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Human Health Risk Assessment for Exposure to Soil in Kosovo and Bosnia

Environmental Protection Programme

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Human Health Risk Assessment for Exposure to Soil in Kosovo and Bosnia

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) carried out on behalf of the DSTL Radiological Protection Services. The object was to look into the human health risk due to soil exposure of British personnel serving in Kosovo and Bosnia.

Acknowledgements

Professor Barry Smith, Programme Manager of the Environmental Protection Programme, reviewed this report.

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Summary

This report describes a human health risk assessment for British personnel serving in Bosnia and Kosovo. The mathematical description of the risk assessment model is developed based on algorithms used in the commercially available software Risk*Assistant. A simple conceptual exposure model of soil ingestion and soil dust inhalation is developed based on a six-month tour of duty. Two exposed groups have been identified, one with an exposure for 12 hours per day and an office based group with an outdoor exposure of 3 hours per day. It is assumed that there is no indoor exposure to soil and soil dust.

The risk calculations indicate that there is no toxic risk at any of the sites and the increased risk of cancer due to soil ingestion and inhalation is below the currently accepted value of one in a million increased risk. Lifetime average daily doses are below the Index Dose thresholds for inhalation of chromium, cadmium and arsenic at all sites.

Since the office based group have an exposure duration that is 75% less than the outdoor group the soil intakes are correspondingly linearly reduced by the same amount. Consequently the hazard quotients and carcinogenic risks are also reduced by 75%.

1 Introduction

This report is the published product of a study by the British Geological Survey (BGS) carried out on behalf of the DSTL Radiological Protection Services. The object was to look into the human health risk due to soil exposure of British personnel serving in Kosovo and Bosnia. This study embraces 30 sites in Kosovo and 12 sites in Bosnia. Heavy metal and metalloid mean concentrations, determined by ICP-AES, were provided as source term concentrations, Table 1 and Table 2.

Table 1 Heavy metal and metalloid concentrations for Kosovo (all values quoted in mg/kg)

Site Code	Pb	Cd	As	Zn	Cu	Ni	Cr
ABA	67	0.5	7	79	16	3298	202
AGA	106	0.5	37	137	47	485	410
AGU	72	0.5	22	95	41	142	133
AHA	87	1.0	21	114	41	140	114
AMU	60	1.0	19	108	49	155	144
APA	43	0.5	10	57	26	195	136
ARI	41	0.5	12	90	38	170	161
ATR	46	0.5	7	81	32	1695	254
AVJ	159	0.5	33	168	52	189	159
AWA	50	0.5	15	50	18	50	61
B1S	170	1.0	27	211	63	149	109
B2S	80	1.0	42	122	48	146	117
B3S	32	0.5	12	69	50	164	130
B4S	88	1.0	19	132	60	180	137
BCQ	54	1.0	14	66	24	90	74
BEF	63	1.0	21	87	44	128	128
BFL	96	0.5	23	114	58	145	166
BG2	41	1.0	8	99	44	64	57
BG3	47	0.5	14	39	16	35	64
BJH	35	2.0	8	69	17	2177	317
BLI	48	0.5	19	74	38	144	154
BNP	50	0.5	14	52	21	200	114
BOB	76	0.5	14	89	33	149	114
BPA	43	0.5	10	50	21	179	135
BRP	52	1.0	20	85	45	126	114
BTD	286	2.0	17	134	54	119	199
DGL	58	1.0	27	88	41	346	321

Table 2 Heavy metal and metalloid concentrations for Bosnia (all values quoted in mg/kg)

Site Code	Pb	Cd	As	Zn	Cu	Ni	Cr
BGR	29	2	12	80	22	43	44
BLM	43	2	27	91	46	67	69
GLA	24	2	8	56	12	17	29
KNE	36	1	11	104	41	60	50
KVA	34	1	12	73	38	117	88
LIS	39	2	9	99	57	222	117
MAN	32	2	18	75	22	38	51
(1)MGB	26	1	10	91	27	52	48
MGS	46	2	16	129	38	37	459
PRI	33	1	11	62	14	63	60
PRN	38	1	11	101	20	81	139
RAD	38	2	34	81	17	32	37
SIP	43	2	18	84	35	35	47

2 Model Development

2.1 THE RISK ASSESSMENT MODEL

The risk assessment modelling is based on Risk*Assistant software developed by the Hampshire Research Institute in the USA, (Benes et al., 1995). In use it was found that the databases of toxicological information were not up to date and a spreadsheet was set up that incorporated the Risk*Assistant algorithms to carry out the risk calculations.

In practice an element or compound may pose a toxic hazard as in the case of high concentrations of cadmium for example, or, as in the case of arsenic, both a toxic and carcinogenic hazard.

In order to calculate the toxic risk the common approach is to compare the exposure dose to an acceptable reference dose or tolerable daily intake. In Risk*Assistant this is achieved by calculating an average daily dose (ADD) and comparing this to a reference dose to calculate a hazard quotient (HQ). The average daily dose in mg/kg(body weight)-day is calculated in the following manner (Equation 1):

$$ADD = \frac{C.IR.ED}{BW.AT} \quad (1)$$

where C is the soil concentration in mg/kg

IR is the ingestion rate (mg/day)

ED is the exposure duration (days)

BW is body weight (kg)

AT is the averaging time (days)

The Hazard Quotient (HQ) is calculated as follows:

$$HQ = \frac{ADD}{RfD} \quad (2)$$

where RfD is the reference dose. It is an estimate of continuous exposure, on a daily basis, over a prolonged period with a reasonable expectation that no adverse effect will occur from that exposure. The units are mg/kg(body weight)- day. In the case of toxic risk due to inhalation the Reference Concentration (RfC) is substituted into equation (2) for the RfD.

For calculating the carcinogenic risk of exposure the following equation is used:

$$CarcinogenicRisk = 1 - [\exp(-LADD.SF)] \quad (3)$$

where LADD is the lifetime average dose and is calculated from the average daily dose using the following formula:

$$LADD = ADD.\frac{ED}{AT} \quad (4)$$

where ED is the exposure duration (years)

AT is the averaging time (years)

SF is the slope factor, the gradient of a dose response curve.

The RfD, RfC and slope factor are obtainable from the U.S. EPA database *IRIS* (Integrated Risk Information System). The following table (Table 3) list the available RfDs and SF used in the calculations along with reference doses derived from sources other than *IRIS*.

Table 3 Reference concentrations used in the risk assessment. (mg/kg(body weight)/day)

Contaminant	RfD	RfC	TDI	SF	Unit Risk	TDSI	IdxD(inh)	IdxD(Or)
Lead	7E-04					7E-04		
Cadmium	0.001		0.001		0.0018	0.00077	1E-05	
Arsenic	0.0003			1.5			2E-05	0.0003
Zinc	0.3							
Copper								
Nickel	0.02		0.005			0.0027		
Chromium	0.003	0.0001	0.003		0.012	0.0028	1E-06	

Table 3 requires some further explanation before proceeding. The reference concentration, RfC, unlike the reference dose is expressed in environmental medium concentration units, e.g. mg/m^3 of air. For some elements an Rfd is not defined, for example copper, and an RfC is only defined for chromium. The Risk*Assistant algorithm citing Wark and Warner, (1981) has been used to convert soil concentration to a dust concentration for exposure assessment via the inhaled pathway. The equation is as follows:

$$C(i) = D.R.f.C(s) \quad (5)$$

where C(i) is the inhaled concentration of contaminant

C(s) is the soil concentration

R is the respirable fraction of dust (73%)

F is the proportion of contaminated dust (1%)

D is the dust concentration (75µg/m^3)

Generally speaking the respirable fraction is considered to be less than 30µm in diameter, however in the present study a particle size analysis of the soils was not carried out and the parameterisation of the variable R is therefore highly uncertain.

For inhalation exposures to elements that have a carcinogenic effect, e.g. cadmium, a unit risk is defined. Similar to the slope factor it is the gradient of the line of the assumed linear relationship between concentration and risk at low doses.

With the introduction of the Environment Agency's CLEA (Contaminated Land Exposure Assessment) model (DEFRA and EA, 2002d), the concepts of the tolerable daily intake or TDI and Index Doses were introduced to UK risk assessors, (DEFRA and EA, 2002a). The TDI is defined as a threshold dose below which adverse health effects are not expected, it relates to exposure from all pathways. Index Doses for inhaled, IdxD(inh) and oral, IdxD(Or) exposures are allocated to substances for which a threshold for an adverse health effect cannot be assumed. The Index Dose is the intake at which the risk is considered minimal. Using the EA derived Index Doses it is therefore possible to calculate the risk for arsenic and cadmium exposure where an RfC is not available. It is assumed that human exposure below the specified levels carries minimal health risk. For completeness the TDSI is given in Table 3, which is the tolerable daily soil intake. Comparison with the RfD for nickel and cadmium shows the TDSI to be relatively conservative, for nickel by nearly an order of magnitude and for cadmium by a factor of 1.3.

Referring back to Table 3, it can be seen that a reference dose for lead is tabulated; in fact there is neither a published RfD nor TDSI. To derive this value use was made of the data quoted by the EA, (DEFRA and EA, 2002c) which cites (page 8) a provisional tolerable weekly intake (PWTI) as being 25µg/kg (body weight). Lead is considered to be an element essentially without an exposure threshold and to derive a TDSI the following formula, equation 6, based on (DEFRA and EA, 2002a) has been used by converting the PWTI to a TDI:

$$TDSI = 0.2 * \frac{PWTI}{7} \quad (6)$$

The TDSI is considered to be equivalent to an RfD for the purposes of calculation.

2.2 THE CONCEPTUAL MODEL

In carrying out the conceptual model development the source – pathway – receptor paradigm has been followed. We are concerned specifically with human exposure to soil and the only pathways considered are oral ingestion and inhalation. No account is taken of food and water ingestion pathways since both are imported into the sites. Two exposed populations have been defined:

1. Outdoor Personnel: this includes guards, soldiers on patrol, and engineers. Indoor exposure to soil and soil dust within this population is not considered to occur. Daily exposure duration is set at 12 hours.
2. Office Workers: The exposure arises from exterior transit around the site and outdoor, daily physical exercise. Once again this subgroup is considered not to experience indoor exposures to soil and soil dust. Daily exposure duration is set at 3 hours.

Both of the subpopulations have exposure factors in common, the only difference being exposure duration of the two groups.

2.2.1 Exposure Factors

Referring back to equations (1) and (4) information is required on soil ingestion rate, and inhalation rate, life expectancy, and body mass.

2.2.1.1 SOIL INGESTION RATE

Based on U.S. studies, the Exposure Factors Sourcebook for European Populations, (Ecetoc, 2001), quotes a median soil ingestion rate of 1.0mg/day for adults as being the best available information, while a mean value of 10mg/day was proposed. (DEFRA and EA, 2002d) consider that a value of 5 to 25 mg/day is reasonable for ingestion by adults, while the U.S.EPA, (USEPA, 1999), consider that 50mg/day represents a good central estimate of adult soil ingestion. In order to maintain a conservative approach to the risk assessment the higher figure of 50 mg/day has been adopted for adult soil ingestion.

2.2.1.2 INHALATION RATE

In order to calculate inhalation exposure the Recommended values of inhalation of the U.S. EPA have been adopted, (USEPA, 1999), Table 4. These values are also considered to be representative of European populations too, (ECETOC, 2001).

Table 4 Recommended values of inhalation based on (USEPA, 1999).

Activity Level (Adult Male)	**Mean Inhalation Rate (m^3/h)**
Rest	0.4
Sedentary Activities	0.5
Light Activities	1.0
Moderate Activities	1.2
Heavy Activities	1.9

To calculate the inhalation rate for the exposure period a time weighted mean, equation 7, is used:

$$IR_{inh} = \frac{1}{T}\sum_{i=1}^{k} IR_i t_i \quad (7)$$

where IR_i is the inhalation rate of the i^{th} activity

t_i is hours spent per day during i^{th} activity

k is the number of activity periods

T is the total time of the exposure period

For the office based workers with a total of three hours a day of exposure a mean inhalation rate of 0.3 m^3/h has been calculated based on two hours of light activity and one hour of moderate activity during P.E. for example.

In the case of the outdoor worker with 12 hours of exposure a mean inhalation rate of 1.85 m^3/h was used and is based on three hours light activity, six hours of moderate activity and three hours of heavy activity.

2.2.1.3 BODY MASS

A mean adult male body weight of 80 kg has been used in the risk calculations and is based on Health and Safety Executive data (ECETOC, 2001). It is consistent with the calculated value of 80.91kg for an adult male used in the CLEA model, (DEFRA and EA, 2002d).

2.2.1.4 AVERAGING TIME

Information on life expectancy is required to calculate the lifetime average daily dose in equation (1.4). The European Exposure Factors Sourcebook gives 77 years as the average male life expectancy for a child born in England in 1996 based on data from the UK Government Actuary's Department. This is not dissimilar from the U.S. EPA 1995-projected figure of 72.8years, (USEPA, 1999).

For the purposes of the calculation of the average daily dose the averaging time is the time over which exposure occurs, and is taken as 6 months or 185 days. This is the typical duration of a tour of duty in Bosnia and Kosovo.

3 Risk Assessment Calculation Results

3.1 BOSNIA - TOXIC RISK

The data presented in Table 5 is for an outside exposure to soil ingestion of 12 hours. It is evident from the data table, Table 5, that all of the calculated HQs are less than one and hence the criterion for a toxic risk through soil ingestion existing, i.e. HQ>1, is not met. Since the daily exposure of an office worker is less by a factor of four, their HQs are correspondingly lowered by a factor of four also. Table 6 provides the calculated HQ for chromium exposure through soil inhalation. The values are very low and much less than 1.0. Even assuming that inhalation is an additive pathway to ingestion, and considering the site MGS (highest Cr concentration) with an oral HQ of 0.028 the addition of the inhalation pathway only increases the HQ to 0.031.

3.2 BOSNIA – CARCINOGENIC RISK

Three elements are classed as human carcinogens, chromium and cadmium through dust inhalation and arsenic through soil ingestion. Table 7 documents the increased cancer risk due to inhaled chromium exposure and Table 8 the increased risk of cancer due to cadmium inhalation. Table 9 presents the increased cancer risk calculation for arsenic via the soil ingestion pathway. The U.S. EPA considers an increased risk of cancer of 1E-6, i.e. one in a million as significant. The calculations indicate that the increased risk of cancer from inhalation of chromium and cadmium, and the ingestion of arsenic is not a cause for concern. Comparing the LADD for inhaled Chromium, Table 7, to the Index Dose of 0.001µg/kg body weight/day, (DEFRA and EA, 2002b), indicates a very low risk with the quotient being of the order of 1E-3. For cadmium the quotient is of the order of 1E-6, Table 8. In Table 10 is presented a comparison of the LADD for arsenic inhalation with the index dose, the quotient is of the order of 1E-8.

Table 5 Hazard Quotient estimates for Bosnia soil exposures through oral ingestion

	Pb	Cd	As	Zn	Cu	Ni	Cr
BGR	28.84615	1.544914	12.14844	79.97154	22.43756	42.84485	44.44325
ADD	5.41E-06	2.9E-07	2.28E-06	1.5E-05	4.21E-06	8.03E-06	8.33E-06
HQ	**0.007727**	**0.00029**	**0.007593**	**5E-05**	**N/d**	**0.000402**	**0.002778**
BLM	43.2381	1.600414	27.02674	91.46893	46.26267	66.69619	69.29884
AverageDD	8.11E-06	3E-07	5.07E-06	1.72E-05	8.67E-06	1.25E-05	1.3E-05
HQ	**0.011582**	**0.0003**	**0.016892**	**5.72E-05**	**N/d**	**0.000625**	**0.004331**
GLA	23.88889	1.53805	8.229475	55.6866	11.57021	17.0043	28.78457
ADD	4.48E-06	2.88E-07	1.54E-06	1.04E-05	2.17E-06	3.19E-06	5.4E-06
HQ	**0.006399**	**0.000288**	**0.005143**	**3.48E-05**	**N/d**	**0.000159**	**0.001799**
KNE	35.90909	1.247754	11.07471	104.3185	41.25027	59.51949	50.15857
ADD	6.73E-06	2.34E-07	2.08E-06	1.96E-05	7.73E-06	1.12E-05	9.4E-06
HQ	**0.009619**	**0.000234**	**0.006922**	**6.52E-05**	**N/d**	**0.000558**	**0.003135**
KVA	34.18182	1.199813	11.62317	73.28238	38.04259	116.8623	87.5352
ADD	6.41E-06	2.25E-07	2.18E-06	1.37E-05	7.13E-06	2.19E-05	1.64E-05
HQ	**0.009156**	**0.000225**	**0.007264**	**4.58E-05**	**N/d**	**0.001096**	**0.005471**
LIS	38.69231	1.500909	8.921967	98.99488	56.81737	222.1386	116.6848
ADD	7.25E-06	2.81E-07	1.67E-06	1.86E-05	1.07E-05	4.17E-05	2.19E-05
HQ	**0.010364**	**0.000281**	**0.005576**	**6.19E-05**	**N/d**	**0.002083**	**0.007293**
MAN	32.36364	1.738137	17.60992	75.16625	22.31718	37.76613	51.4852
ADD	6.07E-06	3.26E-07	3.3E-06	1.41E-05	4.18E-06	7.08E-06	9.65E-06
HQ	**0.008669**	**0.000326**	**0.011006**	**4.7E-05**	**N/d**	**0.000354**	**0.003218**
MGB	25.76923	1.340406	9.820209	91.18299	26.88224	51.94623	48.28219
ADD	4.83E-06	2.51E-07	1.84E-06	1.71E-05	5.04E-06	9.74E-06	9.05E-06
HQ	**0.006902**	**0.000251**	**0.006138**	**5.7E-05**	**N/d**	**0.000487**	**0.003018**
MGS	46.36364	1.753829	15.80824	128.8502	37.52445	37.46065	458.6281
ADD	8.69E-06	3.29E-07	2.96E-06	2.42E-05	7.04E-06	7.02E-06	8.6E-05
HQ	**0.012419**	**0.000329**	**0.00988**	**8.05E-05**	**N/d**	**0.000351**	**0.028664**
PRI	33.45455	1.124367	10.62953	62.3722	14.43625	62.99919	60.28162
ADD	6.27E-06	2.11E-07	1.99E-06	1.17E-05	2.71E-06	1.18E-05	1.13E-05
HQ	**0.008961**	**0.000211**	**0.006643**	**3.9E-05**	**N/d**	**0.000591**	**0.003768**
PRN	38.28571	1.371029	11.32046	101.2338	20.38978	80.81355	139.3372
ADD	7.18E-06	2.57E-07	2.12E-06	1.9E-05	3.82E-06	1.52E-05	2.61E-05
HQ	**0.010255**	**0.000257**	**0.007075**	**6.33E-05**	**N/d**	**0.000758**	**0.008709**
RAD	37.54545	1.769941	34.41508	81.43698	16.86589	31.99841	36.74001
ADD	7.04E-06	3.32E-07	6.45E-06	1.53E-05	3.16E-06	6E-06	6.89E-06
HQ	**0.010057**	**0.000332**	**0.021509**	**5.09E-05**	**N/d**	**0.0003**	**0.002296**
SIP	43.04348	1.647797	18.35522	84.29352	34.78263	34.89259	47.04129
ADD	8.07E-06	3.09E-07	3.44E-06	1.58E-05	6.52E-06	6.54E-06	8.82E-06
HQ	**0.01153**	**0.000309**	**0.011472**	**5.27E-05**	**N/d**	**0.000327**	**0.00294**

Table 6 Chromium Hazard Quotients for soil inhalation

Site	**Cr(soil)**	**Cr(inhaled)**	**ADD(inh)**	**Toxic Risk**
BGR	44	2.43E-06	2.81E-08	2.81E-04
BLM	69	3.79E-06	4.39E-08	4.39E-04
GLA	29	1.58E-06	1.82E-08	1.82E-04
KNE	50	2.75E-06	3.18E-08	3.18E-04
KVA	88	4.79E-06	5.54E-08	5.54E-04
LIS	117	6.39E-06	7.39E-08	7.39E-04
MAN	51	2.82E-06	3.26E-08	3.26E-04
MGB	48	2.64E-06	3.06E-08	3.06E-04
MGS	459	2.51E-05	2.9E-07	2.90E-03
PRI	60	3.30E-06	3.82E-08	3.82E-04
PRN	139	7.63E-06	8.82E-08	8.82E-04
RAD	37	2.01E-06	2.33E-08	2.33E-04
SIP	47	2.58E-06	2.98E-08	2.98E-04

Table 7 Increased risk of cancer through Chromium inhalation, comparison with the Index Dose is also provided.

Site	**Cr(soil)**	**Cr(inhaled)**	**LADD(inh)**	**Risk**	**cf ID**
BGR	44	2.4E-06	1.85E-12	2.E-12	1.83E-04
BLM	69	3.8E-06	2.89E-12	3.E-12	2.85E-04
GLA	29	1.6E-06	1.2E-12	1.E-12	1.18E-04
KNE	50	2.7E-06	2.09E-12	2.E-12	2.06E-04
KVA	88	4.8E-06	3.65E-12	4.E-12	3.60E-04
LIS	117	6.4E-06	4.86E-12	6.E-12	4.80E-04
MAN	51	2.8E-06	2.14E-12	3.E-12	2.12E-04
MGB	48	2.6E-06	2.01E-12	2.E-12	1.98E-04
MGS	459	2.5E-05	1.91E-11	2.E-11	1.89E-03
PRI	60	3.3E-06	2.51E-12	3.E-12	2.48E-04
PRN	139	7.6E-06	5.81E-12	7.E-12	5.73E-04
RAD	37	2.0E-06	1.53E-12	2.E-12	1.51E-04
SIP	47	2.6E-06	1.96E-12	2.E-12	1.93E-04

Table 8 Increased risk of cancer through Cadmium inhalation, comparison with the Index Dose is also provided.

Site	Cd	Cd(inhaled)	ADD(inh)	LADD(inh)	Risk	cf- ID
BGR	1.54	8.46E-08	9.78E-10	6.35E-12	1.E-14	6.35E-07
BLM	1.60	8.76E-08	1.01E-09	6.58E-12	1.E-14	6.58E-07
GLA	1.54	8.42E-08	9.74E-10	6.32E-12	1.E-14	6.32E-07
KNE	1.25	6.83E-08	7.90E-10	5.13E-12	9.E-15	5.13E-07
KVA	1.20	6.57E-08	7.60E-10	4.93E-12	9.E-15	4.93E-07
LIS	1.50	8.22E-08	9.50E-10	6.17E-12	1.E-14	6.17E-07
MAN	1.74	9.52E-08	1.10E-09	7.14E-12	1.E-14	7.14E-07
MGB	1.34	7.34E-08	8.49E-10	5.51E-12	1.E-14	5.51E-07
MGS	1.75	9.60E-08	1.11E-09	7.21E-12	1.E-14	7.21E-07
PRI	1.12	6.16E-08	7.12E-10	4.62E-12	8.E-15	4.62E-07
PRN	1.37	7.51E-08	8.68E-10	5.64E-12	1.E-14	5.64E-07
RAD	1.77	9.69E-08	1.12E-09	7.28E-12	1.E-14	7.28E-07
SIP	1.65	9.02E-08	1.04E-09	6.77E-12	1.E-14	6.77E-07

Table 9 Increased risk of cancer through arsenic ingestion.

Site	As	ADD	LADD	Risk
BGR	12	2.28E-06	1.48E-08	2.E-08
BLM	27	5.07E-06	3.29E-08	5.E-08
GLA	8	1.54E-06	1E-08	2.E-08
KNE	11	2.08E-06	1.35E-08	2.E-08
KVA	12	2.18E-06	1.42E-08	2.E-08
LIS	9	1.67E-06	1.09E-08	2.E-08
MAN	18	3.3E-06	2.14E-08	3.E-08
MGB	10	1.84E-06	1.2E-08	2.E-08
MGS	16	2.96E-06	1.92E-08	3.E-08
PRI	11	1.99E-06	1.29E-08	2.E-08
PRN	11	2.12E-06	1.38E-08	2.E-08
RAD	34	6.45E-06	4.19E-08	6.E-08
SIP	18	3.44E-06	2.23E-08	3.E-08

Table 10 Comparison of lifetime average daily dose of arsenic through inhalation with the index dose.

Site	As	C(inh)	LADD(inh)	cf-ID
BGR	12	6.65E-07	4.99E-11	2.5E-08
BLM	27	1.48E-06	1.11E-10	5.55E-08
GLA	8	4.51E-07	3.38E-11	1.69E-08
KNE	11	6.06E-07	4.55E-11	2.28E-08
KVA	12	6.36E-07	4.78E-11	2.39E-08
LIS	9	4.88E-07	3.67E-11	1.83E-08
MAN	18	9.64E-07	7.24E-11	3.62E-08
MGB	10	5.38E-07	4.04E-11	2.02E-08
MGS	16	8.66E-07	6.5E-11	3.25E-08
PRI	11	5.82E-07	4.37E-11	2.18E-08
PRN	11	6.2E-07	4.65E-11	2.33E-08
RAD	34	1.88E-06	1.41E-10	7.07E-08
SIP	18	1E-06	7.55E-11	3.77E-08

3.3 KOSOVO – TOXIC RISK

The hazard quotient values for the Kosovo sites are presented in Table 11. In all cases the values are much less than 1.0 including addition of chromium toxic risk through soil inhalation, Table 12.

Table 11 Hazard Quotient estimates for Kosovo soil exposures through oral ingestion

Site	**Pb**	**Cd**	**As**	**Zn**	**Cu**	**Ni**	**Cr**
ABA	67	1	7	79	16	3298	202
ADD	1.26E-05	9.38E-08	1.33E-06	1.48E-05	2.98E-06	0.000618	3.79E-05
HQ	**0.017971**	**9.38E-05**	**0.004435**	**4.94E-05**	**N/d**	**0.030922**	**0.012649**
AGA	106	0.5	37	137	47	485	410
ADD	1.98E-05	9.38E-08	7E-06	2.57E-05	8.88E-06	9.09E-05	7.68E-05
HQ	**0.028339**	**9.38E-05**	**0.023344**	**8.57E-05**	**N/d**	**0.004544**	**0.025614**
AGU	72	0.5	22	95	41	142	133
ADD	1.35E-05	9.38E-08	4.1E-06	1.78E-05	7.75E-06	2.67E-05	2.49E-05
HQ	**0.019286**	**9.38E-05**	**0.013665**	**5.92E-05**	**N/d**	**0.001335**	**0.008313**
AHA	87	1	21	114	41	140	114
ADD	1.64E-05	1.88E-07	3.86E-06	2.13E-05	7.66E-06	2.63E-05	2.15E-05
HQ	**0.023418**	**0.000188**	**0.012857**	**7.11E-05**	**N/d**	**0.001317**	**0.007152**
AMU	60	1	19	108	49	155	144
ADD	1.13E-05	1.88E-07	3.55E-06	2.03E-05	9.16E-06	2.91E-05	2.7E-05
HQ	**0.016127**	**0.000188**	**0.011849**	**6.76E-05**	**N/d**	**0.001455**	**0.009008**
APA	43	0.5	10	57	26	195	136
ADD	8.04E-06	9.38E-08	1.86E-06	1.07E-05	4.85E-06	3.66E-05	2.55E-05
HQ	**0.011486**	**9.38E-05**	**0.006205**	**3.55E-05**	**N/d**	**0.001829**	**0.00851**
ARI	41	0.5	12	90	38	170	161
ADD	7.76E-06	9.38E-08	2.16E-06	1.69E-05	7.06E-06	3.18E-05	3.01E-05
HQ	**0.011089**	**9.38E-05**	**0.007212**	**5.63E-05**	**N/d**	**0.001592**	**0.010034**
ATR	46	0.5	7	81	32	1695	254
ADD	8.53E-06	9.38E-08	1.37E-06	1.51E-05	5.92E-06	0.000318	4.76E-05
HQ	**0.012188**	**9.38E-05**	**0.004576**	**5.03E-05**	**N/d**	**0.015893**	**0.015876**
AVJ	159	0.5	33	168	52	189	159
ADD	2.97E-05	9.38E-08	6.19E-06	3.14E-05	9.75E-06	3.54E-05	2.98E-05
HQ	**0.042461**	**9.38E-05**	**0.020649**	**0.000105**	**N/d**	**0.001772**	**0.009928**
AWA	50	0.5	15	50	18	50	61
ADD	9.32E-06	9.38E-08	2.81E-06	9.37E-06	3.38E-06	9.39E-06	1.14E-05
HQ	**0.013314**	**9.38E-05**	**0.009362**	**3.12E-05**	**N/d**	**0.000469**	**0.003795**
B1S	170	1	27	211	63	149	109
ADD	3.18E-05	1.88E-07	5.06E-06	3.96E-05	1.18E-05	0.000028	2.04E-05
HQ	**0.045446**	**0.000188**	**0.016875**	**0.000132**	**N/d**	**0.0014**	**0.006792**
B2S	80	1	42	122	48	146	117
ADD	0.000015	1.88E-07	7.88E-06	2.29E-05	0.000009	2.74E-05	2.19E-05
HQ	**0.021429**	**0.000188**	**0.02625**	**7.63E-05**	**N/d**	**0.001369**	**0.007313**
B3S	32	0.5	12	69	50	164	130
ADD	5.91E-06	9.38E-08	2.16E-06	1.28E-05	9.38E-06	3.07E-05	2.43E-05
HQ	**0.008438**	**9.38E-05**	**0.007188**	**4.28E-05**	**N/d**	**0.001533**	**0.008094**

Table 11 (continued)

Site	Pb	Cd	As	Zn	Cu	Ni	Cr
B4S	88	1	19	132	60	180	137
ADD	1.65E-05	1.88E-07	3.47E-06	2.47E-05	1.13E-05	3.37E-05	2.56E-05
HQ	**0.023571**	**0.000188**	**0.011563**	**8.23E-05**	**N/d**	**0.001683**	**0.008531**
BCQ	54	1	14	66	24	90	74
ADD	1E-05	1.88E-07	2.53E-06	1.24E-05	4.41E-06	1.68E-05	1.39E-05
HQ	**0.01433**	**0.000188**	**0.008438**	**4.13E-05**	**N/d**	**0.000839**	**0.004625**
BEF	63	1.0	21	87	44	128	128
ADD	1.18E-05	1.88E-07	3.88E-06	1.62E-05	8.25E-06	2.39E-05	2.39E-05
HQ	**0.016786**	**0.000188**	**0.012917**	**5.41E-05**	**N/d**	**0.001195**	**0.007969**
BFL	96	0.5	23	114	58	145	166
ADD	1.79E-05	9.38E-08	4.22E-06	2.14E-05	1.08E-05	2.72E-05	3.12E-05
HQ	**0.02558**	**9.38E-05**	**0.014063**	**7.13E-05**	**N/d**	**0.001359**	**0.010391**
BG2	41	1.0	8	99	44	64	57
ADD	7.63E-06	1.88E-07	1.55E-06	1.85E-05	8.2E-06	1.2E-05	1.07E-05
HQ	**0.010906**	**0.000188**	**0.005179**	**6.17E-05**	**N/d**	**0.000601**	**0.003571**
BG3	47	0.5	14	39	16	35	64
ADD	8.81E-06	9.38E-08	2.56E-06	7.28E-06	3.03E-06	6.63E-06	0.000012
HQ	**0.012589**	**9.38E-05**	**0.008542**	**2.43E-05**	**N/d**	**0.000331**	**0.004**
BJH	35	2	8	69	17	2177	317
ADD	6.47E-06	3.75E-07	1.5E-06	1.28E-05	3.09E-06	0.000408	5.94E-05
HQ	**0.009241**	**0.000375**	**0.005**	**4.28E-05**	**N/d**	**0.020409**	**0.019813**
BLI	48	0.5	19	74	38	144	154
ADD	8.95E-06	9.38E-08	3.52E-06	1.38E-05	7.03E-06	0.000027	2.89E-05
HQ	**0.01279**	**9.38E-05**	**0.011719**	**4.61E-05**	**N/d**	**0.00135**	**0.009625**
BNP	50	0.5	14	52	21	200	114
ADD	9.33E-06	9.38E-08	2.54E-06	9.75E-06	4.02E-06	3.75E-05	2.15E-05
HQ	**0.013333**	**9.38E-05**	**0.008472**	**3.25E-05**	**N/d**	**0.001875**	**0.007153**
BOB	76	0.5	14	89	33	149	114
ADD	1.42E-05	9.38E-08	2.58E-06	1.66E-05	6.18E-06	0.000028	2.14E-05
HQ	**0.020286**	**9.38E-05**	**0.008583**	**5.53E-05**	**N/d**	**0.0014**	**0.007138**
BPA	43	0.5	10	50	21	179	135
ADD	8.14E-06	9.38E-08	1.84E-06	9.45E-06	3.9E-06	3.36E-05	2.52E-05
HQ	**0.011625**	**9.38E-05**	**0.006125**	**3.15E-05**	**N/d**	**0.001682**	**0.008413**
BRP	52	1	20	85	45	126	114
ADD	9.79E-06	1.88E-07	3.71E-06	1.59E-05	8.51E-06	2.37E-05	2.15E-05
HQ	**0.013982**	**0.000188**	**0.012375**	**5.31E-05**	**N/d**	**0.001183**	**0.00715**
BTD	286	2.0	17	134	54	119	199
ADD	5.36E-05	3.75E-07	3.14E-06	2.51E-05	1.01E-05	2.22E-05	3.73E-05
HQ	**0.076563**	**0.000375**	**0.010469**	**8.36E-05**	**N/d**	**0.001111**	**0.012448**
DGL	58	1.0	27	88	41	346	321
ADD	1.09E-05	1.88E-07	5.13E-06	1.66E-05	7.65E-06	6.5E-05	6.01E-05
HQ	**0.015563**	**0.000188**	**0.017101**	**5.53E-05**	**N/d**	**0.003248**	**0.020041**

Table 12 Chromium Hazard Quotients for soil inhalation

Site	Cr(soil)	Cr(inhaled)	ADD(inh)	Toxic Risk
ABA	202	1.11E-05	1.28E-07	0.0013
AGA	410	2.24E-05	2.59E-07	0.0026
AGU	133	7.28E-06	8.42E-08	0.0008
AHA	114	6.26E-06	7.24E-08	0.0007
AMU	144	7.89E-06	9.12E-08	0.0009
APA	136	7.45E-06	8.62E-08	0.0009
ARI	161	8.79E-06	1.02E-07	0.0010
ATR	254	1.39E-05	1.61E-07	0.0016
AVJ	159	8.70E-06	1.01E-07	0.0010
AWA	61	3.32E-06	3.84E-08	0.0004
B1S	109	5.95E-06	6.88E-08	0.0007
B2S	117	6.41E-06	7.41E-08	0.0007
B3S	130	7.09E-06	8.2E-08	0.0008
B4S	137	7.47E-06	8.64E-08	0.0009
BCQ	74	4.05E-06	4.68E-08	0.0005
BEF	128	6.98E-06	8.07E-08	0.0008
BFL	166	9.10E-06	1.05E-07	0.0011
BG2	57	3.13E-06	3.62E-08	0.0004
BG3	64	3.50E-06	4.05E-08	0.0004
BJH	317	1.74E-05	2.01E-07	0.0020
BLI	154	8.43E-06	9.75E-08	0.0010
BNP	114	6.27E-06	7.24E-08	0.0007
BOB	114	6.25E-06	7.23E-08	0.0007
BPA	135	7.37E-06	8.52E-08	0.0009
BRP	114	6.26E-06	7.24E-08	0.0007
BTD	199	1.09E-05	1.26E-07	0.0013
DGL	321	1.76E-05	2.03E-07	0.0020

Table 13 Increased risk of cancer through Chromium inhalation

Site	Cr(soil)	Cr(inhaled)	LADD(inh)	Risk
ABA	202	1.11E-05	8.32E-10	1.E-11
AGA	410	2.24E-05	1.68E-09	2.E-11
AGU	133	7.28E-06	5.47E-10	7.E-12
AHA	114	6.26E-06	4.7E-10	6.E-12
AMU	144	7.89E-06	5.92E-10	7.E-12
APA	136	7.45E-06	5.6E-10	7.E-12
ARI	161	8.79E-06	6.6E-10	8.E-12
ATR	254	1.39E-05	1.04E-09	1.E-11
AVJ	159	8.70E-06	6.53E-10	8.E-12
AWA	61	3.32E-06	2.5E-10	3.E-12
B1S	109	5.95E-06	4.47E-10	5.E-12
B2S	117	6.41E-06	4.81E-10	6.E-12
B3S	130	7.09E-06	5.32E-10	6.E-12
B4S	137	7.47E-06	5.61E-10	7.E-12
BCQ	74	4.05E-06	3.04E-10	4.E-12
BEF	128	6.98E-06	5.24E-10	6.E-12
BFL	166	9.10E-06	6.83E-10	8.E-12
BG2	57	3.13E-06	2.35E-10	3.E-12
BG3	64	3.50E-06	2.63E-10	3.E-12
BJH	317	1.74E-05	1.3E-09	2.E-11
BLI	154	8.43E-06	6.33E-10	8.E-12
BNP	114	6.27E-06	4.7E-10	6.E-12
BOB	114	6.25E-06	4.69E-10	6.E-12
BPA	135	7.37E-06	5.53E-10	7.E-12
BRP	114	6.26E-06	4.7E-10	6.E-12
BTD	199	1.09E-05	8.19E-10	1.E-11
DGL	321	1.76E-05	1.32E-09	2.E-11

Table 14 Increased risk of cancer through Cadmium inhalation

Site	Cd	Cd(inhaled)	LADD(inh)	Risk
ABA	0.5	2.74E-08	2.06E-12	1.E-09
AGA	0.5	2.74E-08	2.06E-12	1.E-09
AGU	0.5	2.74E-08	2.06E-12	1.E-09
AHA	1	5.48E-08	4.11E-12	2.E-09
AMU	1	5.48E-08	4.11E-12	2.E-09
APA	0.5	2.74E-08	2.06E-12	1.E-09
ARI	0.5	2.74E-08	2.06E-12	1.E-09
ATR	0.5	2.74E-08	2.06E-12	1.E-09
AVJ	0.5	2.74E-08	2.06E-12	1.E-09
AWA	0.5	2.74E-08	2.06E-12	1.E-09
B1S	1	5.48E-08	4.11E-12	2.E-09
B2S	1	5.48E-08	4.11E-12	2.E-09
B3S	0.5	2.74E-08	2.06E-12	1.E-09
B4S	1	5.48E-08	4.11E-12	2.E-09
BCQ	1	5.48E-08	4.11E-12	2.E-09
BEF	1	5.48E-08	4.11E-12	2.E-09
BFL	0.5	2.74E-08	2.06E-12	1.E-09
BG2	1	5.48E-08	4.11E-12	2.E-09
BG3	0.5	2.74E-08	2.06E-12	1.E-09
BJH	2	1.10E-07	8.22E-12	5.E-09
BLI	0.5	2.74E-08	2.06E-12	1.E-09
BNP	0.5	2.74E-08	2.06E-12	1.E-09
BOB	0.5	2.74E-08	2.06E-12	1.E-09
BPA	0.5	2.74E-08	2.06E-12	1.E-09
BRP	1	5.48E-08	4.11E-12	2.E-09
BTD	2	1.10E-07	8.22E-12	5.E-09
DGL	1	5.48E-08	4.11E-12	2.E-09

Table 15 Increased risk of cancer through arsenic ingestion

Site	As	ADD	LADD	Risk
ABA	7	1.33E-06	8.64E-09	1.E-08
AGA	37	7.00E-06	4.55E-08	7.E-08
AGU	22	4.10E-06	2.66E-08	4.E-08
AHA	21	3.86E-06	2.5E-08	4.E-08
AMU	19	3.55E-06	2.31E-08	3.E-08
APA	10	1.86E-06	1.21E-08	2.E-08
ARI	12	2.16E-06	1.41E-08	2.E-08
ATR	7	1.37E-06	8.91E-09	1.E-08
AVJ	33	6.19E-06	4.02E-08	6.E-08
AWA	15	2.81E-06	1.82E-08	3.E-08
B1S	27	5.06E-06	3.29E-08	5.E-08
B2S	42	7.88E-06	5.11E-08	8.E-08
B3S	12	2.16E-06	1.4E-08	2.E-08
B4S	19	3.47E-06	2.25E-08	3.E-08
BCQ	14	2.53E-06	1.64E-08	2.E-08
BEF	21	3.88E-06	2.52E-08	4.E-08
BFL	23	4.22E-06	2.74E-08	4.E-08
BG2	8	1.55E-06	1.01E-08	2.E-08
BG3	14	2.56E-06	1.66E-08	2.E-08
BJH	8	1.50E-06	9.74E-09	1.E-08
BLI	19	3.52E-06	2.28E-08	3.E-08
BNP	14	2.54E-06	1.65E-08	2.E-08
BOB	14	2.58E-06	1.67E-08	3.E-08
BPA	10	1.84E-06	1.19E-08	2.E-08
BRP	20	3.71E-06	2.41E-08	4.E-08
BTD	17	3.14E-06	2.04E-08	3.E-08
DGL	27	5.13E-06	3.33E-08	5.E-08

Table 16 Comparison of lifetime average daily dose of arsenic through inhalation with the index dose

Site	As	As(inh)	LADD(inh)	cf-ID
ABA	7	3.8853E-07	2.92E-11	1.459E-08
AGA	37	2.0449E-06	1.54E-10	7.677E-08
AGU	22	1.197E-06	8.99E-11	4.494E-08
AHA	21	1.1263E-06	8.46E-11	4.228E-08
AMU	19	1.038E-06	7.79E-11	3.897E-08
APA	10	5.436E-07	4.08E-11	2.041E-08
ARI	12	6.3181E-07	4.74E-11	2.372E-08
ATR	7	4.0086E-07	3.01E-11	1.505E-08
AVJ	33	1.8088E-06	1.36E-10	6.79E-08
AWA	15	8.2015E-07	6.16E-11	3.079E-08
B1S	27	1.4783E-06	1.11E-10	5.549E-08
B2S	42	2.2995E-06	1.73E-10	8.632E-08
B3S	12	6.2963E-07	4.73E-11	2.364E-08
B4S	19	1.0129E-06	7.6E-11	3.802E-08
BCQ	14	7.3913E-07	5.55E-11	2.775E-08
BEF	21	1.1315E-06	8.5E-11	4.248E-08
BFL	23	1.2319E-06	9.25E-11	4.625E-08
BG2	8	4.5364E-07	3.41E-11	1.703E-08
BG3	14	7.4825E-07	5.62E-11	2.809E-08
BJH	8	4.38E-07	3.29E-11	1.644E-08
BLI	19	1.0266E-06	7.71E-11	3.854E-08
BNP	14	7.4217E-07	5.57E-11	2.786E-08
BOB	14	7.519E-07	5.65E-11	2.823E-08
BPA	10	5.3655E-07	4.03E-11	2.014E-08
BRP	20	1.0841E-06	8.14E-11	4.07E-08
BTD	17	9.1706E-07	6.89E-11	3.443E-08
DGL	27	1.4981E-06	1.12E-10	5.624E-08

3.4 KOSOVO – CARCINOGENIC RISK

Table 13 presents estimates of increased risk of cancer through chromium inhalation; all values are much less than 1 in a million.

Table 14 presents estimates of increased risk of cancer through cadmium inhalation; again all the tabulated risk estimates are less than one in a million. Since many of the cadmium data were below the limit of analytical detection a concentration of half of the detection limit was used in the calculations. Even setting the cadmium concentration at the detection limit does not alter this finding and the risk estimate remains unchanged.

In Table 15 the increased risk of cancer due to arsenic from soil ingestion is documented. In all cases the value is less than one in a million. Table 16 documents the comparison of the LADD for arsenic inhalation with the Index Dose for arsenic inhalation. The quotient is very low and of the order of 1E-8.

4 Summary

Toxic risk and carcinogenic risk estimates are presented for military sites in Bosnia and Kosovo. The tabulated data presented is for an adult male exposed for 12 hours per day to soil. The pathways considered in the analysis were soil ingestion and inhalation. The calculations indicate that there is no toxic risk at any of the sites and the increased risk of cancer due to soil ingestion and inhalation is below the currently accepted U.S. EPA value of one in a million increased risk. Lifetime average daily doses are below the Index Dose thresholds for inhalation of chromium, cadmium and arsenic at all sites.

Since the office based group have an exposure that is 75% less than the outdoor group the soil intakes are correspondingly linearly reduced by the same amount. Consequently the hazard quotients and carcinogenic risks are reduced also by 75%.

References

BENES, C M, BENJAMIN, D M, HOWAY, J, LOBO, L, and PAPPAS, C. 1995. Risk*Assistant. Alexandria, Va, Hampshire Research Institute.

DEFRA, and EA. 2002a. Contaminants in soil: Collation of Toxological Data and Intake Values for Humans. *Environment Agency*, R&D Publication CLR 9.

DEFRA, and EA. 2002b. Contaminants in soil: collation of toxicological data and intake values for humans. Chromium. *Environment Agency*, R&D Publication TOX 4.

DEFRA, and EA. 2002c. Contaminants in soil: collation of toxicological data and intake values for humans. Lead. *Environment Agency*, R&D Publication TOX 6.

DEFRA, and EA. 2002d. The Contaminated Land Exposure Assessment Model (CLEA): Technical basis and algorithms. *Environment Agency*, R&D Publication CLR 10.

ECETOC. 2001. Exposure Factors Sourcebook for European Populations (with Focus on UK Data). *European Centre for Ecotoxicology and Toxicology of Chemicals*, Technical Report No. 79.

USEPA. 1999. Exposure Factors Handbook (EFH). *United States Environmental Protection Agency*, EPA/600/C-99/001.

WARK, K, and WARNER, C F. 1981. *Air Pollution: Its Origin and Control* (2nd. edition). (New York: Harper & Row.)