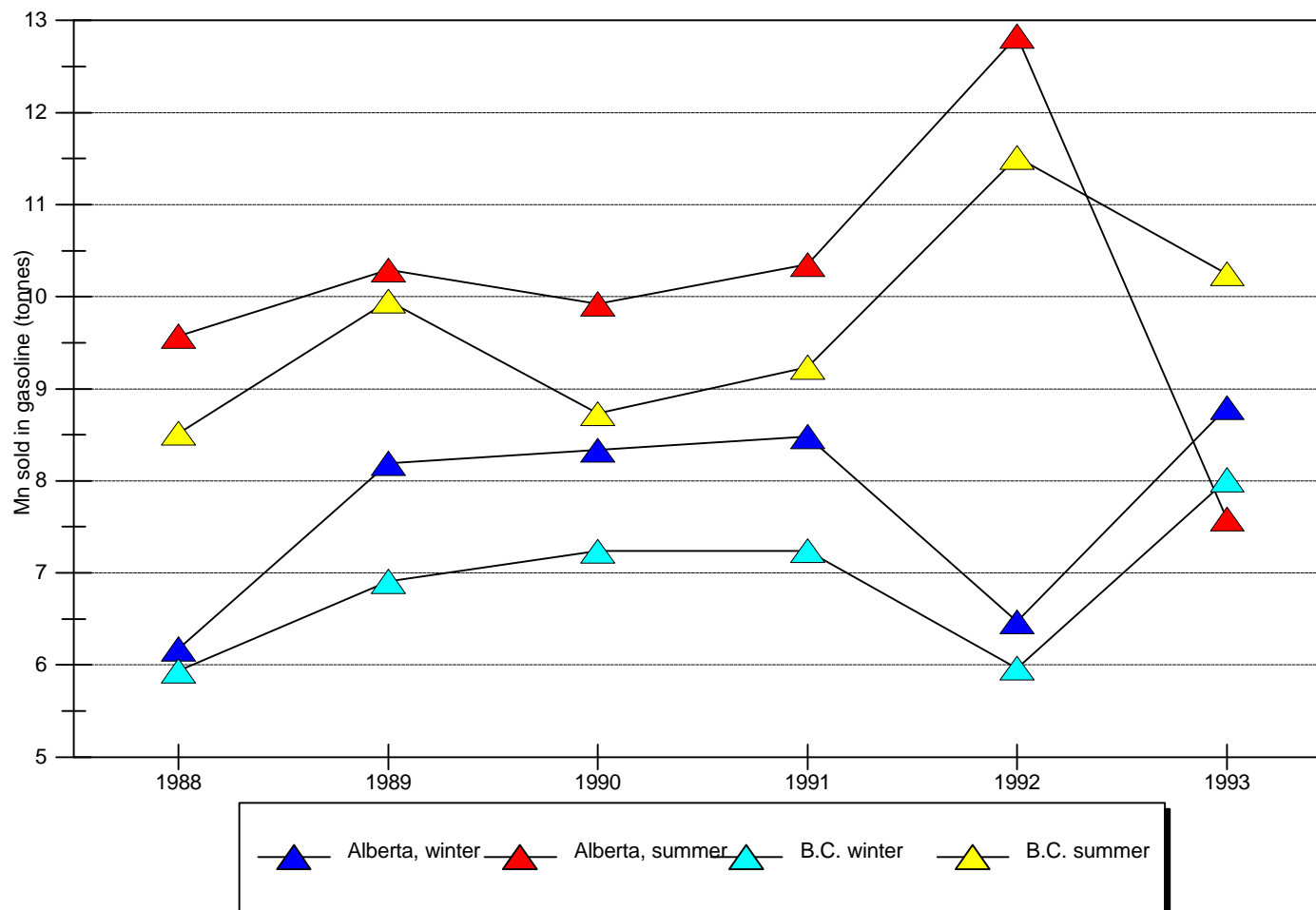
⁵Winter=December, January, February; summer=June, July, August; means are annual arithmetic means

**Fig.8. Seasonal patterns of MMT use in
Quebec and Ontario**



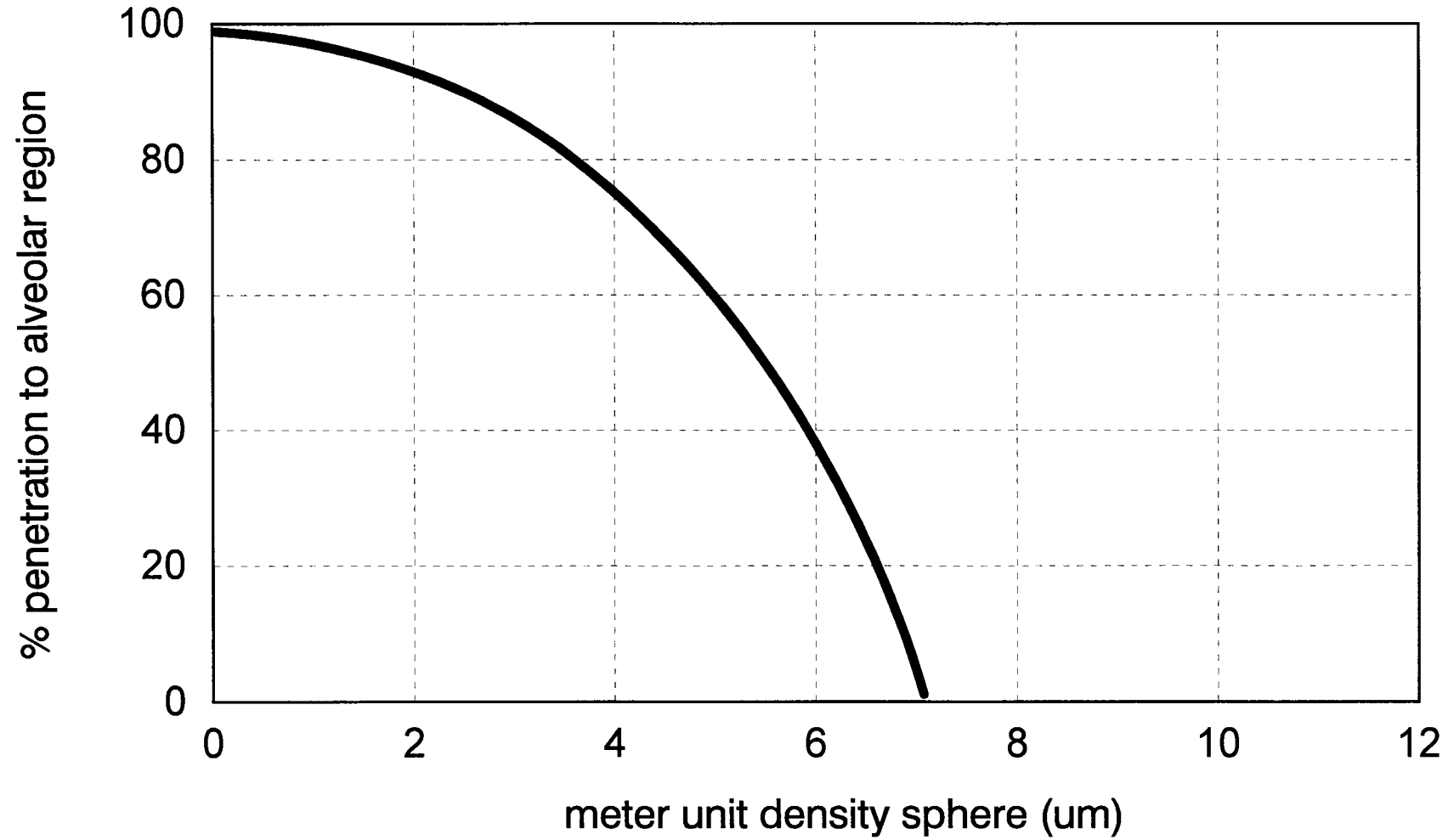
⁶Winter=December, January, February; summer=June, July, August

**Fig.9. Seasonal patterns of MMT use in
Alberta and British Columbia**



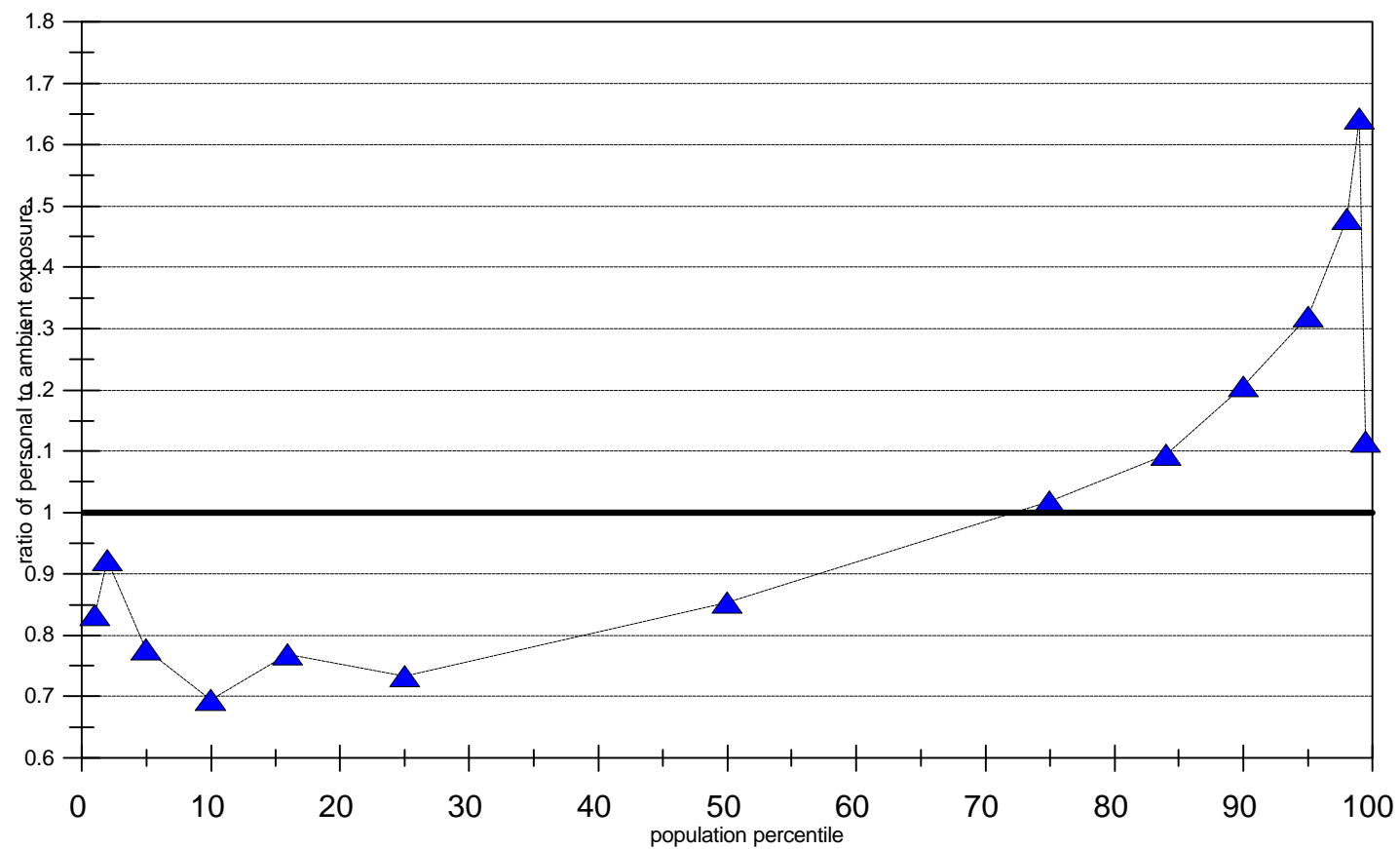
⁷winter=December, January, February; summer=June, July, August

Figure 10. BMRC defining curve for respirable particulates



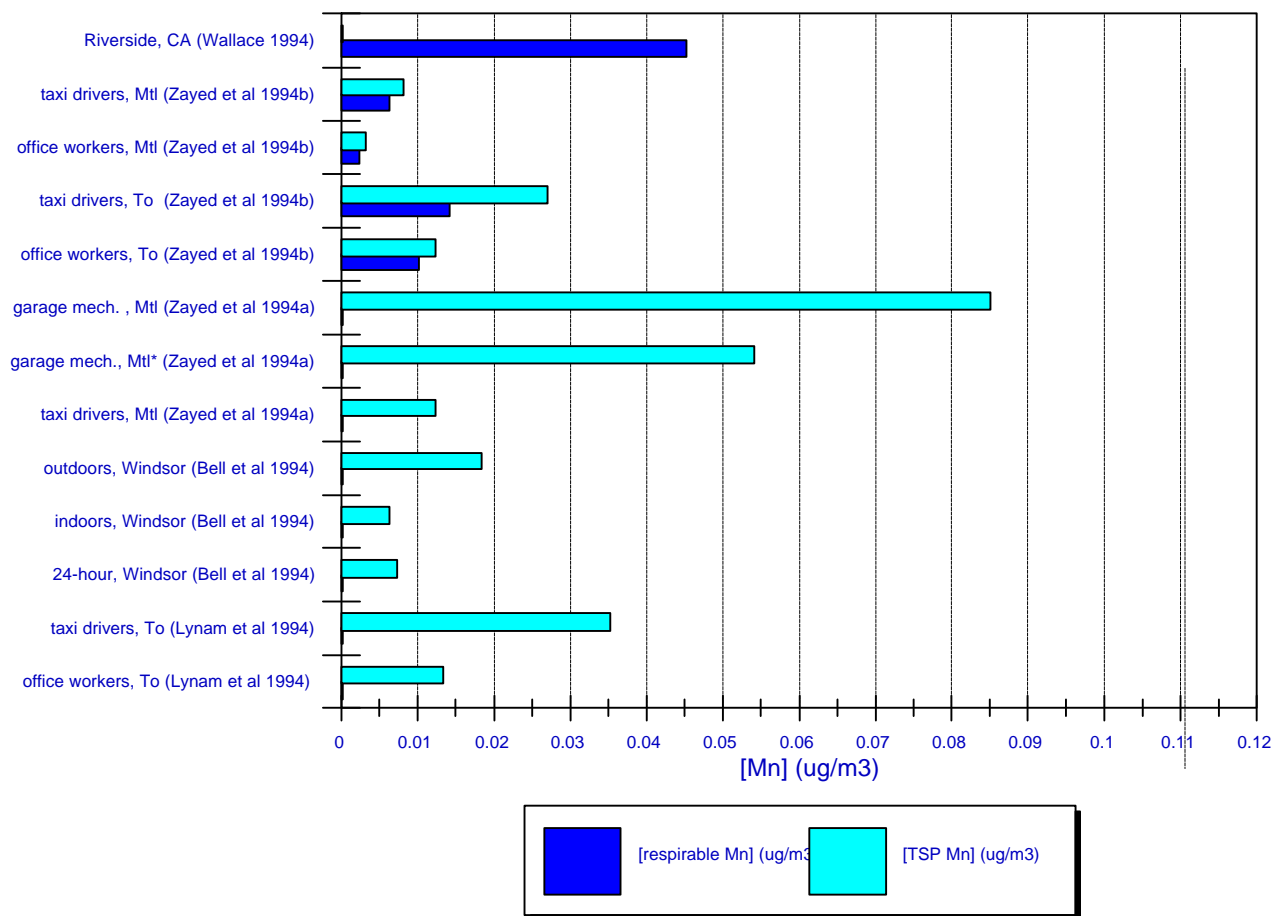
Adapted from ACGIH (1971)

**Fig.11. Ratio of personal to ambient
PM10 Mn exposure in Riverside, CA**



⁸Based on 24-hour monitoring data of PTEAM study

Fig.12. Estimates of 24-hour personal exposure to manganese



⁹*Under ventilated conditions

Table 1. Canadian emissions inventory for manganese based on data from 1984* (tonnes)

Sector	Nfld.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Terr.	Canada	% of total
Industrial Processes:													
manganese-bearing alloy production					576							576	47
primary iron and steel production			6		57	229	6	21	16	2		337	27.5
iron and steel foundries		<1	1	<1	6	29	2	<1	1	1		40	3.3
primary copper and nickel production					<1	<1	<1			<1		<1	<0.1
primary zinc production					<1	<1	<1			<1		<1	<0.1
battery manufacturing						<1	<1					1	0.1
cement manufacturing	<1		<1	<1	4	1	<1	<1	1	<1		7	0.6
metallurgical coke manufacturing			<1			<1		<1		<1		<1	<0.1
non-ferrous alloys					<1	<1						<1	<0.1
welding rods					<1	<1						<1	<0.1
miscellaneous sources													
Fuel Combustion, Stationary Sources:													
power generation	<1	<1	<1	<1	<1	4	<1	4	5	<1	<1	14	1.2
industrial fuel combustion	<1	<1	<1	<1	<1	1	1	<1	<1	<1	<1	3	0.2
commercial fuel combustion	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.1
residential fuel combustion	<1	<1	2	<1	<1	<1	<1	<1	1	<1	<1	3	0.2
Fuel Combustion, Transportation Sources:													
gasoline-powered motor vehicles**	4	1	7	7	42	71	10	12	29	27	1	211	17.2
Solid Waste Incineration:													
municipal refuse incineration		<1			3	2				<1		5	0.4
sewage sludge incineration						<1				<1		<1	<0.1
Miscellaneous Sources:													
pesticide application												28	2.3
Total	4	1	17	7	688	338	20	37	53	31	1	1225	100

* Based on data presented in Jaques (1987)

** Assumes that 100% of manganese in MMT is emitted from the tailpipe

Table 2. Dose-Response Relationship, Respirable Mn Dust Cumulative Exposure and Abnormal Psychomotor Performance‡

	control	quartile 1	quartile 2	quartile 3	quartile 4	total
N ^a	101	23	23	23	23	92
LIRD, ^b integrated respirable dust, $\mu\text{g}/\text{m}^3$ -years	--	264	647	1277	2606	793
range	--	40-516	516-859	902-1665	1729-4433	40-4433
average # of years ^c	--	2.6	3.3	5.9	8.9	5.3
adjusted integrated exposure, ^d $\mu\text{g}/\text{m}^3$	--	101.5	196.1	216.4	292.3	201.6
VRT^e % (# of individuals)	1 (1/101) (p=1.0) ^h	4.3 (1/23) (p=0.34) n.s.	8.7 (2/23) (p=0.09) n.s.	0 (0/23) (p=1.0) n.s.	17.4 (4/23) (p=0.004) *	7.6 (7/92) *
EHC^f % (# of individuals)	5 (5/101) (p=1.0)	8.7 (2/23) (p=0.6) n.s.	43.5 (10/23) (p<0.001) *	13.0 (3/23) (p=0.17) n.s.	26.1 (6/23) (p=0.005) *	22.8 (21/92) *
HST^g % (# of individuals)	4 (4/101) (p=1.0)	4.3 (1/23) (p<1.0) n.s.	8.7 (2/23) (p=0.31) n.s.	17.4 (4/23) (p=0.038) *	21.7 (5/23) (p=0.01) *	13.0 (12/92) *
2 or more, % (# of individuals)	1 (1/101) (p=1.0)	0 (0/23) (p=1.0) n.s.	8.7 (2/23) (p=0.09) n.s.	8.7 (2/23) (p=0.09) n.s.	26.1 (6/23) (p=0.0001) *	10.9 (10/92) *

‡ Data from Roels, *et al.*, 1992; Roels, 1993

a N = Number of individuals examined

b LIRD - Lifetime Integrated Respirable Dust

c Average (arithmetic) number of years worked per group

d LIRD converted to an annual average from an 8-hour shift

e VRT - Visual Reaction Time; percent and number of abnormal responses

f EHC - Eye-Hand Coordination; percent and number of abnormal responses

g HST - Hand Steadiness; percent and number of abnormal responses

h Statistical significance tested by Fisher's Exact Test for difference from control

* Statistically significant at level indicated

n.s. not significant

Table 3. Population distribution of 24-hour personal exposure measures (PEM) and stationary ambient measures (SAM) of PM10 manganese in Riverside, California.

percentile	PEM (ug Mn/m3)	SAM (ug Mn/m3)	PEM measure:SAM arithmetic mean
1	0.010	0.012	0.22
2	0.012	0.013	0.27
5	0.014	0.018	0.31
10	0.016	0.023	0.36
16	0.020	0.026	0.44
25	0.022	0.030	0.49
50	0.035	0.041	0.78
75	0.056	0.055	1.24
84	0.069	0.063	1.53
90	0.082	0.068	1.82
95	0.103	0.078	2.29
98	0.145	0.098	3.22
99	0.212	0.129	4.71
99.5	0.241	0.216	5.36
arithmetic mean	0.045	0.045	1.00

Based on original data provided by Wallace (1994)

Table 4. Annual (1992) ambient air PM10 Mn concentrations

measure	Ambient Mn measurements (ug/m3)			
	St. John	Montreal 2	Hamilton 4	Sault Ste. Marie 2
arithmetic mean	0.011	0.025	0.100	0.158
90th %	0.021	0.034	0.230	0.440
99th %	0.024	0.041	0.370	0.832

Based on data in OMOEE (1993) and original data from Dann (1994)

Table 5. Inhalation exposure to PM10 manganese based on ambient monitoring data

measure	0-6 months**				7months-4 years***				5-11 years****				12-19 years*****				20+ years *****				
	SJ^	MTL^	HAM^	SSM^	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	
uptake* (ug/day)																					
ar. x	0.013	0.030	0.120	0.190	0.033	0.075	0.300	0.474	0.079	0.180	0.720	1.138	0.139	0.315	1.260	1.991	0.152	0.345	1.380	2.180	
90th %	0.025	0.041	0.276	0.528	0.063	0.102	0.690	1.320	0.151	0.245	1.656	3.168	0.265	0.428	2.898	5.544	0.290	0.469	3.174	6.072	
99th %	0.029	0.049	0.444	0.998	0.072	0.123	1.110	2.496	0.173	0.295	2.664	5.990	0.302	0.517	4.662	10.483	0.331	0.566	5.106	11.482	
uptake* (ug/kg bw/day)																					
ar. x	0.002	0.004	0.017	0.027	0.003	0.006	0.023	0.036	0.003	0.007	0.027	0.042	0.002	0.006	0.022	0.035	0.002	0.005	0.020	0.031	
90th %	0.004	0.006	0.039	0.075	0.005	0.008	0.053	0.102	0.006	0.009	0.061	0.117	0.005	0.008	0.051	0.097	0.004	0.007	0.045	0.087	
99th %	0.004	0.007	0.063	0.143	0.006	0.009	0.085	0.192	0.006	0.011	0.099	0.222	0.005	0.009	0.082	0.184	0.005	0.008	0.073	0.164	

^: SJ=St. John; MTL=Montreal; HAM=Hamilton; SSM=Sault Ste. Marie

* : assuming 60% deposition in the pulmonary region, and 100% absorption of manganese deposited in the pulmonary region

** : assuming air intake of 2 m3/day and body weight of 7 kg (Health Canada 1994)

*** : assuming air intake of 5 m3/day and body weight of 13 kg (Health Canada 1994)

**** : assuming air intake of 12 m3/day and body weight of 27 kg (Health Canada 1994)

***** : assuming air intake of 21 m3/day and body weight of 57 kg (Health Canada 1994)

***** : assuming air intake of 23 m3/day and body weight of 70 kg (Health Canada 1994)

Table 6. Estimates of population personal exposure for 1992 based on extrapolation from PTEAM data

measure	Mn personal exposure levels (ug/m3)			
	St. John	Montreal 2	Hamilton 4	Sault Ste. Marie 2
arithmetic mean	0.011	0.025	0.100	0.158
90th %	0.020	0.046	0.183	0.289
99th %	0.052	0.118	0.473	0.747

Table 7. Inhalation exposure to PM10 manganese based on estimates of personal exposure derived from the PTEAM study

measure	0-6 months **				7months-4 years***				5-11 years ****				12-19 years*****				20+ years*****			
	SJ^	MTL^	HAM^	SSM^	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
uptake* (ug/day)																				
ar. x	0.013	0.030	0.120	0.190	0.033	0.075	0.300	0.474	0.079	0.180	0.720	1.138	0.139	0.315	1.260	1.991	0.152	0.345	1.380	2.180
90th %	0.024	0.055	0.220	0.347	0.060	0.137	0.549	0.867	0.145	0.329	1.318	2.082	0.254	0.576	2.306	3.643	0.278	0.631	2.525	3.990
99th %	0.062	0.142	0.568	0.897	0.156	0.355	1.419	2.242	0.375	0.851	3.406	5.381	0.656	1.490	5.960	9.416	0.718	1.632	6.527	10.313
uptake* (ug/kg bw/day)																				
ar. x	0.002	0.004	0.017	0.027	0.003	0.006	0.023	0.036	0.003	0.007	0.027	0.042	0.002	0.006	0.022	0.035	0.002	0.005	0.020	0.031
90th %	0.003	0.008	0.031	0.050	0.005	0.011	0.042	0.067	0.005	0.012	0.049	0.077	0.004	0.010	0.040	0.064	0.004	0.009	0.036	0.057
99th %	0.009	0.020	0.081	0.128	0.012	0.027	0.109	0.172	0.014	0.032	0.126	0.199	0.012	0.026	0.105	0.165	0.010	0.023	0.093	0.147

^: SJ=St. John; MTL=Montreal; HAM=Hamilton; SSM=Sault Ste. Marie

* : assuming 60% deposition in the pulmonary region, and 100% absorption of manganese deposited in the pulmonary region

** : assuming air intake of 2 m3/day and body weight of 7 kg (Health Canada 1994)

*** : assuming air intake of 5 m3/day and body weight of 13 kg (Health Canada 1994)

**** : assuming air intake of 12 m3/day and body weight of 27 kg (Health Canada 1994)

***** : assuming air intake of 21 m3/day and body weight of 57 kg (Health Canada 1994)

***** : assuming air intake of 23 m3/day and body weight of 70 kg (Health Canada 1994)

Table 8. Daily dietary manganese intakes reported in the literature

Age Group	Daily Mn Intake (mg/day)	Country	Reference
average adult	4.1	Canada	Méranger and Smith 1972
average adult	2.93	Canada (Winnipeg)	Kirkpatrick and Coffin 1977
adult pre-menopausal women	3.1	Canada	Gibson and Scythes 1982
elderly women	3.8	Canada	Gibson <i>et al.</i> 1985a
0-6 months 6-12 months	0.47-1.04 1.25-1.68	Canada	Kirkpatrick <i>et al.</i> 1980
22 months	1.5	Canada	Gibson <i>et al.</i> 1985b
blue-collar workers garage mechanics	3.7 2.9	Canada (Montréal)	Loranger and Zayed 1994
6-11 months 2 years 14-16 years, females 14-16 years, males 25-30 years, females 25-30 years, males 60-65 years, females 60-65 years, males	1.11 1.50 1.79 2.79 2.12 2.80 2.20 2.63	U.S.A.	Pennington <i>et al.</i> 1989
adult males adult females	3.4 2.7	U.S.A.	Patterson <i>et al.</i> 1984
1-4 years	1.29	U.S.A. (Mass.)	Stanek <i>et al.</i> 1988
national average	4.02	Britain	Lewis and Buss 1988
average adult	4.6	Britain	Wenlock <i>et al.</i> 1979
average adult	3.7	Sweden	Becker and Kumpulainen 1991
adult	2.6	Belgium	Buchet <i>et al.</i> 1983
9 months infant 2 years 12.5 years, females 12.5 years, males adult, females adult, males	1.06 2.11 3.91 5.08 2.96 5.53	Australia	Fardy <i>et al.</i> 1992
1-3 months (breastfed)	0.003-0.004	Finland	Vuori 1979

Table 9. Daily manganese consumption derived from individual foodstuffs

Foodstuff	Mn content (mg/100 g)	Mean consumption of foodstuffs (g/day)					Mean consumption of Mn (mg/day)					Percentage of total Mn derived from foodgroup				
		0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+
DAIRY PRODUCTS																
milk, whole	0.004	274.16	377.88	323.16	255.65	138.24	0.011	0.015	0.013	0.010	0.006	1.662	0.876	0.481	0.343	0.157
milk,2%	0.002	188.60	194.50	185.61	194.75	60.64	0.004	0.004	0.004	0.004	0.001	0.572	0.225	0.138	0.130	0.034
milk, skim	0.002	21.20	59.67	55.57	72.56	30.83	0.000	0.001	0.001	0.001	0.001	0.064	0.069	0.041	0.049	0.017
evap. milk, can.	0.006	59.78	12.04	6.54	7.06	11.46	0.004	0.001	0.000	0.000	0.001	0.543	0.042	0.015	0.014	0.019
cream, 10-12% bf	0.001	0.00	1.63	2.83	2.65	10.19	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.003
ice cream	0.006	1.37	15.35	25.59	25.78	12.80	0.000	0.001	0.002	0.002	0.001	0.012	0.053	0.057	0.052	0.022
yogurt	0.004	0.00	0.78	0.48	0.87	1.54	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.002
cheese, cheddar	0.01	0.11	2.56	3.18	5.66	8.33	0.000	0.000	0.000	0.001	0.001	0.002	0.015	0.012	0.019	0.024
cheese, cottage	0.003	0.00	1.73	1.33	1.74	5.35	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.002	0.005
cheese, proc. cheddar	0.015	0.06	3.59	4.92	6.43	3.81	0.000	0.001	0.001	0.001	0.001	0.001	0.031	0.027	0.032	0.016
butter	0.004	0.73	7.06	12.94	16.67	13.61	0.000	0.000	0.001	0.001	0.001	0.004	0.016	0.019	0.022	0.015
TOTAL DAIRY PRODUCTS		546.0	676.8	622.2	589.8	296.8	0.019	0.023	0.021	0.020	0.011	2.861	1.334	0.794	0.665	0.314
CEREAL & GRAIN PRODUCTS																
bread, white [US]	0.432	2.12	34.00	76.80	94.88	67.45	0.009	0.147	0.332	0.410	0.291	1.388	8.512	12.347	13.731	8.255
bread, wholewheat & rye [US]	1.561	0.00	5.49	6.47	7.43	19.76	0.000	0.086	0.101	0.116	0.308	0.000	4.966	3.759	3.885	8.738
rolls and biscuits [US]	0.43	0.00	3.64	11.63	15.92	10.00	0.000	0.016	0.050	0.068	0.043	0.000	0.907	1.861	2.293	1.218
flour, wheat	2.24	0.28	3.86	10.38	5.17	6.93	0.006	0.086	0.233	0.116	0.155	0.950	5.010	8.653	3.880	4.398
cake [US]	0.285	0.19	8.59	25.62	42.52	20.37	0.001	0.024	0.073	0.121	0.058	0.082	1.419	2.717	4.060	1.645
cookies	0.46	1.50	18.87	26.00	23.08	15.58	0.007	0.087	0.120	0.106	0.072	1.045	5.030	4.451	3.557	2.030
danish and donuts [US]	0.36	0.00	3.60	5.39	9.53	5.49	0.000	0.013	0.019	0.034	0.020	0.000	0.751	0.722	1.149	0.560
crackers [US]	0.724	0.04	4.83	5.14	5.67	3.45	0.000	0.035	0.037	0.041	0.025	0.044	2.026	1.385	1.375	0.708
pancakes [US]	0.367	0.00	2.16	2.93	3.37	2.04	0.000	0.008	0.011	0.012	0.007	0.000	0.459	0.400	0.414	0.212
cereals, cooked wheat [US]	0.52	13.50	13.94	5.72	4.73	6.53	0.070	0.072	0.030	0.025	0.034	10.637	4.201	1.107	0.824	0.962
cereals, oatmeal	0.585	33.12	20.86	19.95	12.26	16.44	0.194	0.122	0.117	0.072	0.096	29.357	7.072	4.343	2.403	2.725
cereals, corn	0.35	1.07	3.42	5.37	3.40	1.82	0.004	0.012	0.019	0.012	0.006	0.567	0.694	0.699	0.399	0.180
cereals wheat and bran	4.51	0.09	3.37	3.37	3.35	2.31	0.004	0.152	0.152	0.151	0.104	0.615	8.807	5.656	5.061	2.951
rice	0.53	0.00	6.73	13.98	14.56	15.14	0.000	0.036	0.074	0.077	0.080	0.000	2.067	2.757	2.585	2.273
pasta, ordinary	0.28	0.00	10.85	26.24	10.32	13.47	0.000	0.030	0.073	0.029	0.038	0.000	1.760	2.734	0.968	1.068
muffins [US]	0.5	0.00	0.39	0.53	2.12	1.56	0.000	0.002	0.003	0.011	0.008	0.000	0.113	0.099	0.355	0.221
TOTAL CEREALS AND GRAINS		51.9	144.6	245.5	258.3	208.3	0.295	0.928	1.443	1.401	1.346	44.685	53.795	53.691	46.939	38.144
MEATS/POULTRY/EGGS																
beef, steak	0.014	0.07	3.09	7.37	10.89	17.38	0.000	0.000	0.001	0.002	0.002	0.001	0.025	0.038	0.051	0.069
beef, roast & stewing	0.016	0.27	6.49	12.21	23.27	27.00	0.000	0.001	0.002	0.004	0.004	0.007	0.060	0.073	0.125	0.122
beef, hamburg, reg.	0.017	31.36	20.05	19.23	30.84	21.61	0.005	0.003	0.003	0.005	0.004	0.808	0.198	0.122	0.176	0.104
veal	0.036	0.00	0.50	0.33	1.79	2.16	0.000	0.000	0.000	0.001	0.001	0.000	0.010	0.004	0.022	0.022
pork, fresh	0.02	0.00	7.24	11.98	22.74	22.73	0.000	0.001	0.002	0.005	0.005	0.000	0.084	0.089	0.152	0.129
pork, cured	0.03	0.00	1.95	3.96	4.40	7.78	0.000	0.001	0.001	0.001	0.002	0.000	0.034	0.044	0.044	0.066
lamb	0.022	0.00	0.03	1.80	1.20	0.78	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.009	0.005
chicken & turkey	0.02	0.00	13.24	16.72	20.32	21.17	0.000	0.003	0.003	0.004	0.004	0.000	0.153	0.124	0.136	0.120
eggs	0.004	4.67	24.16	21.05	21.50	32.29	0.000	0.001	0.001	0.001	0.001	0.028	0.056	0.031	0.029	0.037
liver, kidneys	0.181	0.00	0.91	1.85	2.27	2.81	0.000	0.002	0.003	0.004	0.005	0.000	0.095	0.125	0.138	0.144
cold cuts, fresh [a691.758]	0.04	0.00	5.72	7.85	11.27	9.27	0.000	0.002	0.003	0.005	0.004	0.000	0.133	0.117	0.151	0.105
luncheon meats, canned	0.037	0.00	0.88	0.97	2.20	2.10	0.000	0.000	0.000	0.001	0.001	0.000	0.019	0.013	0.027	0.022
weiners,fresh/canned	0.016	0.00	2.26	6.35	5.45	2.41	0.000	0.000	0.001	0.001	0.000	0.000	0.021	0.038	0.029	0.011
TOTAL MEAT/POULTRY/EGGS		36.4	86.5	111.7	158.1	169.5	0.006	0.015	0.022	0.032	0.034	0.844	0.889	0.834	1.089	0.956

Table 9 (cont'd). Daily manganese consumption derived from individual foodstuffs

Foodstuff	Mn content (mg/100 g)	Mean consumption of foodstuffs (g/day)					Mean consumption of Mn (mg/day)					Percentage of total Mn derived from foodgroup				
		0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+
FISH /SHELLFISH																
F/F marine fish	0.063	0.50	1.52	4.81	5.00	6.59	0.000	0.001	0.003	0.003	0.004	0.048	0.055	0.113	0.106	0.118
F/F freshwater fish	0.458	0.00	1.12	1.08	1.09	1.26	0.000	0.005	0.005	0.005	0.006	0.000	0.297	0.184	0.167	0.163
canned fish	0.049	0.00	0.43	1.84	4.13	4.07	0.000	0.000	0.001	0.002	0.002	0.000	0.012	0.034	0.068	0.056
F/F shellfish	1.106	0.00	0.28	0.64	1.00	1.93	0.000	0.003	0.007	0.011	0.021	0.000	0.179	0.263	0.371	0.605
TOTAL FISH/SHELLFISH		0.5	3.4	8.4	11.2	13.9	0.000	0.009	0.016	0.021	0.033	0.048	0.544	0.594	0.711	0.942
MIXED DISHES																
soups, meat, canned	0.14	3.37	39.23	42.77	35.94	54.76	0.005	0.055	0.060	0.050	0.077	0.715	3.183	2.228	1.686	2.172
soups, pea, canned	0.25	1.09	14.52	19.97	37.58	30.41	0.003	0.036	0.050	0.094	0.076	0.413	2.104	1.858	3.147	2.154
soups, tomato canned	0.102	0.37	7.70	11.66	7.39	7.02	0.000	0.008	0.012	0.008	0.007	0.057	0.455	0.443	0.253	0.203
soups, dehydrated	0.079	0.00	10.02	7.98	7.92	7.65	0.000	0.008	0.006	0.006	0.006	0.000	0.459	0.235	0.210	0.171
pie, apple	0.2	0.00	2.02	3.87	3.71	9.25	0.000	0.004	0.008	0.007	0.019	0.000	0.234	0.288	0.249	0.524
pie, other	0.21	0.08	3.68	10.35	10.77	11.70	0.000	0.008	0.022	0.023	0.025	0.025	0.448	0.809	0.758	0.696
pizza	0.22	0.00	0.12	3.09	5.99	1.74	0.000	0.000	0.007	0.011	0.004	0.000	0.015	0.253	0.375	0.108
pasta, mixed dishes [US]	0.164	0.00	17.67	36.90	46.99	15.81	0.000	0.029	0.061	0.077	0.026	0.000	1.679	2.252	2.582	0.735
TOTAL MIXED DISHES		4.9	95.0	136.6	155.4	138.3	0.008	0.148	0.225	0.276	0.239	1.210	8.577	8.365	9.258	6.763
ROOT VEGETABLES																
potatoes, raw	0.263	0.00	0.25	0.00	0.00	0.04	0.000	0.001	0.000	0.000	0.000	0.000	0.038	0.000	0.000	0.003
potatoes, baked	0.229	0.00	2.08	2.95	3.05	4.92	0.000	0.005	0.007	0.007	0.011	0.000	0.276	0.251	0.234	0.319
potatoes boiled, skins on	0.14	0.00	2.13	1.81	3.54	5.43	0.000	0.003	0.003	0.005	0.008	0.000	0.173	0.094	0.166	0.215
potatoes, boiled, skins off	0.14	7.51	45.22	77.66	100.9	82.11	0.011	0.063	0.109	0.141	0.115	1.593	3.669	4.046	4.736	3.257
potatoes, french fried	0.3	0.01	18.46	22.78	33.02	20.68	0.000	0.055	0.068	0.099	0.062	0.005	3.209	2.543	3.319	1.758
potatoes, chips	0.44	0.00	1.64	5.18	7.81	1.31	0.000	0.007	0.023	0.034	0.006	0.000	0.418	0.848	1.151	0.163
carrots	0.142	1.39	8.14	10.34	11.08	14.19	0.002	0.012	0.015	0.016	0.020	0.299	0.670	0.546	0.527	0.571
onions	0.137	0.00	0.89	2.45	3.05	6.15	0.000	0.001	0.003	0.004	0.008	0.000	0.071	0.125	0.140	0.239
rutabagas or turnip [boiled]	0.15	0.58	2.40	3.51	3.29	5.69	0.001	0.004	0.005	0.005	0.009	0.132	0.209	0.196	0.165	0.242
beets [boiled]	0.24	0.00	0.43	1.26	1.00	1.80	0.000	0.001	0.003	0.002	0.004	0.000	0.060	0.113	0.080	0.122
TOTAL ROOT VEGETABLES		9.5	81.6	127.9	166.8	142.3	0.01	0.15	0.24	0.31	0.24	2.03	8.79	8.76	10.52	6.89
VEGETABLES - OTHERS																
corn	0.161	0.56	9.90	17.60	12.02	8.16	0.001	0.016	0.028	0.019	0.013	0.137	0.924	1.055	0.648	0.372
cabbage	0.18	0.00	2.69	5.05	6.21	10.26	0.000	0.005	0.009	0.011	0.018	0.000	0.281	0.338	0.374	0.523
celery	0.102	0.03	1.59	2.43	3.45	8.34	0.000	0.002	0.002	0.004	0.009	0.005	0.094	0.092	0.118	0.241
peppers	0.116	0.00	0.05	0.27	0.43	1.28	0.000	0.000	0.000	0.000	0.001	0.000	0.003	0.012	0.017	0.042
lettuce	0.512	0.00	2.37	4.49	8.21	12.70	0.000	0.012	0.023	0.042	0.065	0.000	0.703	0.856	1.408	1.842
cauliflower	0.203	0.00	0.26	0.11	1.11	1.46	0.000	0.001	0.000	0.002	0.003	0.000	0.031	0.008	0.075	0.084
broccoli	0.229	0.87	0.34	1.34	0.20	2.19	0.002	0.001	0.003	0.000	0.005	0.302	0.045	0.114	0.015	0.142
beans [boiled&drained]	0.294	0.32	2.66	4.27	4.49	6.82	0.001	0.008	0.013	0.013	0.020	0.143	0.453	0.467	0.442	0.568
peas [boiled&drained]	0.525	31.10	6.10	6.09	7.66	9.34	0.163	0.032	0.032	0.040	0.049	24.73	1.856	1.190	1.347	1.389
tomatoes	0.105	0.00	3.19	7.47	11.16	17.90	0.000	0.003	0.008	0.012	0.019	0.000	0.194	0.292	0.393	0.532
tomato juice	0.077	0.00	5.28	4.52	5.64	10.02	0.000	0.004	0.003	0.004	0.008	0.000	0.236	0.130	0.145	0.219
tomatoes:sauce,can.,ketchup	0.18	0.00	4.91	7.15	8.88	6.40	0.000	0.009	0.013	0.016	0.012	0.000	0.512	0.479	0.535	0.326
mushrooms, canned	0.086	0.00	0.47	0.86	2.11	1.63	0.000	0.000	0.001	0.002	0.001	0.000	0.023	0.028	0.061	0.040
cucumbers	0.061	0.00	3.47	8.27	11.27	11.37	0.000	0.002	0.005	0.007	0.007	0.000	0.123	0.188	0.230	0.196
baked beans	0.35	0.00	3.11	7.27	12.14	8.12	0.000	0.011	0.025	0.042	0.028	0.000	0.631	0.947	1.423	0.805
TOTAL VEGETABLES - OTHER		32.9	46.4	77.2	95.0	116.0	0.17	0.11	0.17	0.22	0.26	25.32	6.11	6.19	7.23	7.32

Table 9 (cont'd). Daily manganese consumption derived from individual foodstuffs.

Foodstuff	Mn content (mg/100 g)	Mean consumption of foodstuffs (g/day)					Mean consumption of Mn (mg/day)					Percentage of total Mn derived from foodgroup				
		0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+	0-6 mo.	7mo.-4yrs	5-11yrs	12-19 yrs	20 yrs+
FRUIT PRODUCTS																
citrus fruit - raw	0.021	0.00	11.47	24.70	22.29	33.25	0.000	0.002	0.005	0.005	0.007	0.000	0.140	0.193	0.157	0.198
citrus fruit, canned	0.007	0.00	0.00	0.17	0.04	0.16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
citrus juice	0.018	3.46	34.61	22.54	32.98	35.01	0.001	0.006	0.004	0.006	0.006	0.094	0.361	0.151	0.199	0.179
citrus juice canned	0.024	11.82	9.69	12.96	11.05	13.38	0.003	0.002	0.003	0.003	0.003	0.430	0.135	0.116	0.089	0.091
apples - raw [skin]	0.045	1.15	26.79	41.38	33.85	20.52	0.001	0.012	0.019	0.015	0.009	0.078	0.699	0.693	0.510	0.262
apple juice, can. unsweet.	0.113	14.98	44.21	26.66	9.65	13.30	0.017	0.050	0.030	0.011	0.015	2.565	2.895	1.121	0.365	0.426
apple sauce, canned	0.075	1.45	3.91	8.81	3.16	5.97	0.001	0.003	0.007	0.002	0.004	0.165	0.170	0.246	0.079	0.127
bananas	0.152	3.25	12.98	21.42	11.19	12.82	0.005	0.020	0.033	0.017	0.019	0.748	1.143	1.212	0.570	0.552
grapes	0.718	0.00	0.82	1.52	2.67	2.94	0.000	0.006	0.011	0.019	0.021	0.000	0.341	0.406	0.642	0.598
grape juice, bottled	0.36	0.00	5.27	2.52	5.02	2.15	0.000	0.019	0.009	0.018	0.008	0.000	1.099	0.338	0.605	0.219
peaches	0.047	0.50	12.25	10.27	6.56	10.17	0.000	0.006	0.005	0.003	0.005	0.036	0.334	0.180	0.103	0.135
pears	0.076	73.53	18.10	6.70	4.06	7.73	0.056	0.014	0.005	0.003	0.006	8.467	0.797	0.189	0.103	0.166
plums/dr.prunes/can.plums	0.13	0.95	2.15	2.72	2.64	4.74	0.001	0.003	0.004	0.003	0.006	0.187	0.162	0.132	0.115	0.175
cherries	0.102	0.00	0.90	1.15	0.88	1.64	0.000	0.001	0.001	0.001	0.002	0.000	0.053	0.044	0.030	0.047
melons	0.034	0.00	1.18	7.39	3.82	9.53	0.000	0.000	0.003	0.001	0.003	0.000	0.023	0.094	0.044	0.092
stawberries	0.29	0.00	3.01	7.56	5.39	7.75	0.000	0.009	0.022	0.016	0.022	0.000	0.506	0.816	0.524	0.637
blueberries	0.282	0.67	0.67	1.00	1.51	1.99	0.002	0.002	0.003	0.004	0.006	0.286	0.109	0.105	0.143	0.159
pineapple	1.65	0.00	0.70	1.68	1.66	2.22	0.000	0.012	0.028	0.027	0.037	0.000	0.669	1.032	0.918	1.038
raisins	0.29	0.00	0.50	0.53	1.08	0.62	0.000	0.001	0.002	0.003	0.002	0.000	0.084	0.057	0.105	0.051
TOTAL FRUIT PRODUCTS		111.8	189.2	201.7	159.5	185.9	0.086	0.168	0.191	0.158	0.182	13.05	9.721	7.123	5.301	5.151
FATS & OILS																
cooking fats & salad oils [US]	0.002	0.00	1.23	2.21	3.97	4.95	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003
margarine [U.S.]	0.002	0.02	2.65	6.13	8.34	6.23	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005	0.006	0.004
peanut butter & peanuts	1.88	0.16	2.98	6.08	6.60	3.52	0.003	0.056	0.114	0.124	0.066	0.456	3.247	4.254	4.157	1.875
TOTAL FATS AND OILS		0.180	6.860	14.420	18.910	14.700	0.003	0.056	0.114	0.124	0.066	0.456	3.251	4.260	4.165	1.881
FOODS, PRIMARILY SUGAR																
sugar, white	0.007	1.54	7.08	11.66	14.46	19.20	0.000	0.000	0.001	0.001	0.001	0.016	0.029	0.030	0.034	0.038
syrup	1.7	3.13	2.89	6.45	5.59	4.94	0.053	0.049	0.110	0.095	0.084	8.062	2.847	4.081	3.184	2.379
jams	0.09	0.28	3.55	6.76	9.63	6.14	0.000	0.003	0.006	0.009	0.006	0.038	0.185	0.226	0.290	0.157
honey	0.08	1.30	0.86	2.02	1.88	2.17	0.001	0.001	0.002	0.002	0.002	0.158	0.040	0.060	0.050	0.049
puddings	0.037	18.13	13.16	8.85	10.59	8.78	0.007	0.005	0.003	0.004	0.003	1.016	0.282	0.122	0.131	0.092
candy, chocolate bars	0.47	0.16	3.14	5.45	8.10	3.58	0.001	0.015	0.026	0.038	0.017	0.114	0.855	0.953	1.275	0.477
candy, others	0.086	0.01	5.36	8.47	10.39	4.58	0.000	0.005	0.007	0.009	0.004	0.001	0.267	0.271	0.299	0.112
gelatin dessert	0.003	0.09	9.59	7.49	5.98	7.80	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.008	0.006	0.007
TOTAL FOODS/SUGARS		24.640	45.630	57.150	66.620	57.190	0.062	0.078	0.155	0.157	0.117	9.406	4.522	5.752	5.270	3.310
NON-ALCOHOLIC DRINKS																
coffee	0.027	0.00	6.48	11.99	83.95	347.77	0.000	0.002	0.003	0.023	0.094	0.000	0.101	0.120	0.759	2.660
tea	0.219	0.00	8.47	22.20	81.64	354.13	0.000	0.019	0.049	0.179	0.776	0.000	1.075	1.809	5.990	21.971
soft drinks	0.022	2.39	100.33	193.57	240.70	109.91	0.001	0.022	0.043	0.053	0.024	0.080	1.279	1.585	1.774	0.685
TOTAL NON-ALCOHOLIC DRINKS		2.390	115.280	227.760	406.290	811.810	0.001	0.042	0.094	0.254	0.894	0.080	2.455	3.515	8.523	25.316
ALCOHOLIC DRINKS																
wine	0.39	0.00	0.02	0.73	1.84	23.54	0.000	0.000	0.003	0.007	0.092	0.000	0.005	0.106	0.240	2.601
beer	0.012	0.00	1.22	1.93	21.44	121.05	0.000	0.000	0.000	0.003	0.015	0.000	0.008	0.009	0.086	0.412
TOTAL ALCOHOLIC DRINKS		0.000	1.240	2.660	23.280	144.590	0.000	0.000	0.003	0.010	0.106	0.000	0.013	0.115	0.327	3.012
GRAND TOTAL		821.040	1492.470	1833.100	2109.280	2299.310	0.660	1.726	2.687	2.985	3.530	100.000	100.000	100.000	100.000	100.000

Table 10. Canadian dietary manganese intake for different age groups, and different infant diets.

age class	Mn concentration in food (mg/100 g)	Consumption (g/day)	Mn intake (mg/day)
0-6 months, exclusively breastfed	0.002*	750	0.000
0-6 months, fed exclusively milk-based formula	0.010**	750	0.000
0-6 months, fed exclusively soya-based formula	0.063**	750	0.000
0-6 months***			0.660
7 months - 4 years***			1.726
5 - 11 years***			2.687
12 - 19 years***			2.985
20 years +***			3.530

* Vaughan et al 1979

**Dabeka and McKenzie 1992

***based on data derived in Table 9

Table 11. Ingestion of manganese through food, water and soil.

ingestion source	0-6 months ,breast-fed				0-6 months, milk-based formula				0-6 months, soya-based formula				0-6 months			
	SJ*	MTL*	HAM*	SSM*	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
dietary Mn (mg/day)	0.015	0.015	0.015	0.015	0.075	0.075	0.075	0.075	0.473	0.473	0.473	0.473	0.660	0.660	0.660	0.660
Mn in drinking H2O (mg/l)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
consumption (l/day)	0.000	0.000	0.000	0.000	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
drinking H2O Mn (mg/day)	0.000	0.000	0.000	0.000	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Mn in soil (mg/g)	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500
ingestion (g/day)	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
soil Mn (mg/day)	0.018	0.018	0.088	0.088	0.018	0.018	0.088	0.088	0.018	0.018	0.088	0.088	0.018	0.018	0.088	0.088
total Mn ingested (mg/day)	0.033	0.033	0.103	0.103	0.168	0.168	0.238	0.238	0.566	0.566	0.636	0.636	0.753	0.753	0.823	0.823
intestinal absorption (fraction)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
total Mn absorbed (mg/day)	0.033	0.033	0.103	0.103	0.168	0.168	0.238	0.238	0.566	0.566	0.636	0.636	0.753	0.753	0.823	0.823
total Mn absorbed (ug/day)	33.2	33.2	102.5	102.5	168.2	168.2	237.5	237.5	566.2	566.2	635.5	635.5	753.2	753.2	822.5	822.5
biliary excretion (fraction)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
manganese uptake (ug/day)	33.2	33.2	102.5	102.5	168.2	168.2	237.5	237.5	566.2	566.2	635.5	635.5	753.2	753.2	822.5	822.5
manganese uptake (ug/kg bw/day)	4.7	4.7	14.6	14.6	24.0	24.0	33.9	33.9	80.9	80.9	90.8	90.8	107.6	107.6	117.5	117.5

ingestion source	7 months - 4 years				5-11 years				12-19 years				+20 years			
	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
dietary Mn (mg/day)	1.726	1.726	1.726	1.726	2.687	2.687	2.687	2.687	2.985	2.985	2.985	2.985	3.530	3.530	3.530	3.530
Mn in drinking H2O (mg/l)	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
consumption (l/day)	0.800	0.800	0.800	0.800	0.900	0.900	0.900	0.900	1.300	1.300	1.300	1.300	1.500	1.500	1.500	1.500
drinking H2O Mn (mg/day)	0.080	0.080	0.080	0.080	0.090	0.090	0.090	0.090	0.130	0.130	0.130	0.130	0.150	0.150	0.150	0.150
Mn in soil (mg/g)	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500	0.520	0.520	2.500	2.500
ingestion (g/day)	0.050	0.050	0.050	0.050	0.035	0.035	0.035	0.035	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020
soil Mn (mg/day)	0.026	0.026	0.125	0.125	0.018	0.018	0.088	0.088	0.010	0.010	0.050	0.050	0.010	0.010	0.050	0.050
total Mn ingested (mg/day)	1.832	1.832	1.931	1.931	2.795	2.795	2.865	2.865	3.125	3.125	3.165	3.165	3.690	3.690	3.730	3.730
intestinal absorption (fraction)	0.1	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
total Mn absorbed (mg/day)	0.183	0.183	0.193	0.193	0.140	0.140	0.143	0.143	0.156	0.156	0.158	0.158	0.185	0.185	0.187	0.187
total Mn absorbed (ug/day)	183.2	183.2	193.1	193.1	139.76	139.76	143.22	143.22	156.27	156.27	158.25	158.25	184.52	184.52	186.5	186.5
biliary excretion (fraction)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
manganese uptake (ug/day)	54.96	54.96	57.93	57.93	41.928	41.928	42.967	42.967	46.881	46.881	47.475	47.475	55.356	55.356	55.95	55.95
manganese uptake (ug/kg bw/day)	4.2	4.2	4.5	4.5	1.6	1.6	1.6	1.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

*SJ=St. John; MTL=Montreal; HAM=Hamilton; SSM=Sault Ste. Marie

Table 12 . Total manganese uptake from all sources (inhalation exposure based on ambient monitoring data)

measure	0-6 months, breast-fed				0-6 months, milk formula				0-6 months, soya formula				0-6 months, CEPA foods			
	SJ^	MTL^	HAM^	SSM^	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
total Mn uptake (ug/day)																
mean	33.21	33.23	102.62	102.69	168.21	168.23	237.62	237.69	566.21	566.23	635.62	635.69	753.21	753.23	822.62	822.69
90th %*	33.23	33.24	102.78	103.03	168.23	168.24	237.78	238.03	566.23	566.24	635.78	636.03	753.23	753.24	822.78	823.03
99th %*	33.23	33.25	102.94	103.50	168.23	168.25	237.94	238.50	566.23	566.25	635.94	636.50	753.23	753.25	822.94	823.50
total Mn uptake (ug/kg bw/day)																
mean	4.74	4.75	14.66	14.67	24.03	24.03	33.95	33.96	80.89	80.89	90.80	90.81	107.60	107.60	117.52	117.53
90th %	4.75	4.75	14.68	14.72	24.03	24.03	33.97	34.00	80.89	80.89	90.83	90.86	107.60	107.61	117.54	117.58
99th %	4.75	4.75	14.71	14.79	24.03	24.04	33.99	34.07	80.89	80.89	90.85	90.93	107.60	107.61	117.56	117.64

measure	7 months-4 years				5-11 years				12-19 years				20 + years			
	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
total Mn uptake (ug/day)																
mean	54.99	55.04	58.23	58.40	42.01	42.11	43.69	44.11	47.02	47.20	48.74	49.47	55.51	55.70	57.33	58.13
90th %	55.02	55.06	58.62	59.25	42.08	42.17	44.62	46.14	47.15	47.31	50.37	53.02	55.65	55.83	59.12	62.02
99th %	55.03	55.08	59.04	60.43	42.10	42.22	45.63	48.96	47.18	47.40	52.14	57.96	55.69	55.92	61.06	67.43
total Mn uptake (ug/kg bw/day)																
mean	4.23	4.23	4.48	4.49	1.56	1.56	1.62	1.63	0.82	0.83	0.86	0.87	0.79	0.80	0.82	0.83
90th%	4.23	4.24	4.51	4.56	1.56	1.56	1.65	1.71	0.83	0.83	0.88	0.93	0.79	0.80	0.84	0.89
99th %	4.23	4.24	4.54	4.65	1.56	1.56	1.69	1.81	0.83	0.83	0.91	1.02	0.80	0.80	0.87	0.96

^SJ=St. John; MTL=Montreal; HAM=Hamilton; SSM=Sault Ste. Marie

* Percentiles refer to percentiles of inhalation exposure; no population distribution was used for ingestion sources.

Table 13. Fractional manganese uptake from air (based on ambient data), food, water and soil.

measure	0-6 months, breast-fed				7 months-4 years				5-11 years				12-19 years				20 + years			
	SJ [^]	MTL [^]	HAM [^]	SSM [^]	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM	SJ	MTL	HAM	SSM
total Mn uptake (ug/day)																				
mean	33.21	33.23	102.62	102.69	54.99	55.04	58.23	58.40	42.01	42.11	43.69	44.11	47.02	47.20	48.74	49.47	55.51	55.70	57.33	58.13
air uptake/total Mn uptake (percent)																				
mean	0.04	0.09	0.12	0.18	0.06	0.14	0.52	0.81	0.19	0.43	1.65	2.58	0.29	0.67	2.59	4.02	0.27	0.62	2.41	3.75
food uptake/total Mn uptake (percent)																				
mean	45.16	45.14	14.62	14.61	94.16	94.09	88.92	88.66	95.96	95.73	92.27	91.40	95.24	94.88	91.88	90.53	95.39	95.06	92.36	91.09
drinking water uptake/total Mn uptake (percent)																				
mean	0.00	0.00	0.00	0.00	4.36	4.36	4.12	4.11	3.21	3.21	3.09	3.06	4.15	4.13	4.00	3.94	4.05	4.04	3.92	3.87
soil uptake/total Mn uptake (percent)																				
mean	54.20	54.17	85.75	85.70	1.42	1.42	6.44	6.42	0.64	0.64	3.02	2.99	0.32	0.32	1.54	1.52	0.27	0.27	1.31	1.29

[^] SJ=St. John; MTL=Montreal; HAM=Hamilton; SSM=Sault Ste. Marie

Table 14. Manganese exposure for occupations with high potential inhalation exposure to manganese

route	office workers*	taxi drivers*	garage mechanics**	battery plant workers (Roels 1992, Q1)***	battery plant workers (Roels 1992, Q2)****	battery plant workers (Roels 1992, Q3)*****	battery plant workers (Roels 1992, Q4)*****	battery plant workers (Roels 1992, total)*****
24-hr [Mn] in air (ug/m3)	0.01	0.014	0.085	31.54	60.92	67.2	90.8	62.6
inhalation Mn uptake (ug/day)^	0.138	0.1932	1.173	435.252	840.696	927.36	1253.04	863.88
inhalation Mn uptake (ug/kg bw/day)	0.002	0.003	0.017	6.218	12.010	13.248	17.901	12.341
dietary Mn intake (mg/day)^^	3.53	3.53	3.53	3.53	3.53	3.53	3.53	3.53
drinking H2O Mn intake (mg/day)^^	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
soil Mn intake (mg/day)^^	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
total ingested Mn (mg/day)	3.69	3.69	3.69	3.69	3.69	3.69	3.69	3.69
ingested Mn uptake (ug/day)^^^	55.35	55.35	55.35	55.35	55.35	55.35	55.35	55.35
total Mn uptake (ug/day)	55.49	55.54	56.52	490.60	896.05	982.71	1308.39	919.23
total Mn uptake (ug/kg bw/day)	0.793	0.793	0.807	7.009	12.801	14.039	18.691	13.132
inhalation Mn/total Mn (%)	0.2	0.3	2.1	88.7	93.8	94.4	95.8	94.0

* inhalation exposure based on 24-hour personal exposure monitoring of respirable Mn (Zayed et al 1994b)

** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 0.25 ug Mn/m3 (TSP) in an car repair garage (Zayed et al 1994) and off-work exposure of 0.025 ug Mn/m3

*** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 101.5 ug Mn/m3 and off-work exposure of 0.025 ug Mn/m3

**** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 196.1 ug Mn/m3 and off-work exposure of 0.025 ug Mn/m3

***** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 216.4 ug Mn/m3 and off-work exposure of 0.025 ug Mn/m3

***** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 292.3 ug Mn/m3 and off-work exposure of 0.025 ug Mn/m3

***** inhalation exposure based on at-work exposure (10m3/day, 5 days./week) of 201.6 ug Mn/m3 and off-work exposure of 0.025 ug Mn/m3

^ assuming 60% deposition of PM10 in the pulmonary region and 100% absorption of manganese deposited in the pulmonary region

^^based on data of adult manganese ingestion from food, water and soil presented in Table 11.

^^^assuming 5% absorption across the gastrointestinal tract and 70% biliary excretion (uptake=1.5% of intake)

Table A1. Individual exposure and response data for 92 workers in Roels et al. (1992).

CRD	LIRD	ind. #	VRT	EHC	HST	# yrs.	age
0021	63	15	0	0	0	3.0	39.3
0021	65	77	0	0	0	3.1	31.2
0021	55	66	0	0	0	2.6	27.1
0046	520	52	0	1	1	11.3	40.0
0046	460	60	0	0	0	10.0	37.5
0046	207	84	0	0	0	5.7	39.6
0065	1176	53	0	0	0	7.6	32.8
0065	1390	86	0	0	1	8.4	44.0
0065	256	47	1	0	0	8.0	32.7
0104	1053	16	0	0	0	6.3	26.3
0104	569	38	0	1	0	3.6	24.2
0104	605	28	0	1	0	3.8	29.3
0104	390	27	0	0	0	2.6	26.4
0104	498	62	0	0	1	3.2	24.0
0104	516	4	0	0	0	3.3	32.0
0104	516	11	0	0	0	3.3	29.1
0163	2421	2	0	0	0	12.1	48.2
0163	575	23	0	1	0	3.3	22.6
0163	163	6	0	0	0	1.0	33.3
0163	700	10	0	1	0	4.0	33.4
0163	1309	82	0	0	0	7.4	46.4
0163	718	18	0	0	0	4.1	29.5
0179	1647	34	0	1	0	9.2	49.5
0179	752	51	1	0	0	4.2	31.7
0179	1074	37	0	0	0	6.0	31.5
0179	2685	61	0	0	1	15.0	39.5
0179	1844	41	0	0	0	10.3	36.3
0179	627	56	0	0	0	3.5	23.8
0179	806	44	0	0	0	4.5	27.6
0179	1450	48	0	0	0	8.1	27.4
0179	1665	1	0	0	0	9.3	34.7

CRD	LIRD	ind. #	VRT	EHC	HST	# yrs.	age
0179	2506	40	0	0	0	14.0	49.6
0179	752	49	0	0	0	4.2	36.3
0179	430	50	0	0	0	2.4	22.0
0179	1307	19	0	0	0	7.3	29.0
0179	1967	78	0	0	0	10.4	41.2
0179	0527	017	0	0	0	3.5	23.5
0179	609	81	0	1	0	3.4	26.0
0179	1790	3	0	0	0	10.0	32.2
0179	1396	63	0	0	0	7.8	35.7
0179	859	21	0	0	0	4.8	26.7
0179	3162	74	0	0	0	17.7	49.3
0179	1307	65	0	0	0	7.3	29.7
0179	1844	29	0	0	0	10.3	49.0
0179	1110	68	0	0	0	6.2	25.8
0179	1951	26	0	0	0	10.9	33.4
0201	1469	71	0	0	0	7.3	36.7
0201	1328	92	0	0	0	6.6	28.8
0201	604	91	0	0	0	3.0	39.9
0201	624	90	0	0	0	3.1	34.0
0201	2012	46	0	0	0	1.0	35.6
0201	302	14	0	0	0	1.5	36.1
0201	40	20	0	0	0	0.2	22.2
0201	60	22	0	1	0	0.3	22.1
0201	40	12	0	0	0	0.2	22.5
0201	80	42	0	1	0	0.4	23.9
0201	1389	5	0	0	0	6.9	31.1
0201	362	7	0	0	0	1.8	23.1
0201	262	8	0	0	0	1.3	39.0
0201	403	25	0	0	0	2.0	23.4
0243	97	83	0	0	0	0.4	23.5
0243	2911	72	0	0	0	6.7	29.6
0243	3519	39	0	1	1	8.0	31.0
0244	477	88	0	0	0	2.3	24.0

CRD	LIRD	ind. #	VRT	EHC	HST	# yrs.	age
0244	477	33	0	0	0	2.3	24.0
0244	477	69	0	0	0	2.3	23.0
0265	677	32	0	1	0	3.3	23.6
0314	565	85	0	0	0	2.4	22.9
0314	618	35	0	0	1	2.7	22.9
0319	569	67	0	0	0	2.4	22.7
0468	1123	9	0	0	0	2.4	25.3
0468	2668	24	1	1	0	5.7	30.8
0468	2480	31	0	1	1	5.3	30.8
0468	1872	30	0	0	0	4.0	24.6
0468	2380	13	0	0	0	5.0	34.8
0499	902	80	0	0	1	3.4	31.5
0499	750	59	0	1	0	2.4	33.8
0499	768	64	1	1	0	2.5	26.9
0499	578	45	0	1	0	2.0	28.6
0530	977	87	0	0	0	3.5	49.4
0530	941	36	0	0	0	3.3	30.8
0613	2061	70	0	0	0	7.8	29.3
0634	1117	75	0	0	0	3.7	23.8
0796	1082	79	0	1	1	2.6	24.9
0907	3715	43	0	1	1	7.0	32.0
0907	3574	73	1	1	0	6.7	38.3
0907	4433	76	1	0	0	9.4	28.9
0907	1562	58	0	1	1	2.4	36.6
0907	3668	57	0	0	0	6.9	35.7
1201	2651	89	0	0	0	9.1	30.0
1317	1729	55	1	1	1	3.3	25.6
1317	1603	54	0	0	0	2.6	23.8

Figure A1. Exposure and response distribution from Roels et al. 1992

