Jyoti, V., Saini-Eidukat, B., Hopkins, D. and DeSutter, T., 2010, Geochemical characteristics of cadmium-rich soils of the Pembina Escarpment, North Dakota: Institute on Lake Superior Geology Proceedings, 56th Ann Mtg., Intl. Falls, MN, v. 56, part 1, p. 33-34.

Geochemical characteristics of cadmium-rich soils of the Pembina Escarpment, North Dakota

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Investigations of topsoils in northeastern North Dakota (Hopkins et al., 1999) revealed that trace element levels of cadmium (Cd), are 10 to 20 times higher than the baseline level of 0.3 mg/kg total Cd established by Garrett (1994) for northern prairie soils of Canada and the adjoining states of United States. North Dakota produces 96% of the nation's flaxseed, 50% of all durum wheat, and is the top U.S. producer of confectionary sunflower (NDASS, 2008). All these crops are known to bioaccumulate Cd.

Naturally occurring Cd concentrations were determined for soils on the Pembina Escarpment in Cavalier County, NE North Dakota. These soils overlie the Cretaceous Pierre Formation and the glacial till parent materials include considerable shale lithic fragments. Surface and core sampling locations from both residual and transported soils included an active agricultural field, a field currently in the Conservation Reserve Program (CRP), and former agricultural fields that are now grassland fields in a North Dakota State Wildlife Management Area (WMA). Samples were analyzed for Cd and other trace elements using nitric acid digestion followed by ICP–OES at NDSU. Results revealed marked differences in measured Cd values between different sampling sites, e.g., values for WMA fields range from 0.3 mg/kg to 7.0 mg/kg (n=139) for the 0-30 cm depth, whereas values for the agricultural field and CRP area range from 3.0 mg/kg to 16.4 mg/kg (n=25), for samples ranging in depth from surface soils to 1.5 m. Values for core samples from the WMA measured at 15 cm intervals down to 225 cm depth range from 0.01 mg/kg (detection limit) to 1.9 mg/kg (n=188). The measured values for Cd concentrations in several samples in this study confirm earlier results showing significantly higher concentrations of Cd compared to the 'environmental baseline' value of 0.3 mg/kg reported by Garrett (1994).

Chemical analyses for cores were grouped by soil horizon and lithology and correlation matrices were calculated for each class. A subset of results illustrates the correlation of Cd concentrations with other analytes for each sample class (Table 1).

In bedrock material, the highest positive correlations for Cd are with Ca, Fe, Mn, organic matter, and electrical conductivity, while a weaker positive correlation is seen for Cd-Ni. Cd-pH shows a weak negative correlation. In sand and silt layers, Cd is strongly positively correlated with As. Interestingly, most of these Cd-analyte pairs (with the exception of organic matter) are negatively correlated in topsoil.

References

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Table 1. Correlations of Cd with other analytes in soil horizons and lithologic units of cores taken from formerly cropped fields on the Pembina Escarpment in eastern Cavalier County, ND. Top value: Pearson correlation coefficients; second value: Prob > |r| under H0: Rho=0. Analyte pairs with $p < 0.05$ are in bold. EC: Electrical Conductivity; OM: Organic Matter; n: no. of observations.

	Topsoil	Sand & Silt	Argillic	Shale/ Claystone Contact	Shale	Bedrock	Carbonate
Al	0.5223 0.0671	-0.4520 0.1401	-0.0024 0.9872	-0.0332 0.9273	-0.0270 0.8076	0.2902 0.5769	-0.7948 0.0588
As	0.4462 0.1265	**0.8443** **0.0006**	0.0029 0.9848	-0.3489 0.3231	**0.2248** **0.0398**	0.2970 0.5677	-0.5338 0.2754
Ca	**-0.7071** **0.0069**	-0.0559 0.8630	-0.0596 0.6940	0.2294 0.5239	-0.1151 0.2970	**0.9326** **0.0067**	0.6525 0.1602
Co	-0.0347 0.9103	-0.4021 0.1951	-0.0232 0.8781	-0.0143 0.9688	**-0.2762** **0.0110**	0.4110 0.4183	-0.2300 0.6610
Cr	-0.4866 0.0917	0.3111 0.3250	-0.0537 0.7231	-0.1552 0.6685	-0.0036 0.9739	-0.5916 0.2161	**-0.8484** **0.0327**
Cu	-0.5146 0.0720	0.5872 0.0447	0.1572 0.2968	-0.2217 0.5382	0.1411 0.2004	0.5623 0.2454	-0.6847 0.1335
Fe	0.0130 0.9664	-0.0642 0.8430	0.0677 0.6549	-0.2225 0.5367	**0.2971** **0.0061**	**0.9542** **0.0031**	**-0.8845** **0.0192**
Mn	-0.5024 0.0802	**-0.3479** **0.2679**	**-0.3838** **0.0085**	0.0972 0.7894	**-0.3030** **0.0051**	**0.9724** **0.0011**	0.3275 0.5264
Mo	0.0323 0.9165	0.7907 0.0022	0.1808 0.2292	-0.2604 0.4675	0.0565 0.6099	0.2543 0.6267	-0.5448 0.2636
Ni	-0.4427 0.1298	-0.3163 0.3165	0.0312 0.8372	0.21408 0.5526	**-0.3201** **0.0030**	0.7446 0.0895	-0.5448 0.2636
Zn	-0.3397 0.2562	**-0.2677** **0.4003**	**0.5441** **<.0001**	-0.08486 0.8157	-0.0158 0.8863	0.4436 0.3783	**-0.9208** **0.0092**
OM	0.3361 0.2615	0.4367 0.1558	**0.4244** **0.0033**	0.1346 0.7109	**0.3723** **0.0005**	**0.8919** **0.0169**	**-0.9449** **0.0045**
pH	-0.4932 0.1231	-0.4500 0.1177	0.0225 0.8876	0.5565 0.0948	-0.1676 0.1324	-0.9958 0.0587	**0.9069** **0.0126**
EC	**-0.7882** **0.0040**	0.4638 0.1508	-0.2525 0.1067	0.2002 0.5791	-0.2152 0.0521	**0.9976** **0.0441**	0.4759 0.3400
n	13	12	46	10	84	6	6

Support from NIH grant P20 RR016471 from the INBRE program of the National Center for Research Resources is gratefully acknowledged.