gene reduces the expression of the kafirin and ASG genes would be valuable information to better understand the linkage between the soft-kernel characteristics and the improved protein quality of the P721O line and of the higher yielding lines derived from its crosses with elite inbreds.

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Cadmium, Lead, Mercury, and Arsenic Concentrations in Crops and Corresponding Soils in The Netherlands

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Cereals, potatoes, vegetables, fruits, and fodder crops were collected from their major growing areas in The Netherlands and were analyzed, together with their corresponding soils, for Cd and Pb and partly for Hg and As. After a large number of samples per crop were collected, the base-line levels could be determined. The Cd and Pb levels of cereals were high with respect to the proposed maximum acceptable concentrations for human consumption in The Netherlands. In lettuce and spinach relatively high Cd levels occurred, and in fruits such as tomatoes, cucumbers, and apples Cd levels were low. The Pb level in curly kale was high. The soils had median values for Cd, Pb, Hg, and As of 0.4, 23, 0.07, and 11 mg/kg of dry soil, respectively; the levels of the greenhouse soils were somewhat higher for Cd, Pb, and Hg. In the case of high metal concentrations in a crop the source of contamination could sometimes be indicated.

INTRODUCTION

There is international concern about human intake of toxic trace elements such as cadmium, lead, mercury, and arsenic. Intake of relatively low doses of these elements over a long period can lead to malfunction of organs and chronic toxicity. Toxic trace elements are in part ingested with the edible parts of agricultural and horticultural crops or derived products. The determination of the base-line levels of Cd, Pb, Hg, and As in agricultural and horticultural crops is necessary to evaluate their toxicological significance and to set action levels.

In a number of countries a survey of Cd, Pb, and Hg in various crops has been carried out. Extensive studies were reported from Sweden (Fuchs et al., 1976), Denmark (Hansen and Andersen, 1982), and Finland (Koivistoinen, 1980). Between 1971 and 1975 several publications appeared in Great Britain, each concerning a different metal (Ministry of Agriculture, Fisheries and Food, 1971, 1972, 1973, 1975). In Germany vegetables and fruits were bought at retail markets and analyzed for Cd, Pb, Hg, and As (Barudi and Bielig, 1980). The major agricultural crops of the U.S. were also analyzed for cadmium and lead (Wolnik et al., 1983, 1985). Besides these extensive studies, in several countries one or more crops were analyzed for

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Table I. Cd Contents Found in Dutch Crops

crop	mean dry-matter content	n	contents, mg/kg fresh weight: min–max	mean	median	prop max acceptable level for The Netherlands	% above acceptable level
			Greenhouse Crops				
lettuce	4.4	75	0.01–0.19	0.05	0.04	0.2	0
tomato	5.6	40	0.002–0.08	0.02	0.01	0.1	0
cucumber	3.2	45	0.0003–0.011	0.003	0.003	0.03	0
			Vegetables in the Open				
spinach	6.3	82	0.01–0.15	0.06	0.06	0.2	0
endive	5.8	82	0.003–0.10	0.03	0.02	0.2	0
curly kale	15.1	19	0.014–0.07	0.03	0.02	0.1	0
cauliflower	6.9	84	0.002–0.014	0.006	0.006	0.1	0
cabbage	8.4	86	0.001–0.017	0.005	0.004	0.1	0
carrot	8.1	100	0.005–0.16	0.04	0.03	0.2	0
onion	10.9	83	0.004–0.032	0.013	0.011	0.1	0
			Arable Crops				
potato	21.8	94	0.002–0.09	0.03	0.03	0.1	0
wheat	85[a]	84	0.02–0.35[b]	0.07	0.06	0.15	6
barley	85[a]	45	0.01–0.54	0.13	0.11	0.15	24
oats	85[a]	39	0.03–0.22	0.09	0.08	0.15	10
			Apples				
Golden Delicious	14.3	50	0.001–0.006	0.001	0.001	0.03	0
Cox's O. Pippin	14.2	50	0.001–0.002	0.001	0.001	0.03	0

[a] Cereal fresh weight was calculated on the basis of a dry-matter content of 85%. [b] Two samples with high levels from river flood plains.

Table II. Cd Contents of Crops Reported in Various Studies

crop	n	contents, mg/kg fresh weight: min	max	mean	median	country	literature
lettuce	75	0.01	0.19	0.05	0.04	The Netherlands	this study
	31	<0.013	0.051	0.024	0.021	Denmark	Hansen and Andersen, 1982
	15			0.033		Germany	Barudi and Bielig, 1980
	31	0	0.060	0.029		Sweden	Fuchs et al., 1976
	150	0.001	0.160	0.026	0.017	U.S.	Wolnik et al., 1983
tomato	40	0.002	0.08	0.02	0.01	The Netherlands	this study
	53	<0.005	0.09	0.009	0.007	Denmark	Hansen and Andersen, 1982
	30	0	0.03	0.01		Sweden	Fuchs et al., 1976
	13			0.015		Germany	Barudi and Bielig, 1980
	10	0.01	0.08	0.02		Great Britain	Min. Agr. Fish. Food, 1973
	231	0.002	0.048	0.017	0.014	U.S.	Wolnik et al., 1985
cucumber	45	0.0003	0.011	0.003	0.003	The Netherlands	this study
	17	0	0.014	0.003		Sweden	Fuchs et al., 1976
spinach	82	0.01	0.15	0.06	0.06	The Netherlands	this study
	20			0.026		The Netherlands	Ellen, 1977
	13			0.069		Germany	Barudi and Bielig, 1980
	9	0.019	0.070	0.045		Sweden	Fuchs et al., 1976
	104	0.012	0.195	0.065	0.061	U.S.	Wolnik et al., 1985
endive	82	0.003	0.10	0.03	0.02	The Netherlands	this study
	20			0.02		The Netherlands	Ellen, 1977
	20	0.006	0.04	0.01		The Netherlands	Min. Volksgez. Milieuh., 1980
curly kale	19	0.014	0.07	0.03	0.02	The Netherlands	this study
	33	0.010	0.084	0.028	0.024	The Netherlands	Ellen et al., 1979
	28	0.011	0.054	0.030	0.032	Denmark	Hansen and Andersen, 1982
cauliflower	84	0.002	0.014	0.006	0.006	The Netherlands	this study
	8	<0.008	0.08	0.04	0.05	Denmark	Hansen and Andersen, 1982
	15			0.009		Germany	Barudi and Bielig, 1980
	12	0.003	0.02	0.01		Sweden	Fuchs et al., 1976
cabbage	86	0.001	0.017	0.005	0.004	The Netherlands	this study
white	42	<0.005	0.03	0.008	0.005	Denmark	Hansen and Andersen, 1982
red	18	<0.005	0.04	0.009	0.006	Denmark	Hansen and Andersen, 1982
	41	0	0.017	0.004		Sweden	Fuchs et al., 1976
	17			0.007		Germany	Barudi and Bielig, 1980
	23	0.01	0.15	0.05		Great Britain	Min. Agr. Fish. Food, 1973
carrot	100	0.005	0.16	0.04	0.03	The Netherlands	this study
	14	0.03	0.22	0.09		Great Britain	Min. Agr. Fish. Food, 1973
	47	0.003	0.160	0.041		Sweden	Fuchs et al., 1976
	12			0.018		The Netherlands	Ellen, 1977
	207	0.002	0.13	0.028	0.017	U.S.	Wolnik et al., 1985
onion	83	0.004	0.032	0.013	0.011	The Netherlands	this study
	21	0	0.036	0.01		Sweden	Fuchs et al., 1976
	39	<0.01	0.38	0.04	0.03	Denmark	Hansen and Andersen, 1982
	11	0.01	0.09	0.04		Great Britain	Min. Agr. Fish. Food, 1973
	230	0.001	0.054	0.011	0.009	U.S.	Wolnik et al., 1985

Table II (Continued)

crop	n	contents, mg/kg fresh weight min	max	mean	median	country	literature
potato	94	0.002	0.09	0.03	0.03	The Netherlands	this study
	60	0.010	0.12	0.033		The Netherlands	Min. Volksgez. Milieuh., 1980
	20	0.004	0.020	0.010		Finland	Varo et al., 1980b
	63	0.005	0.055	0.016		Sweden	Fuchs et al., 1976
	100			0.020		Germany, Niedersachsen	Ocker et al., 1984
	297	0.002	0.182	0.031	0.028	U.S.	Wolnik et al., 1983
wheat	84	0.02	0.35	0.07	0.06	The Netherlands	this study
	100	0	0.25	0.04		Germany	Bundesgesundheitsamt, 1975
	85	0.017	0.085	0.05		Finland	Varo et al., 1980a
	107	0.024	0.145	0.06		Sweden	Andersson and Pettersson, 1981
	113	0.006	0.126	0.057		Austria	Schindler, 1983
	288	<0.0017	0.207	0.043	0.030	U.S.	Wolnik et al., 1983
	29	0.02	0.05	0.03		U.S.	Manske and Johnson, 1977
barley	45	0.01	0.54	0.13	0.11	The Netherlands	this study
	47	0.004	0.037	0.021		Finland	Varo et al., 1980a
oats	39	0.03	0.22	0.09	0.08	The Netherlands	this study
	36	0.004	0.068	0.041		Finland	Varo et al., 1980a
	67			0.016		Germany	Bundesgesundheitsamt, 1975
apple							
Golden Delicious	50	0.001	0.006	0.001	0.001	The Netherlands	this study
Cox's O. Pippin	50	0.001	0.002	0.001	0.001	The Netherlands	this study
	31			0.010		Germany	Barudi and Bielig, 1980

Table III. Pb Contents Found in Dutch Crops

crop	n	contents, mg/kg fresh weight min	max	mean	median	prop max acceptable level for The Netherlands	% above acceptable level
				Greenhouse Crops			
lettuce	75	0.03	2.25	0.14	0.09	0.5	4
tomato	40	0.002	0.080	0.010	0.008	0.3	0
cucumber	45	0.001	0.014	0.005	0.004	0.3	0
				Vegetables in the Open			
spinach	82	0.01	0.29	0.09	0.08	0.5	0
endive	82	0.03	0.43	0.08	0.07	0.5	0
curly kale	19	0.15	0.91	0.56	0.54	2.5	0
cauliflower	84	0.002	0.38	0.012	0.007	0.3	0
cabbage	86	0.002	0.23	0.015	0.006	0.3	0
carrot	100	0.011	0.21	0.05	0.04	0.3	0
onion	83	0.009	0.05	0.02	0.02	0.3	0
				Arable Crops			
potato	94	0.01	0.08	0.03	0.03	0.2	0
wheat	84	0.03	0.65	0.16	0.14	0.5	2
barley	45	0.08	0.71	0.27	0.24	0.5	7
oats	39	0.09	0.52	0.30	0.28	0.5	3
				Apples			
Golden Delicious	50	0.04	0.12	0.06	0.06	0.3	0
Cox's O. Pippin	50	0.02	0.13	0.05	0.04	0.3	0

Cd and Pb, sometimes for Hg and rarely for As.

To protect man from harmful effects of Cd, Pb, and Hg, the weekly intake by humans should not exceed the levels given by the World Health Organization (WHO, 1973, 1978). These levels are 450, 4500, and 300 mg, respectively, per 60 kg of mean body weight. A safe diet can be achieved by calculating maximum acceptable metal concentrations in edible parts of crops and/or processed foods. Taking into account the "natural" levels in the edible parts of crops and the maximum permissible weekly doses of the WHO, the Dutch government proposed maximum acceptable concentrations for Cd, Pb, and Hg in several crops and food products (Klitsie, 1983; Ned. Staatscourant, 1985). In the Federal Republic of Germany, maximum acceptable concentrations for Cd, Pb, and Hg were also proposed for several crops and food products (Bundesgesundheitsamt, 1979).

In this study 15 agricultural and horticultural crops for human consumption and 3 fodder crops were sampled from the main growing areas, together with soils on which they were cultivated. The samples were analyzed for Cd and Pb and in most cases also for Hg and As. The large number of crop samples made it possible to establish the base-line level of that metal and the frequency with which a proposed maximum metal concentration has been exceeded. To study the main source of Cd, Pb, Hg, and As for cattle, the major fodder crops in The Netherlands—grass, silage maize, and crowns and leaves of sugar beet—were analyzed.

MATERIALS AND METHODS

Crop and Site Selection. Agricultural and horticultural crops were selected according to their importance for consumption. In this way a wide selection of crops such as cereals, potato tubers, carrots, green vegetables, and fruits was obtained. The crops and the corresponding soils were sampled in the main production areas.

Information about Pollution. The farmer or grower was asked to provide information about possible contaminating factors that might give higher metal concentrations

Table IV. Pb Contents of Crops Reported in Various Studies

crop	n	contents, mg/kg fresh weight min	max	mean	median	country	literature
lettuce	75	0.03	2.25	0.14	0.09	The Netherlands	this study
	31	<0.027	0.280	0.045	0.033	Denmark	Hansen and Andersen, 1982
	31	0.003	0.161	0.043		Sweden	Fuchs et al., 1976
	15			0.116		Germany	Barudi and Bielig, 1980
	150	0.001	0.078	0.013	0.008	U.S.	Wolnik et al., 1983
tomato	40	0.002	0.08	0.010	0.008	The Netherlands	this study
	30	0.006	0.04	0.01		Sweden	Fuchs et al., 1976
	53	<0.018	0.10	0.02	0.01	Denmark	Hansen and Anderson, 1982
	13			0.05		Germany	Barudi and Bielig, 1980
	231	<0.0001	0.025	0.002	0.002	U.S.	Wolnik et al., 1985
cucumber	45	0.001	0.014	0.005	0.004	The Netherlands	this study
	17	0.006	0.044	0.013		Sweden	Fuchs et al., 1976
spinach	82	0.01	0.29	0.09	0.08	The Netherlands	this study
	20			0.096		The Netherlands	Ellen, 1977
	9	0.009	0.104	0.041		Sweden	Fuchs et al., 1976
	13			0.492		Germany	Barudi and Bielig, 1980
	104	0.016	0.17	0.045	0.039	U.S.	Wolnik et al., 1985
endive	82	0.03	0.43	0.08	0.07	The Netherlands	this study
	20			0.08		The Netherlands	Ellen, 1977
curly kale	19	0.15	0.91	0.56	0.54	The Nethelands	this study
	33	0.53	5.9	1.7	1.4	The Netherlands	Ellen et al., 1979
	28	0.05	5.2	0.44	0.26	Denmark	Hansen and Andersen, 1982
cauliflower	84	0.002	0.38	0.012	0.007	The Netherlands	this study
	12	0.009	0.020	0.015		Sweden	Fuchs et al., 1976
	8	<0.021	0.08	0.04	0.05	Denmark	Hansen and Andersen, 1982
	15			0.04		Germany	Barudi and Bielig, 1980
cabbage	86	0.002	0.23	0.015	0.006	The Netherlands	this study
	41	0	0.04	0.01		Sweden	Fuchs et al., 1976
white	42	<0.02	0.09	0.01	<0.01	Denmark	Hansen and Andersen, 1982
red	18	<0.02	0.08	0.01	<0.01	Denmark	Hansen and Andersen, 1982
	17			0.06		Germany	Barudi and Bielig, 1980
	31	<0.01	0.54	0.09		Great Britain	Min. Agr. Fish. Food, 1975
carrot	100	0.011	0.21	0.05	0.04	The Netherlands	this study
	47	0.004	0.141	0.021		Sweden	Fuchs et al., 1976
	15	<0.01	0.12	0.04		Great Britain	Min. Agr. Fish Food, 1975
	207	0.001	0.125	0.009	0.0065	U.S.	Wolnik et al., 1985
onion	83	0.009	0.05	0.02	0.02	The Netherlands	this study
	21	0.005	0.05	0.01		Sweden	Fuchs et al., 1976
	39	<0.03	0.21	0.03	<0.01	Denmark	Hansen and Andersen, 1982
	12	<0.01	0.38	0.06		Great Britain	Min. Agr. Fish. Food, 1975
	230	<0.0002	0.054	0.005	0.004	U.S.	Wolnik et al., 1985
potato	94	0.01	0.08	0.03	0.03	The Netherlands	this study
	60	0.01	0.09	0.05		The Netherlands	Ellen, 1977
	63	0.01	0.06	0.02		Sweden	Fuchs et al., 1976
	20	0.01	0.03	0.02		Finland	Varo et al., 1980b
	66	0.02	1.90	0.36	0.15	Germany	Bundesgesundheitsamt, 1975
	100			0.016		Germany, Niedersachsen	Ocker et al., 1984
	297	0.0002	0.370	0.009	0.005	U.S.	Wolnik et al., 1983
wheat	84	0.03	0.65	0.16	0.14	The Netherlands	this study
	85	0.010	0.14	0.050		Finland	Varo et al., 1980a
	44	0.05	0.40	0.126		Germany	Ocker, 1974
	110			0.047		Germany	Siebel and Ocker, 1979
	115	0.001	0.670	0.057		Austria	Schindler, 1983
	288	<0.0008	0.716	0.037	0.0017	U.S.	Wolnik et al., 1983
barley	45	0.08	0.71	0.27	0.24	The Netherlands	this study
	47	0.01	0.14	0.06		Finland	Varo et al., 1980a
oats	39	0.09	0.52	0.30	0.28	The Netherlands	this study
	31	0.030	0.110	0.061		Finland	Varo et al., 1980a
apple							
Golden Delicious	50	0.04	0.12	0.06	0.06	The Netherlands	this study
Cox's O. Pippin	50	0.02	0.13	0.05	0.04	The Netherlands	this study
	17	0.009	0.288	0.033		Sweden	Fuchs et al., 1976
	31			0.094		Germany	Barudi and Bielig, 1980

in the soil and crop sampled such as location of the sampling site on harbor dredge spoils or on a river flood plain, location of the sampling site with respect to roads and industry, the use of sewage sludge, compost, and fertilizers, and pesticides and herbicides that may contain heavy metals.

Crop Sampling. The crops were sampled in 1976 and 1977; the vegetables endive, cauliflower, cabbage, onions, and curly kale, in 1980 and 1981. The field crops were sampled from sites of 400 m^2; the sites in the greenhouses were about 100 m^2. The collected quantities were sufficient to provide a representative sample, i.e. 7 heads of lettuce, 30 fruits from 15 tomato plants, 20 fruits from 10 cucumber plants, 1 kg of spinach leaves, 15 bunches of endive, 12 cauliflower heads, 8 cabbage heads, 10 kg of onions, 10 kg of leaves from 20 curly kale plants, 200 roots of carrots, tubers of 10 potato plants, 400 ears of wheat, barley, and oats, 100 apples from 20 trees, 3 kg of grass in 3 cuttings, 20 maize plants harvested at the silage stage, and 10 crowns and leaves of sugar beet.

Table V. Hg Contents Found in Dutch Crops

crop	n	contents, mg/kg fresh weight: min	max	mean	median	prop max acceptable level for The Netherlands	% above acceptable level
			Greenhouse Crops				
lettuce	75	0.0005	0.011	0.002	0.002	0.03	0
tomato	40	0.0001	0.008	0.0013	0.0004	0.03	0
cucumber	45	0.0001	0.0015	0.0003	0.0002	0.03	0
			Vegetables in the Open				
spinach	82	<0.001	0.029	0.005	0.002	0.03	0
carrot	100	0.0006	0.005	0.002	0.002	0.03	0
			Arable Crops				
potato	94	<0.0001	0.017	0.003	0.002	0.02	0
wheat	84	<0.0001	0.029	0.005	0.003	0.03	0
barley	45	0.001	0.030	0.006	0.003	0.03	0
oats	39	<0.0001	0.020	0.008	0.006	0.03	0
			Apples				
Golden Delicious	50	0.0006	0.002	0.001	0.001	0.01	0
Cox's O. Pippin	50	0.0004	0.003	0.001	0.001	0.01	0

Table VI. Hg Contents of Crops Reported in Various Studies

crop	n	contents, mg/kg fresh weight: min	max	mean	median	country	literature
lettuce	75	0.0005	0.011	0.002	0.002	The Netherlands	this study
	15			0.0014		Germany	Barudi and Bielig, 1980
	6	0.001	0.002	0.001		Finland	Varo et al., 1980b
	7	0.0005	0.0028	0.0014		Austria	Aichberger, 1976
tomato	40	0.0001	0.008	0.0013	0.0004	The Netherlands	this study
	13			0.01		Great Britain	Cross et al., 1978
	13			0.002		Germany	Barudi and Bielig, 1980
	6	0.0003	0.001	0.0006		Austria	Aichberger, 1976
cucumber	45	0.0001	0.0015	0.0003	0.0002	The Netherlands	this study
	5	0.0002	0.002	<0.001		Finland	Varo et al., 1980b
spinach	82	<0.001	0.029	0.005	0.002	The Netherlands	this study
	13			0.005		Germany	Barudi and Bielig, 1980
	23	0.005	0.035	0.020		Switzerland	Quinche and Dvorak, 1975
	8	0.002	0.023	0.008		Austria	Aichberger, 1976
carrot	100	0.0006	0.005	0.002	0.002	The Netherlands	this study
	8	0.0008	0.0028	0.0014		Austria	Aichberger, 1976
potato	94	<0.0001	0.017	0.003	0.002	The Netherlands	this study
	20	0.0004	0.010	0.002		Finland	Varo et al., 1980b
	44	0.0008	0.015	0.004		Germany	Bundesgesundheitsamt, 1975
wheat	84	<0.0001	0.029	0.005	0.003	The Netherlands	this study
	75	0.002	0.009	0.004		Finland	Varo et al., 1980a
	403	0.0005	0.016	0.002		Germany	Ocker and Hack, 1975
	223	0.002	0.012	0.008		Canada	Tkachuk and Kuzina, 1983
	12	0.01	0.03	0.02		U.S.	Gomez and Markakis, 1974
barley	45	0.001	0.030	0.006	0.003	The Netherlands	this study
	46	0.002	0.004	<0.004		Finland	Varo et al., 1980a
oats	39	<0.0001	0.020	0.008	0.006	The Netherlands	this study
	36	0.002	0.004	<0.004		Finland	Varo et al., 1980a
apple							
Golden Delicious	50	0.0006	0.002	0.001	0.001	The Netherlands	this study
Cox's O. Pippin	50	0.0004	0.003	0.001	0.001	The Netherlands	this study
	31			0.002		Germany	Barudi and Bielig, 1980

Table VII. As Contents Found in Dutch Crops

crop	n	contents, mg/kg fresh weight: min	max	mean	median	crop	n	contents, mg/kg fresh weight: min	max	mean	median
		Greenhouse Crops						Arable Crops			
lettuce	75	0.002	0.139	0.011	0.008	potato	94	0.002	0.041	0.013	0.010
tomato	40	0.0002	0.002	0.001	0.001	wheat	84	0.005	0.285	0.045	0.027
cucumber	45	0.0001	0.084	0.023	0.019	barley	45	0.005	0.377	0.067	0.035
		Vegetables in the Open				oats	39	0.009	0.544	0.189	0.179
spinach	82	0.005	0.020	0.011	0.011			Apples			
carrot	100	0.005	0.089	0.022	0.017	Golden Delicious	50	0.0014	0.215	0.014	0.006
						Cox's O. Pippin	50	0.0014	0.011	0.004	0.004

Table VIII. As Contents of Crops Reported in Various Studies

crop	n	contents, mg/kg fresh weight min	max	mean	median	country	literature
lettuce	75	0.002	0.139	0.011	0.008	The Netherlands	this study
	15			0.147		Germany	Barudi and Bielig, 1980
	28	0	0.04	0.015		U.S.	Jelinek and Corneliussen, 1977
tomato	40	0.0002	0.002	0.001	0.001	The Netherlands	this study
	13			0.08		Germany	Barudi and Bielig, 1980
spinach	82	0.005	0.020	0.011	0.011	The Netherlands	this study
	13			0.23		Germany	Barudi and Bielig, 1980
carrot	100	0.005	0.089	0.022	0.017	The Netherlands	this study
	28			0.02		U.S.	Jelinek and Corneliussen, 1977
potato	94	0.002	0.041	0.013	0.010	The Netherlands	this study
	268	0	0.23	0.008		U.S.	Jelinek and Corneliussen, 1977
wheat	84	0.005	0.285	0.045	0.027	The Netherlands	this study
	55			<0.05		Finland	Varo et al., 1980a
barley	45	0.005	0.377	0.067	0.035	The Netherlands	this study
oats	39	0.009	0.544	0.189	0.179	The Netherlands	this study
	16	0.03	0.08	<0.05		Finland	Varo et al., 1980a
apple							
Golden Delicious	50	0.0014	0.215	0.014	0.006	The Netherlands	this study
Cox's O. Pippin	50	0.0014	0.011	0.004	0.004	The Netherlands	this study
	68	<0.01	0.38	0.026		Germany	Reinhard, 1974

Soil Sampling. The soil samples were collected from the sites where the crops were sampled. The samples were taken from the 0–20-cm layer, and for grassland, the 0–5-cm layer. In orchards the soil samples were taken around 20 trees.

Sample Preparation. The edible parts of the crops, as used for human consumption, were washed with demineralized water, dried at 105 °C, and ground in special mills with provisions to prevent contamination (wearing parts made of aluminum and titanium). From the cereal crop the grains were used. The fodder crops were not washed. The soil samples were dried at 40 °C and sieved through an aluminum sieve.

Sample Analysis. *Cadmium and Lead Determination.* The dried crop samples were digested in quartz dishes by stepwise raising the temperature to 450 °C. After ashing, HNO_3 was added, and the sample was heated until white ash appeared. The ash was dissolved in 3 M HCl, and the Cd and Pb concentrations were determined by differential-pulse anodic stripping voltammetry (see also Capar et al., 1982). Dry soil was ashed at 450 °C and dissolved in 3 M HCl. After complexation of the metals with ammonium pyrrolidinedithiocarbamate and extraction with methyl isobutyl ketone, the Cd and Pb concentrations were determined by flame atomic absorption spectrometry (see also Friend et al., 1977).

Mercury Determination. The crop samples were digested with concentrated HNO_3 at 140 °C for 2 h and under high pressure (bomb destruction). The mercury was determined by cold vapor absorption spectrometry (see also Pearce et al., 1976). The mercury of the soil was extracted with concentrated HNO_3 at 120 °C and determined by cold vapor absorption spectrometry.

Arsenic Determination. The crop samples were digested at 450 °C in the presence of $Mg(NO_3)_2$. The ash was dissolved in a HCl (1:1) solution and brought into the reaction vessel of an atomic absorption hydride system. The As^{5+} was reduced by KI and HCl to As^{3+}, converted into AsH_3 with $NaBH_4$ and conducted with N_2 to a measuring cell at 1000 °C in an atomic absorption spectrometer (see also Tam and Lacroix, 1982). The dry soil was digested with a mixture of concentrated HNO_3 and H_2SO_4 (Van der Veen et al., 1985). A part of the digestate was transferred with some HCl into the reaction vessel of an atomic absorption hydride system. The further procedure was identical with that for the crop.

RESULTS AND DISCUSSION

Cd, Pb, Hg, and As Contents of the Crops for Human Nutrition. In Table I the Cd contents found in the crops are presented and compared with the proposed maximum acceptable Cd contents for these crops in The Netherlands. In only a few cases do the Cd contents of the cereals, especially of barley and oats, exceed the proposed maximum level of 0.15 mg/kg fresh weight. In The Netherlands barley and oats are mostly used as animal feeds, for which a higher Cd level is acceptable. Two wheat samples with high Cd levels come from contaminated river flood plains. Apart from the high levels in the cereals, the Cd levels in spinach and lettuce are relatively high; the levels in cucumber, cauliflower, cabbage, onion, and apple are relatively low. The Cd concentrations found in the crops can be compared with concentrations presented in the literature (Table II), but possible differences in methods of sampling, number of samples analyzed, and analytical methodology should be kept in mind. Cd levels in our study did not differ greatly from those reported in the literature; the levels in wheat, barley, oats, and lettuce are relatively high, and the level in apple is low. For some crops, however, the number of reference concentrations available is only small.

The Pb contents of the crops in our study and the proposed maximum acceptable Pb concentrations for those crops in The Netherlands are presented in Table III. The proposed maximum acceptable Pb concentrations were only exceeded in a few of the cereal and lettuce samples. The Pb levels found in the crops are similar to those found in the literature, with the exception of the Pb levels of the cereals, which are relatively high; for barley and oats, however, only Finnish reference contents are available (Table IV). The Pb level in curly kale is high, a result that was also found in a Danish report and a different Dutch study.

The Hg contents found in the crops and the proposed maximum acceptable Hg concentrations for those crops in The Netherlands are presented in Table V. None of the Hg contents exceed the proposed maximum acceptable concentrations. The Hg levels of the crops are compared with the levels reported in literature, but reference values are scarce (Table VI).

The As contents found in the crops are presented in Table VII. The As levels in cereals, especially oats, are

Table IX. Cd, Pb, Hg, and As Contents of Soils in Various Studies

element	n	contents, mg/kg dry soil min	max	mean	country	literature
cadmium	708	0.04	14	0.5 (median = 0.4)	The Netherlands, soils used for agric and hortic	this study
	673	0.04	1.0	0.4	The Netherlands, same soils, without the highest 5% (outdoors)	this study
	155	0.08	11	0.8 (median = 0.6)	The Netherlands, greenhouse soils	this study
	147	0.08	1.3	0.6	The Netherlands, same soils, without the highest 5%	this study
	248	clay		0.5	The Netherlands	Driel van and Smilde, 1982
		without susp soils		0.34	The Netherlands	Ibid
	63	sand		0.3	The Netherlands	Ibid
	361	0.03	2.3	0.22	Sweden	Andersson, 1977
	51			0.26	Denmark	Tjell and Hovmand, 1978
	2223			0.21	Germany, Hessen	Brüne and Ellinghaus, 1982
	2742			0.78	Germany, Baden—Württemberg	Hoffmann et al., 1982
	472			0.8	Germany, Nordrhein—Westfalen	Kick et al., 1980
	296	0.10	8.1	0.56	Canada, Ontario	Frank et al., 1976
lead	708	0	460	31 (median = 23)	The Netherlands, soils used for agric and hortic	this study
	673	0	72	25	The Netherlands, same soils, without the highest 5% (outdoors)	this study
	155	4	420	71 (median = 45)	The Netherlands, greenhouse soils	this study
	147	4	230	58	The Netherlands, same soils, without the highest 5%	this study
	248	clay		43	The Netherlands	Driel van and Smilde, 1982
		without susp soils		30	The Netherlands	Ibid
	63	sand		31	The Netherlands	Ibid
	361	2	364	16	Sweden	Andersson, 1977
	51			24	Denmark	Tjell and Hovmand, 1978
	2223			20	Germany, Hessen	Brüne and Ellinghaus, 1982
	2742			40	Germany, Baden—Württemberg	Hoffmann et al., 1982
	472			50	Germany, Nordrhein—Westfalen	Kick et al., 1980
	35	no susp soils		23	Switzerland	Häni et al., 1982
	296	2	888	46	Canada, Ontario	Frank et al., 1976
mercury	707	0.00	31	0.16 (median = 0.07)	The Netherlands, soils used for agric and hortic	this study
	671	0.00	0.32	0.08	The Netherlands, same soils, without the highest 5% (outdoors)	this study
	155	0.02	7.2	0.36 (median = 0.16)	The Netherlands, greenhouse soils	this study
	147	0.02	1.1	0.24	The Netherlands, same soils, without the highest 5%	this study
	248	clay		0.2	The Netherlands	Driel van and Smilde, 1982
	63	sand		0.2	The Netherlands	Ibid
	273	0.004	0.922	0.06	Sweden	Andersson, 1967
	221			0.11	Germany, Hessen	Brüne and Ellinghaus, 1982
	1041			0.12	Germany, Baden—Württemberg	Hoffmann et al., 1982
	472			0.06	Germany, Nordrhein—Westfalen	Kick et al., 1980
	40	0.005	0.340	0.095	Austria	Wimmer and Haunold, 1973
	296	0.01	1.14	0.11	Canada, Ontario	Frank et al., 1976
arsenic	704	0.1	110	12 (median = 11)	The Netherlands, soils used for agric and hortic	this study
	668	0.1	27	10	The Netherlands, same soils, without the highest 5% (outdoors)	this study
	155	1	35	12 (median = 12)	The Netherlands, greenhouse soils	this study
	147	1	24	11	The Netherlands, same soils, without the highest 5%	this study
	248	clay		14	The Netherlands	Driel van and Smilde, 1982
	63	sand		5	The Netherlands	Ibid
	221			9	Germany, Hessen	Brüne and Ellinghaus, 1982
	296	1,1	92	12	Canada, Ontario	Frank et al., 1976

Table X. Cd, Pb, Hg, and As Contents of Fodder Crops and Corresponding Soils

element	contents, mg/kg dry material n	min	max	mean	median	contents, mg/kg dry material n	min	max	mean	median
	grass (unwashed)					corresponding soils				
cadmium	86	0.03	0.84	0.15	0.11	78	0.2	14	1.0	0.5
lead	86	0.7	9.1	2.5	2.2	78	11	460	62	36
mercury	86	0.008	0.095	0.021	0.019	78	0.01	3.2	0.24	0.10
arsenic	86	0.07	1.11	0.28	0.22	78	1	38	12	11
	silage maize (unwashed)					corresponding soils				
cadmium	46	0.14	6.8	0.43	0.24	46	0.1	2.9	0.4	0.3
lead	46	1.0	4.1	2.2	2.2	46	6	110	20	16
mercury	46	0.009	0.028	0.016	0.016	46	0.01	0.49	0.06	0.04
arsenic	46	0.06	0.47	0.17	0.15	46	1	110	10	4
	crowns and leaves of sugar beet (unwashed)					corresponding soils				
cadmium	46	0.11	1.1	0.31	0.25	46	0.1	2.2	0.4	0.4
lead	46	1.9	7.2	3.6	3.5	46	3	124	26	20
mercury	46	0.05	0.20	0.11	0.11	46	0.01	0.28	0.07	0.06
arsenic	46	0.09	1.6	0.51	0.46	46	1	36	14	15

high compared with those of the other crops. This can be partly explained by the high dry-matter contents of cereal grains. Some individual samples have a high As content, but reference contents are scarce (Table VIII).

Some of the high metal concentrations in the crops coincide with high concentrations of the same metals in the soil, especially when the locations are on river flood plains. For other high metal concentrations in the crops no correlation with the concentrations in the soil can be established, and the data of the questionnaire do not provide an explanation. In a few cases a significant correlation has been found between the metal level in the soil and the edible part of the crops. But a crop is usually cultivated on a limited number of soil types, and therefore the observed correlations are of limited value.

Cd, Pb, Hg, and As Contents of the Corresponding Soils. Soil samples were taken from the sites on which the crops were grown; they were analyzed for Cd, Pb, Hg, and As. The metal contents are presented in Table IX. The Pb and Hg levels in the soils of the greenhouses were higher than those in the arable soils; the Cd level was slightly higher. Some of the high metal contents of the arable soils can be related to information obtained through the questionnaire, e.g. the soils are located on frequently flooded river flood plains. The Cd, Pb, Hg, and As levels of the soils that were studied fell within the range of levels found in the literature (Table IX).

Cd, Pb, Hg, and As Contents of Fodder Crops and the Corresponding Soils. Samples of the fodder crops—grass, silage maize, and crowns and leaves of sugar beet—were taken in the main production areas, together with the corresponding soils. The unwashed crop samples and the soil samples were analyzed for Cd, Pb, Hg, and As. The results, on a dry-matter basis, are presented in Table X. The Hg level in the crowns and leaves of sugar beet is much higher than the Hg levels of grass and silage maize. The As level of the crowns and leaves of sugar beet is about twice as high as the As levels of grass and silage maize. Some of the samples with high metal contents come from frequently flooded river flood plains, but other high metal contents of the fodder crops cannot be explained by the concentrations in the corresponding soils or the data of the questionnaire.

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Registry No. Cd, 7440-43-9; Pb, 7439-92-1; Hg, 7439-97-6; As, 7440-38-2.

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