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Energetic materials and metals contamination at CFB/ASU Wainwright, Alberta

Phase I

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Technical Report
DRDC Valcartier TR 2007-385
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Abstract

Military training on fields and ranges at Canadian Force Bases is essential to prepare our troops for potential wars and/or peace missions. On the other hand, the growing concern of DND leaders and of the general population makes it necessary to evaluate the impacts of training on the environment. During the last 10 years, new methods of characterization have been developed to assess the energetic materials contamination, which is different from the usual contamination in residential or industrial scenarios. The CFB/ASU Wainwright in Alberta was characterized to assess the contamination by metals and energetic materials into the soil and the biomass. This location was selected based on its intensive use by Canadian and allied troops and based on its potential for heavier training intensity in the future. Several types of training sites were visited such as grenade, rifle, battle run, small arms and anti-tank ranges. The different methods of characterization were adapted for each situation, i.e. the type of fired ammunition, the concentration of contaminants, and the size and the pattern of the training sites. Soil and biomass samples were taken using a composite approach to be statistically representative. The metal analyses were performed at PSC laboratory in Edmonton and the energetic materials were analyzed at DRDC Valcartier. This work was realized in May-June 2004 and was supported by the Director Land Environment (DLE), Ottawa, Canada and the Strategic Environmental Research and Development Program (SERDP), Washington D.C., USA.

R□sum□

L□entra□nement militaire dans les secteurs d□entra□nement des bases des Forces canadiennes est essentiel pour pr□parer les troupes aux guerres potentielles et/ou aux missions de paix. D□autre part, l□int□r□t grandissant du MDN et de la population par rapport □l□environnement rend n□cessaire l□□valuation de l□impact de l□entra□nement sur l□environnement. Au cours des 10 derni□res ann□es, de nouvelles m□thodes de caract□risation on □t□d□velopp□es pour □valuer la contamination en mat□riaux □nerg□tiques, diff□rente des sc□narios habituels, i.e. r□sidentiel ou industriel. La caract□risation de BFC/USS Wainwright en Alberta a permis d□□valuer la contamination en m□taux et en mat□riaux □nerg□tiques dans les sols et la biomasse. Cette base a □t□s□lectionn□e pour son utilisation intensive par les troupes canadiennes et □trang□res, et pour son utilisation future qui sera de plus en plus fr□quente. Plusieurs sites d□entra□nement ont □t□visit□s comme le site de grenade, des armes de petits calibres et anti-chars, et diff□rentes m□thodes d□□chantillonnage adapt□es □chaque situation ont □t□utilis□es, i.e. le type de munitions tir□es, la concentration des contaminants, et la grandeur et la topologie du site d□entra□nement. Les □chantillons de sols et de biomasses ont □t□pr□lev□s suivant une approche composite pour □tre statistiquement repr□sentatifs. Les analyses de m□taux ont □t□effectu□es au laboratoire PSC □Edmonton, tandis que les analyses de mat□riaux □nerg□tiques ont □t□r□alis□es □RDDC Valcartier. Ce travail a □t□r□alis□aux mois de mai et de juin 2004 et a □t□support□par DLE □Ottawa et SERDP, □Washington D.C., aux □tats-Unis.

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Executive summary

The international context of demilitarization, the closure of military bases and the more stringent aspects of environmental laws have led to the establishment of new areas for research and development. Many activities of the Canadian Forces such as the firing of ammunition, demolitions, and the destruction of obsolete ammunition by open burning and open detonation may lead to the dispersion of energetic compounds and other munitions-related contaminants in the environment. Within this context, Defence Research and Development Canada -Valcartier (DRDC Valcartier), the US Army Engineer Research and Development Center (ERDC) and the Cold Regions Research and Engineering Laboratory (CRREL) initiated research programs to study the environmental impact of energetic materials that are found in the Department of National Defence (DND) and in the US Department of Defence (DoD) ammunition stockpiles. The Programs on site characterization allowed the development of a unique expertise and positioned our departments to better understand the impacts of live fire training and to be in a readiness state to answer any inquiries and take corrective actions if needed. The first training areas to be characterized within the Canadian Programme, sponsored by Director Land Environment (DLE) and by a major US funding program, the Strategic Environmental R&D Program (SERDP), were mainly army bases such as CFB Chilliwack, Shilo, Valcartier and Gagetown. Moreover, interest grew to study the training ranges from Cold Lake Air Weapon Ranges (CLAWR) in Alberta; this study represented the first internal efforts to characterize an entire Air Force Base.

This report describes the first phase of the characterization campaign done in June 2004 at Canadian Forces Base/Area Support Unit (CFB/ASU) in Wainwright. In 1998, a preliminary study was performed on the anti-tank ranges but this base was never entirely characterized. The aim of this campaign was to assess the soil surface contamination of various types of ranges and to increase our knowledge about the potential environmental impacts caused by live firing activities. Sampling strategies, such as circular sampling around targets and linear sampling before and after the firing positions, developed during the previous campaign were used. Moreover, soils and biomass samples were collected using the compositing technique. Samples were analyzed for explosive contamination using High Performance Liquid Chromatography (HPLC) and heavy metals concentrations were measured by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) by an external laboratory (PSC Analytical Services, Edmonton, Alberta).

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Sommaire

Le contexte international de la d□militarisation, de la fermeture de bases et de la s□v□rit□ croissante des lois environnementales a conduit □l□□mergence de nouveaux champs de R&D. Plusieurs activit□s des Forces arm□es canadiennes telles que l□entra□hement au tir de diverses munitions et la destruction de munitions, jug□es d□su□tes ou en surplus, par br□lage ou d□tonation ext□rieure peuvent conduire □la dispersion dans l□environnement de compos□s comme les mat□riaux □nerg□tiques et les m□taux. Dans ce contexte, Recherches et D□veloppement pour la D□fense Canada □Valcartier (RDDC Valcartier) en collaboration avec □Cold Regions Research and Engineering Laboratory□(CRREL), □US Army Engineer Research and Development Center (ERDC)□et □ERDC Environmental Laboratory (EL)□, ont entrepris des programmes de recherche afin d□□tudier les impacts environnementaux des compos□s □nerg□tiques associ□s aux activit□s du minist□re de la d□fense nationale (MDN) et du Department of Defence (DoD). Les programmes de caract□risation de sites ont permis de d□velopper une expertise unique et ont aid□nos organisations de d□fense □mieux comprendre les impacts des entra□hements □tir r□el et □□tre pr□tes □r□pondre □toute □ventualit□pour prendre des mesures correctives, si n□cessaire. Les premiers sites d□entra□hement □□tre □tudi□s dans le cadre du programme canadien financ□par RDDC, DGE, DLE ainsi que par un programme majeur de fonds am□ricains, le □Strategic Environmental R&D Programme (SERDP)□□taient situ□s sur les bases de Chilliwack, Shilo, Valcartier et Gagetown. De plus, la caract□risation des secteurs d□entra□hement de la base de l□air □Cold Lake en Alberta, r□alis□e en 2002, repr□sentait les premiers efforts internes pour □chantillonner une base enti□re des forces a□riennes.

Ce rapport d□crit la premi□re phase d□□chantillonnage r□alis□e en juin 2004 □la base des Forces canadiennes/Unit□de soutien de secteur (BFC/USS) □Wainwright en Alberta, effectu□e dans le cadre du projet de caract□risation des bases militaires canadiennes. Cette premi□re phase a permis d□□tudier les impacts environnementaux potentiels caus□s par les activit□s de tirs r□els sur les sites de grenades, d□anti-char, de petits calibres et de mortiers et de cibler les probl□mes potentiels de contamination. Des □chantillons de sols et, dans certains cas, de biomasse ont □t□collect□s en utilisant la technique des sous-□chantillons composites. Pour la caract□risation des mat□riaux □nerg□tiques, les □chantillons ont □t□analys□s □RDDC Valcartier par chromatographie liquide □haute performance (CLHP). En ce qui concerne les analyses de m□taux, la caract□risation a □t□r□alis□e par spectrom□trie de masse coupl□e □un plasma inductif (SM/CPI) par un laboratoire priv□(PSC Analytical Services, Edmonton, Alberta).

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Introduction

Military training ranges in Canadian Force Bases are essential to prepare troops for potential wars and peace missions. On the other hand, the growing concern of the leaders from the Department of National Defence (DND) and of the general population makes it necessary to evaluate the impacts of training on the environment. During the last 10 years, methods of characterization have been developed to assess the contamination by energetic materials, which is different compared to the contamination in residential or industrial scenarios [1]. Testing and training ranges are key elements in maintaining the capability, readiness, and interoperability of the Armed Forces. The potential environmental impacts of live-fire training mandate that our organizations demonstrate responsible management of these facilities in order to continue the military activities. Moreover, many other countries, such as the United States and the United Kingdom, use Canadian training ranges under international agreements. Recently, awareness has increased that the energetic residues and heavy metals associated with munitions can be released in the environment during training activities and, over time, can potentially contaminate the underlying groundwater. For instance, munitions training and testing exercises were suspended at the Massachusetts Military Reservation following the discovery of low concentrations of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in the groundwater beneath the main training area (EPA Order #2). On military training ranges, munitions-related pollutants can be released to the environment from breaches in the casings of unexploded ordnances (UXO) or partially exploded ordnance (low-order detonations), from poor disposal practices, such as unconfined burning operations, from blow-in-place operations, and from live-fire operations. The Strategic Environmental Research and Development Program (SERDP) funded several studies directed at the assessment of source terms, pathways of biodegradation, and fate of munitions residues on military training facilities. Moreover, Director Land Environment (DLE) tasked DRDC Valcartier to initiate a research program for the environmental characterization of their main training areas. The work carried out at Canadian Forces Base/Area Support Unit (CFB/ASU) Wainwright was co-sponsored by both programs.

The most extensive study achieved up to now was conducted at the Canadian Forces Ammunition Depot (CFAD) Dundurn open detonation range, where the impact of the open detonation of Canadian obsolete munitions was evaluated [2]. The first training range visited was the CFB Shilo training area where research demonstrated the environmental impacts of live fire training [3-4]. Antitank firing ranges across Canada were also the topic of other studies [5-7]. Moreover, many papers were written in recent years concerning the fate and analysis of explosives in various types of sites [1,8-32]. A protocol describing the different methods of sampling and the analytical chemistry was developed in collaboration with CRREL [1] and was recently updated. It is now available on the Web under the auspices of The Technical Cooperation Program (TTCP) by the member nations (Canada, the United States, the United Kingdom, Australia and New Zealand) [23]. Research results to date have demonstrated that explosives exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In the United States, concerted efforts have been made to develop analytical chemistry, to establish the best sampling procedures and to understand the complex fate of explosives in the environment [8-10, 16-17, 19, 28-29, 33-42].

Energetic materials are prominent components of munitions and weapons that can be found in war zones, training ranges and on production sites. During the past decade, many requirements have emerged related to the identification, quantification, and elimination of energetic contaminants dispersed by munitions, or present in explosives dumps, trials, or destruction fields, firing areas, and production sites [1, 2, 5, 8-10, 13, 14, 16-19, 23, 29, 34-42]. Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning/open detonation (OB/OD) ranges, which were used to destroy out-of-specification materials, were highly suspected of being contaminated with energetic constituents as described in the literature [2, 5, 8, 9, 13, 14, 18, 19, 29, 34, 40-42]. High explosives used by both Canada and the United States generally contain either 2,4,6-trinitrotoluene (TNT) or mixtures of TNT with hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), or for some older munitions, tetryl (n-methyl-n-2,4,6-tetranitroaniline). Most of the air weapons contain TNT with aluminum (tritonal explosives). The most powerful weapons contain Composition B (TNT with RDX) or Octol (TNT with HMX). When unexploded ordnances (UXOs) are found on sites, they are often blown-in-place (BIP) using C4, a mixture of RDX with a polymer. These BIP operations often spread explosives into the environment [40]. In addition, nitroglycerin (NG) and 2,4-dinitrotoluene (DNT) are compounds used in the propellant formulations that could be found at firing positions. Nitrocellulose is also a major ingredient in propellant formulations, but it is not considered toxic.

CFB/ASU Wainwright was opened in 1939 when World War II broke out. Before this time, the area was a Buffalo National Park. The federal government was looking for a huge area in Canada to train full brigades with all the necessary equipment. Therefore, the National Park was closed and CFB/ASU Wainwright was established. This 614 km^2 base is located 200 km southeast of Edmonton and 400 km northeast of Calgary.

This report describes the surface work carried out during phase I in June 2004 to assess the contamination by metals and energetic materials into the soil and biomass. Previous studies were performed in 1996 on the contamination of anti-tank ranges in Valcartier, Wainwright and Dundurn [2], where the two anti-tank ranges in Wainwright were characterized. The objective of the study performed in 2004 was to evaluate the approaches used to characterize CFB/ASU Wainwright. The sampling pattern was adapted for each situation (i.e., the type of fired ammunition, the concentration of contaminants -in some situations, higher concentrations could be visually located- and the size and the pattern of the training sites). Soil and biomass samples were taken using a composite approach to be statistically representative, as explained in the experimental section. The hydrogeology study, which was performed by the Institut National de la Recherche Scientifique Eau, Terre et Environnement (INRS-ETE), will not be discussed in this report (see reference 43 for details). Defence Construction Canada (DCC) was responsible for hiring the analytical laboratory, providing manpower and logistics, and liaising range control personnel.

1. Experimental

The characterization of the contamination produced by military training was performed by collecting soil and biomass samples in the different ranges. The following section will describe the different sampling patterns used to realise this study and all extraction and analytical methods taken to analyse soil and biomass collected samples.

1.1 Background

Background samples are critical for establishing the anthropogenic contribution versus the natural contribution for all metallic parameters. Background composite samples of soil and biomass were collected randomly, in circles of approximately 10-m diameter in different locations inside and outside the base at the periphery of the live-fire area. A minimum of 30 increments was collected to form each background sample.

A statistical analysis was conducted to identify a mean background concentration and to define a limit for a value that can be considered normal. Values at the extremities of the lognormal curve were identified. The limits, named mean background (MBG) concentrations, were chosen for a probability of 97.72 percent (two times the standard deviation). The probability of finding a result with a value higher than this limit is 2.28 percent. When the analytical laboratory did not detect a specific parameter, a value of half of the detection limit was used for the data analysis.

1.2 Sample Handling, Treatment and Analytical Methods

The usual strategy for soil sampling included systematically sampling at firing positions, around a representative number of targets and around suspected hot spots (broken casings, UXOs, or debris, etc.) as described in the soil sampling protocol. Usually, surface soils were collected up to a depth of 2.5 cm. Soil sample duplicates were taken to reach approximately 10 percent of the number of collected samples. Wherever vegetation samples were collected, the method consisted in building composite samples of indigenous living plants by randomly cutting various types of plants. A minimum of 25 to 30 increments of mixed vegetative material was collected to build the vegetation samples around targets and in transects [5]. Only the upper part of the plants (without roots) was collected, since grazing animals rarely eat the roots of the plants. Metals can bio-accumulate either in the upper plant system or in the roots, depending on their solubility. All of the composite samples were stored in polyethylene bags.

Soil samples were analyzed for metals and energetic materials, while vegetation (biomass) samples were analyzed for metals only. No biomass samples were analyzed for energetic materials, since no explosives were detected in other studies [3-4]. Metals were analyzed using the EPA Method 3050 [44] involving a nitric acid/hydrogen peroxide digestion followed by Inductively Coupled Plasma/Mass Spectrometry (ICP/MS) by an external laboratory (PSC Analytical Services, Edmonton, Alberta). Metals analyzed for this study were silver (Ag), aluminium (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), bismuth

(Bi), calcium (Ca), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), mercury (Hg), potassium (K), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), Sodium (Na), nickel (Ni), phosphorus (P), lead (Pb), rubidium (Rb), sulphur (S), selenium (Se), antimony (Sb), tin (Sn), strontium (Sr), tellurium (Te), titanium (Ti), thallium (Tl), uranium (U), vanadium (V), zinc (Zn), and zirconium (Zr). The samples were frozen and sent to DRDC Valcartier and PSC laboratory for energetic materials and metal analyses, respectively. Samples analyzed for both types of analytes (energetic materials and metals) were first homogenized and divided at DRDC Valcartier before sending one portion to PSC laboratory.

For energetic materials analyses, soil samples were air-dried in the dark, and homogenized by adding acetone to form a slurry, which was then evaporated. Homogenized soils were sieved through 25-mesh sieves and extracted according to the following procedure. Eight grams of soil were put into an amber vial and mixed with acetonitrile (10 ml). A vortex was applied for one minute, followed by sonication for 18 h in an ultrasonic bath in the dark. The samples were left to settle for 30 min. Acetonitrile (2 ml) was recovered from the vial and diluted with water (2 ml) containing calcium chloride (1%). The removed mixture was filtered on a 0.45-microns filter to get 1 ml of solution for injection into the high performance liquid chromatograph (HPLC). Soil extracts were maintained at 4 C until analyzed by HPLC according to EPA Method 8330 [45].

The HPLC method was preferred to the gas chromatography (GC) method recently published, since reproducible results with the GC/electron capture detector (ECD) method were difficult to achieve and concentrations expected were in the range of the mg/kg, easily achievable by the more rugged HPLC method [35-36]. The HPLC method achieved a detection limit of 0.25 mg/kg for all analytes, which was reduced to 0.06 mg/kg when the sample extracts were concentrated in a Zymark apparatus (Turbovap evaporator, produced by Zymark Corporation, Hopkinton, MA, USA). To obtain lower limits of detection, 2 ml of acetonitrile from the soil extract were concentrated by evaporating to dryness and adding 0.5 ml of water and 0.5 ml of acetonitrile. Analyses were performed with a HPLC Agilent HP 1100 equipped with a degasser G1322A, a quaternary pump model G1311A, an autosampler G1313A, and an ultraviolet (UV) diode array detector model G1315A monitoring at 210, 220, and 254 nm. The injection volume was 20 µl and the column used was a Supelcosil LC-8 column 25 cm x 3 mm x 5 µm eluted with 15:85 isopropanol/water (v/v) at a flow rate of 0.75 ml/min. The column temperature was maintained at 25^{o} C during the analysis. Standards and solvents were diluted 1:2, acetonitrile to water (0.5 ml ACN /0.5 ml water).

Toxicity characteristic leaching procedure (TCLP) was conducted on selected samples from the target area on small arms training ranges and the munitions dump area. The sample was thoroughly agitated in an aqueous acidic media during 24 h and analyzed for metals as described at the online source for EPA Method 1311 [46]. The following elements were analyzed: Ag, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Hg, Ni, Pb, Se, Sb, Tl, U, V, Zn and Zr.

2. Range Descriptions and Sampling Strategies

This section describes the set-ups of characterization chosen based on the topography of the site and on the type of the training done in the range. The number of soil and biomass samples is also given, while their global positioning system (GPS) positions are listed in Annex A. The map of CFB/ASU Wainwright showing all training ranges (location and size) is presented in Annex B and on a CD-Rom at the end of this report.

2.1 Background

A total of 21 soil and biomass background samples were collected around the military training areas and their GPS locations are listed in Table A1. The same GPS numbers are reported for soil and biomass backgrounds because they were collected at the same location. The sampling was done in sections where live-fire training had never occurred. Four field replicates of soil and four field replicates of biomass were also collected

2.2 Grenade Range (#2)

Only hand grenades are fired at Range #2. The bunker, where military personnel fires, is located at the entrance of the range, and, in front of it, there is an area of 20 x 50 m made principally of sand. The regions on each side (areas A to F in Figure 1) contain more vegetation than the principal shooting area. One composite of 25 to 30 increments was collected in each single region A, B, C, D, E and F, and in each area 5 x 20 m in front of the bunker (see Figure 1 for the sampling pattern). In all, 15 soils samples were taken including one duplicate. One biomass sample was also collected covering the entire surface in front of the bunker, excluding areas A to F. The GPS positions of locations identified by letters a to l in Figure 1 are given in Table A2.

2.3 Light/Medium Mortar Range (#12)

The munitions fired at Range 12 are 51- (UK), 60- and 81-mm mortars. Range 12 has four firing positions identified by piles of sand bags (the total width between the first and the last bag is 40 m) and the munitions are fired in front of the firing position in a huge area with several tanks used as targets. The sampling was done between 0 and 5 m in front of bags 1, 2, 3, and 4 and between 0 and 5 m and 5 to 15 m behind each bag, for a total of 12 samples. In the target area (Figure 2), composites of 25 to 30 increments were taken around three targets (tank) within a radius of 1 m. One hot spot in the target area, shown in Figure 3, was also sampled. A total of 17 samples were taken: eight behind and four in front of the firing position and five in the target area. No field replicates and no biomass samples were collected at this location. The GPS positions of each pile of bags and targets are grouped in Table A3.

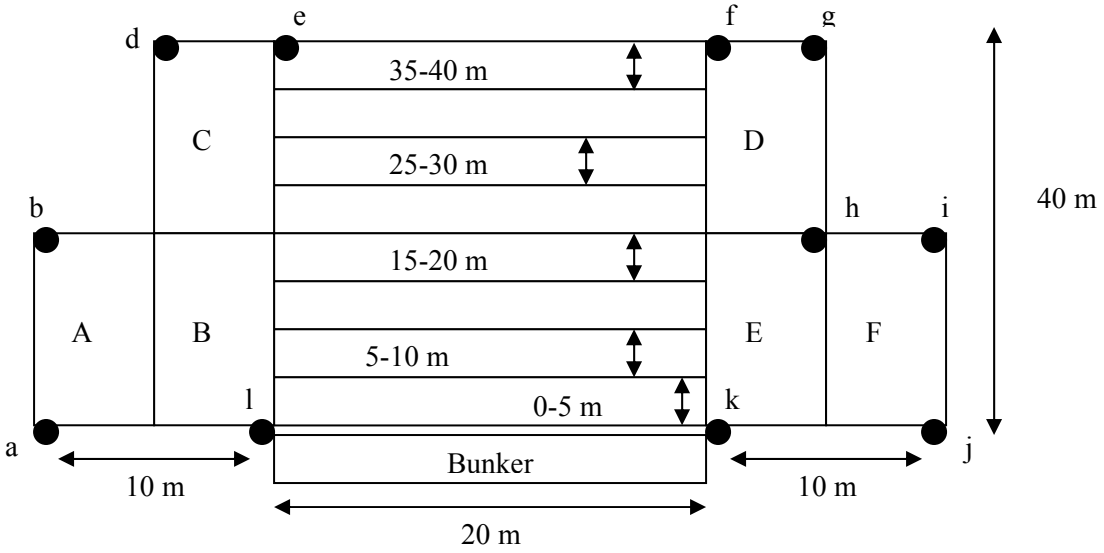

Figure 1. *Diagram of the sampling in the Grenade Range 2.*

Figure 2. *The target area in Range 12.*

Figure 3. *Hot spot sampled in Range 12.*

2.4 Demolition Range (#14)

In the demolition range, all types of munitions are destroyed. Range #14 is divided into four sections, as shown in Figure 4, and three of them are devoted to surface charges demolition and one to depth demolition (underground). The soil is principally composed of sand. Three composites of 100 increments each were taken in each section (for a total of 12 samples). A composite sample was also collected in another area close to the four areas on Figure 4, where craters from fresh detonations were observed (Figure 5). A total of 13 composite soil samples were collected. No vegetation was present in this range and, consequently, no biomass sample was collected. GPS positions of points represented by the letters a to p in Figure 4 and distances in meter between these points are given in Tables A4 and A5 in Annex A, respectively.

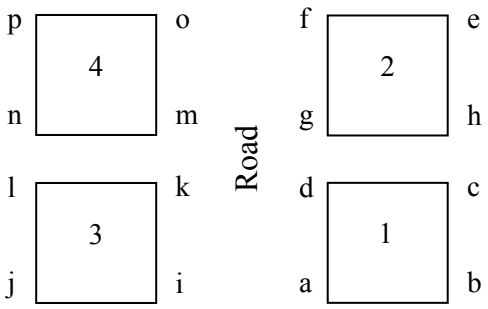

Figure 4. *Demolition areas in Range 14.*

Figure 5. *Fresh craters sampled in Range 14.*

2.5 Armoured Fighting Vehicle (AFV) Static Range (#16)

Various munitions are fired at Range 16: rifle (C3, C7 and C8), LAW, MAW, ERYX, gun (20-, 25- and 30-mm), pistol (9-mm, .22, .38 and .40), mortar (51-, 60- and 81-mm), TOW missile and explosives (105-mm tank and howitzer, 155-mm projectile, 120-mm tank, 76-mm, M76 grenade fragmentation). Range 16 is a 4000-m direct fire range containing two concrete pads from which vehicles fire, and rails for moving targets, described in the next paragraph. The first pad, presented in Figure 6, is used more frequently than the second one. Each pad contains 11 concrete rectangles. The sampling was performed in front of the five rectangles located in the middle of the pad because the contamination was surmised to be concentrated in this region as mentioned by military personnel. Soil composites of 25 to 30 increments were taken in front of these pads within areas 1 (0-10 m), 2 (10-20 m), 3 (20-30 m), 4 (30-40 m), and 5 (40-50 m) (Figure 7). One duplicate was taken for each pad. The surface in front of the first pad is flat; for the second pad, the surface slopes away at 35 m in front of the firing point. A total of 12 soil and four biomass samples were taken for both firing points (i.e. concrete pads). Table A6 lists the GPS locations of the points identified by letters a to p in Figure 7.

Two rails for movable targets are located behind earthen berms in this range; rail A illustrated in Figure 8 is 60-m long, and rail B is 1-km long. Berms are located in the middle of the impact area of Range 16 and are visible on the map of CFB/ASU Wainwright in Annex B. Their GPS positions are given in Table A7. Rail A was divided into two equal parts and one composite soil sample of 25 to 30 increments was taken in each part, while the biomass sample was made with 25 to 30 increments over the entire undivided surface (10 x 60 m). At rail B, only the 60-m long south extremity was sampled because of visual evidence of many 25-mm bullets on the ground at that location (Figure 9). As for rail A, the 60-m section of rail B was divided into two equal parts and one composite soil sample of 25 to 30 increments was taken in each part, while the biomass sample was made with 25 to 30 increments over the entire 60-m surface.

2.6 Field Firing, Artillery, Mortar and Air Weapons Range (Permanent Danger Area 4)

Permanent Danger Area 4 is an indirect fire range, where several types of training were performed (see the map in Annex B for the dimension of the range). A lot of British troops used this area for their training. The strategy used at this range was to drive or walk through the range to find source terms such as hot spots, fresh craters and firing positions (see Figure10). The discussions with military personnel allowed to find more rapidly the source terms. The first two composites were taken inside craters of approximately of two months of age located at these two GPS positions: 0520705-5832550 and 0520733-5832531. Samples were also collected into seven fresh craters (GPS positions are available in Table A8). Four firing positions of mortars were also found up a hill and four samples were taken at this location (GPS positions: A) 0524456-5831705; B) 0524455-5831108; C) 0524464-5831742; and D) 0524465-5831752). Two composites of 40 increments were also collected in areas covering two firing positions (AB and CD). Finally, a small amount of ashes formed by the destruction of UXOs and a hot spot which was a 25-mm long green British ammunition were also sampled and their GPS locations were 0524443-5831718 and 0524441-5831720,

respectively. The hot spot was probably an anti-tank ammunition but the green color does not correspond to the usual color code attributed by NATO.

Figure 6. *Pad 1 at Range 16.*

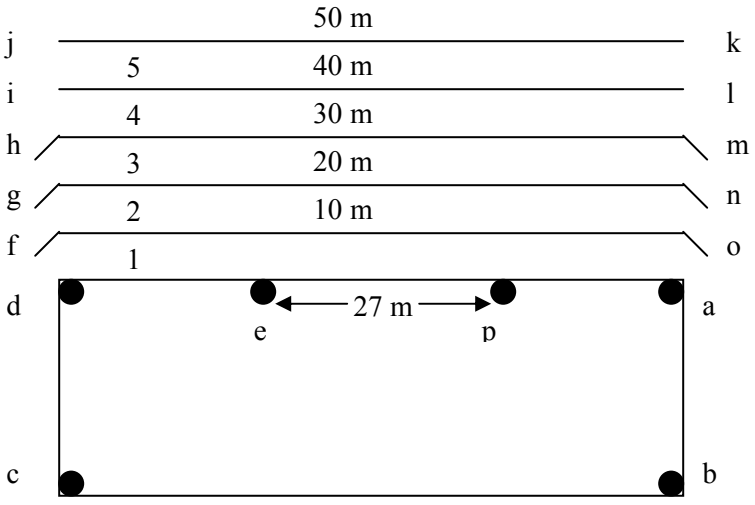

Figure 7. *Description of sampling done at the firing position in Range 16.*

Figure 8. *Rail A in Range 16.*

Figure 9. *Bullet remnants at rail B in Range 16.*

Figure 10. *Impact area in Permanent Danger Area 4.*

2.7 Platoon Field Firing Defensive Position (#21)

Various munitions are fired at Range 21, for example rifle C3 (7.62-mm), C7 (5.56 mm) and C8 (5.56-mm), pistol 9-mm, ERYX and, mortar 51- and 60-mm. The firing position at Range 21 is composed of a 300-m long trench and six lines where soldiers can shoot in the direction of the target area, as shown in Figure 11 (only three lines are drawn). Soldiers used the trench when they want to change their firing location. For the sampling, the trench was separated into three 100-m sections, and one part was not sampled. The assumption was made that the sampled 200 m was more contaminated than the 100-m unsampled section because metal casings and munitions fragments were present only in the sampled 200 m. The majority of the samples were taken inside the lines 1 to 6 (one soil sample in each line) and the trench (two samples named Trench A and Trench B). One sample was also collected outside of the mortar pit (around the hole) and one outside line 1 (around the line). Sixteen soil samples, including two duplicates and three biomass samples, were collected.

Targets are located in the field in front of lines 1 to 6. The closest sampled target (Target 1) was located at 378 m from the firing point. Three soil and one biomass samples were

collected around the targets. GPS positions of the mortar pit, the trench, the lines and targets are grouped in Table A9.

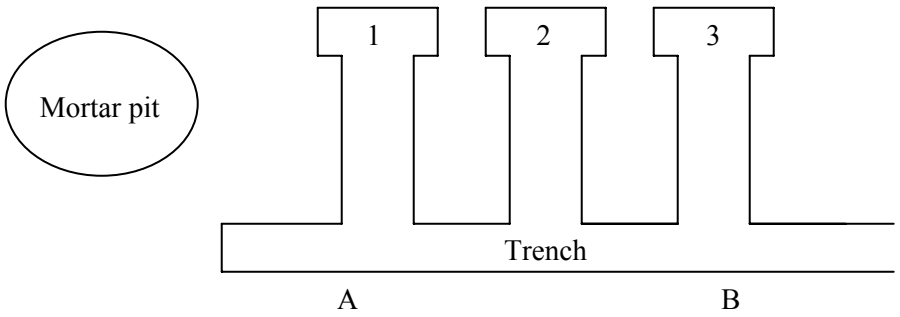

Figure 11. *Illustration of the firing positions at range 21.*

2.8 Grenade Launcher Range (#26)

Three types of weapons are fired at Range #26: grenade launcher 40-mm, rifle C7 5.56-mm and riot gun 38-mm. Range 26 is a 1000-m field firing range composed of three firing positions and a target area. The firing positions are composed of two holes and one pile of bags. Two composites of 25 to 30 increments were taken inside and outside the holes, totaling four samples, and one around bags. Two composites of 50 increments were also collected in front and behind the complete area of the firing point. In the target area, three targets were sampled totaling three soil samples. Figure 12 describes the target area with the three targets sampled and their distance from the firing point. A total of 10 soil and two biomass samples were taken. One biomass sample was collected 5 m behind and in front the firing position and one in the target area inside the triangle formed by the three targets (Figure 12). The GPS positions of firing positions and targets are given in Table A10.

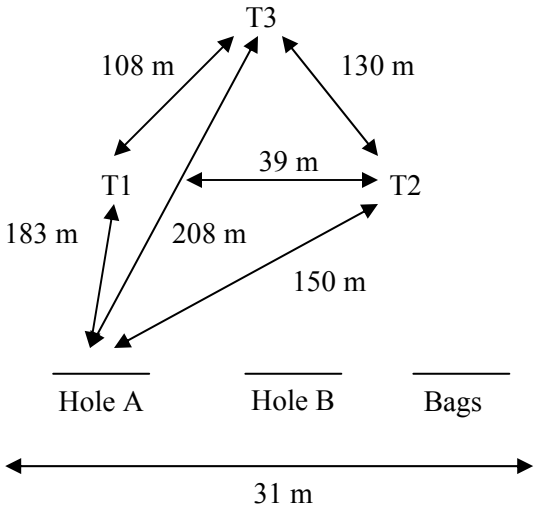

Figure 12. *Illustration of the target area in Range 26.*

2.9 Vernonburg Site (Ammunition Dumps)

Vernonburg site is made of two dumps containing many obsolete munitions that have been there for at least 20 years. A large variety of munitions can be found: high explosive (HE) 105-mm and 155-mm, TOW missile, smoke 105-mm, etc. At the first of the two dump sites, munitions are entirely covered by the ground; at the second one, most of the munitions are visible at the surface, as shown in Figure 13. Sampling was done only around the second site. Three soil and one biomass samples were taken in an area safe for walking. A fence had been erected around the safe zone to prevent personnel from walking into the danger zone and accidentally causing detonation of live UXOs.

2.10 Small Arms Ranges

This section describes the patterns adopted to sample the small arms ranges in CFB/ASU Wainwright. The two most used rifle ranges, Ranges 1 and 8, were characterised during phase I, while Ranges 4, 5, 6 and 9 will be sampled during phase II planned for summer 2005. Finally, the pistol shooting range (#24) was also sampled during phase I.

Figure 13. *Vernonburg ammunition dump site.*

2.10.1 500-Yard Conventional and 600-Meter Conventional Ranges (#1 and 8)

The same sampling pattern was adopted for these two ranges. These training areas are typical rifle ranges made of five to six firing lines (one at each 100-m distance from the target), one sandy stop butt with wooden targets, and one berm supporting moving mechanical targets between the stop butts and the firing points, as shown in Figure 14. Only the first two firing lines (100 and 200 m) were sampled to verify the extent of contamination. Ranges 1 and 8 have 12 and 24 targets with a width of 41 and 83.5 m, respectively. Figure 15 shows that the stop butt was divided into three sections (A, B, and C) to verify if the contamination can migrate by gravity, with the wind and/or rain, from the targets to the road. The width of the target area sections is not available for Range 1, while for Range 8, the width of sections A, B and C is equal to 10.2, 20.8 and 8.6 m, respectively. Sections A and B are sandy, and most of section C was covered by vegetation.

Areas in front of targets were sampled by collecting three composites of 25 to 30 increments in the regions A, B and C, respectively. The areas in front of

the targets are in groups of three or four depending on the number of targets present in the range. In Range 1, composite soil samples were collected in front of targets 1 to 3, 4 to 6, 6 to 9, and 10 to 12, while in Range 8, composite soil samples were collected in front of every group of four targets (1-4, 5-8, É). The same strategy (regrouping targets) was adopted for the firing position sampling without the different sections A, B, and C. Only the firing positions at 100- and 200-m were sampled. A total of 23 and 34 soil samples were taken in Ranges 1 and 8, respectively, including four duplicates for each range. Samples at stop butts were analyzed for metals only, while samples at firing points were analyzed for both metals and energetic materials. Biomass samples were collected in the target area in Ranges 1 (five samples) and 8 (six samples). The GPS positions of firing positions and targets at Ranges 1 and 8 are given in Table A11.

Figure 14. *The 12 wooden targets and first firing position at 93 m in Range 1.*

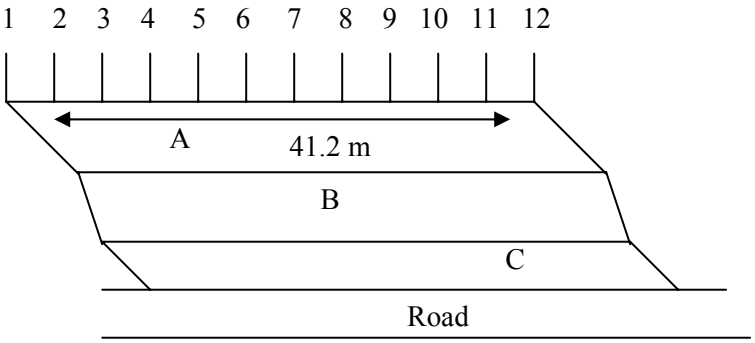

Figure 15. *Representation of target area in Range 1 (Range 8 has the same pattern, but number of targets is 24 and the width is 83.5 m).*

2.10.2 25-Meter Outdoor Range (#24) (Pistol Shooting Range)

This range is approximately 25-m long and 8-m wide. It is composed of two parts: a sand butt into which bullets are fired and firing lines at 10, 15, 20, and 25 m from the sand butt (Figure 16). Each firing position was sampled by taking a composite of 25 to 30 increments on the line covering the entire width of the range. The sand butt was subdivided in two sections: the higher and the lower elevation of the sand. Six soil samples were taken in this range with one biomass sample (25 to 30 increments) between the sand butt and the firing position at 10 m. The GPS positions of the butt sand and firing positions are given in Table A12.

2.11 Anti-Tank Ranges

2.11.1 Hand-Held Anti-Tank (Stationary Targets) (#13) and Hand-Held Anti-Tank Weapon (#22)

Ranges 13 and 22 are 450- and 1000-m anti-tank ranges, respectively, and munitions fired at these ranges are 66- (M72), 84- and 94-mm. In the case of Range 22, ERYX is also fired. The dimensions of the firing positions at Ranges 13 and 22 are given in Figures 17 and 18 respectively, while the distance between the firing point and Targets 1, 2, 3 and 4 in Ranges 13 and 22 are shown in Figures 19 and 20, respectively. The difference observed between these two ranges is that the firing point in Range 22 is divided into three distinct positions represented by holes (squares A, B and C in Figure 18), while in Range 13, the firing position structure is continuous with the possibility to fire from three different positions. For both ranges, the firing position was sampled according to Figure 21. At each site, seven soil

Figure 16. *Firing positions and shooting butts of Range 24.*

composites of 25 to 30 increments including one duplicate were collected behind and in front of the firing point at various distances (0-5, 5-10, É .., up to 25-30 m) for a total of 14 soil samples. Finally, the GPS locations of the different points in Figures 17 to 20 are given in Tables A13 and A14.

In the target area of Range 13, four targets were sampled. One duplicate was collected around Target 1 and Target 3 was sampled in two sections: close (within a radius of 1 m) and far from the target (at approximately 30 m in front of the target). In total, six soil and one biomass samples were collected. For Range 22, four targets were also sampled and one biomass sample was taken around Target 2.

Finally, vertical soil profiling was performed at Range 22. The main objective of the profiling at the firing point was to verify the vertical migration of contaminants. Two holes were dug 60-cm deep at a distance of 2 m from each other (Figure 22) behind the firing point (BFP). For each hole, one sample was collected in each 10-cm wide layer for a total of six samples. After the

hole was dug completely, the sampling was started at the bottom of the hole to avoid the contamination in the upper layers.

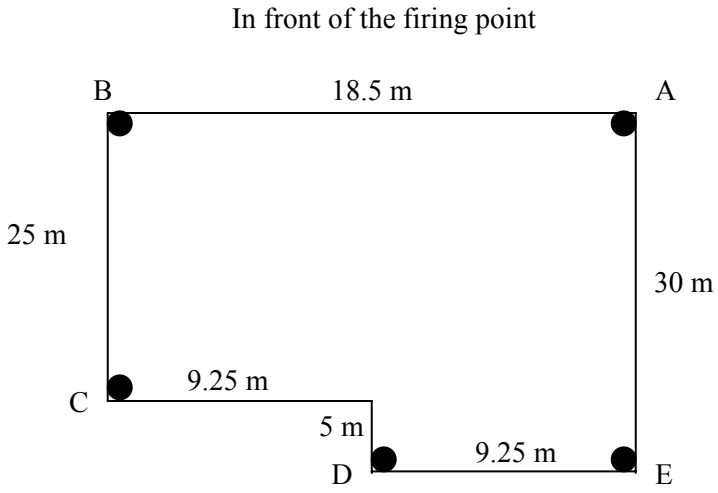

Figure 17. *Firing position in Range 13.*

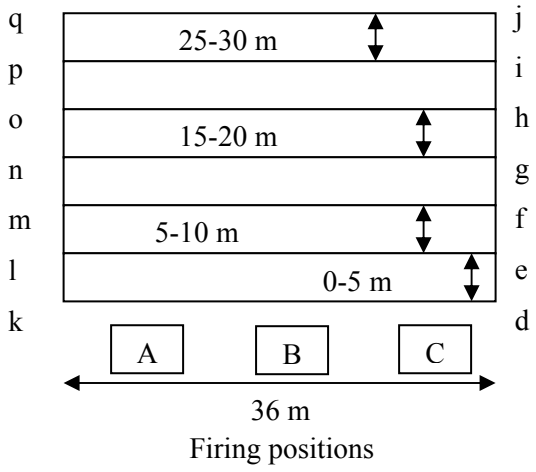

Figure 18. *Firing position in Range 22.*

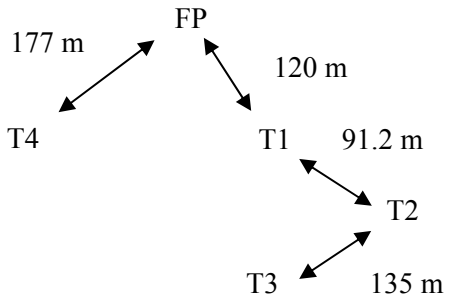

Figure 19. *Target area in Range 13.*

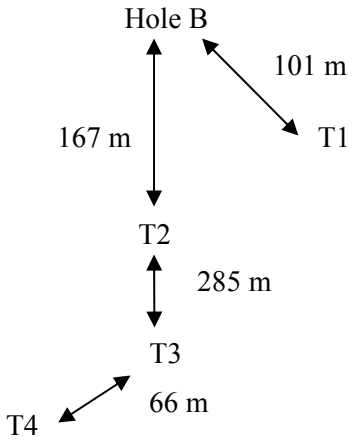

Figure 20. *Target area in Range 22.*

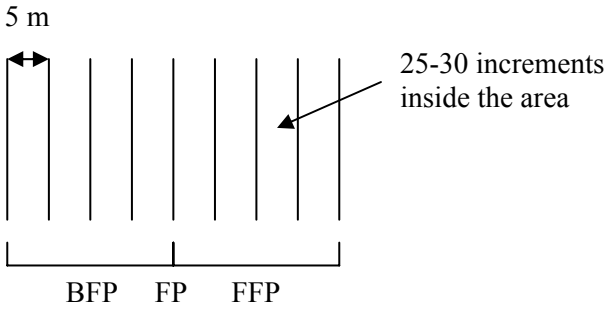

Figure 21. *Sampling pattern used at firing positions in anti-tank ranges (BFP: behind firing point; FP: firing point; and FFP: in front of firing point).*

Figure 22. *Vertical sampling in one of two holes 60-cm deep at the firing point in Range 22.*

2.12 Area 3A

Area 3A is a very broad impact area with hills and plane surfaces (Figure 23). During military training, soldiers can fire everywhere in this region. Then, it is difficult to establish a sampling strategy because the contamination is dispersed on the entire surface. In this case, a preliminary sampling was done to assess the magnitude of the contamination and during the second phase, according to the results obtained, the characterization of this area will be completed.

Jeep Hill is targeted during the training to shoot, for example, TOW missiles and mortars. The GPS position of the top of the hill is 0498026-5842814. Three composites of 50 increments were collected in the sandy area from the bottom to the top of the hill and another composite was taken among 12 visible craters in the same area.

A linear sampling was also applied in area 3A. Two samples were collected after reaching 40% of the surface, starting at the end of range 16, corresponding to the black point in Figure 23. The GPS location of this point is 0499762-5841957. The sampling was performed walking from the road to 300 m at the left side and at the right side of the road while keeping constant one GPS coordinate. One duplicate was also collected totaling three samples. Several

craters were observed at a GPS location of 0499762-5841957, and one composite was collected among them. A lot of smoke pots were found in this region.

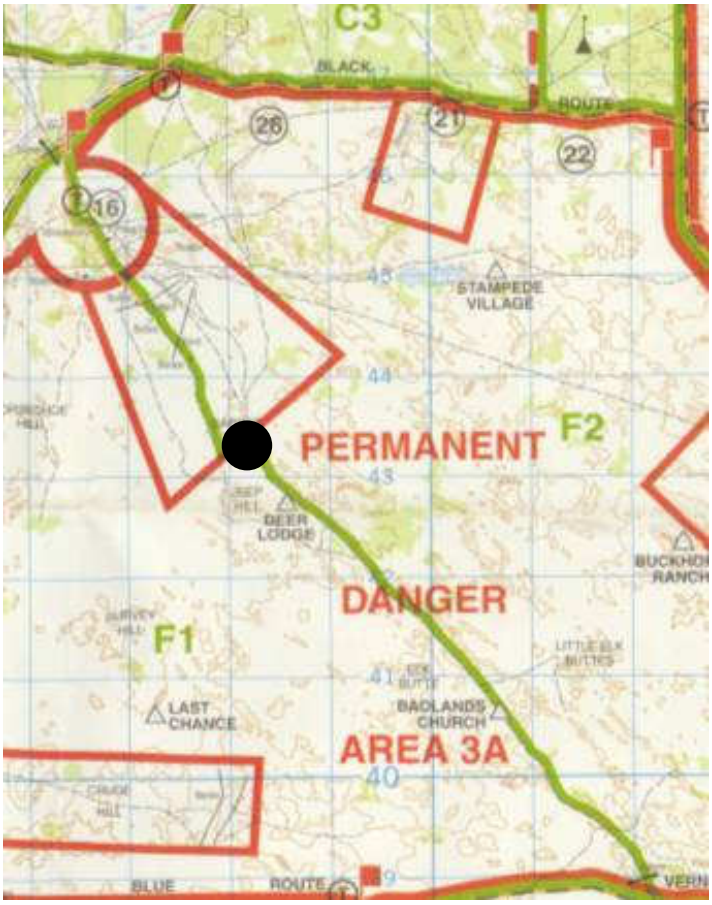

Figure 23. *Area 3A*

2.13 Sampling Summary

Table 1 summarizes the soil and biomass samples collected at firing positions and around the targets. A total of 177 soil and 24 biomass samples were collected during phase I of this campaign.

Table 1. *Soil and biomass samples collected during the campaign at CFB/ASU Wainwright*

RANGE	NUMBER OF SAMPLES	
	Soil	***Biomass***
Background	21	21
2	15	1
12	12 (FP); 5 (targets)	0
14	13	0
16	13 (FP); 4 (rail)	4 (FP); 2 (rail)
17	17	0
21	13 (FP); 3 (target)	2 (FP); 1 (target)
26	7 (FP); 3 (target)	1 (FP); 1 (target)
Vernonburg	3	1
1	10 (FP); 13 (target)	5 (target)
8	14 (FP); 20 (target)	6 (target)
24	4 (FP); 2 (target)	1 (FP)
13	14 (FP); 6 (target)	1 (target)
22	14 (FP); 4 (target)	1 (target)

Note: FP means firing position.

3. Results and Discussion

This section describes the energetic materials and metals characterization in soil and/or biomass samples collected among the 14 ranges, described in the previous section, during phase I of the campaign at CFB/ASU Wainwright. Tables C1 to C4 in Annex C list the results for metals in soils, while Tables D1 to D4 in Annex D list those obtained for biomass samples. The names of the samples included in the following tables are different than those in the annexes. In fact, in the following text, the range number is removed at the beginning of the name because the title already gives this information. Table 2 gives the 2006 Canadian Council of Ministers of the Environment (CCME) thresholds for metals in soils (no values exist for biomass) and the MBG (see section 2.1). The MBG permits to detect areas where the metallic concentrations were significantly increased by military activities without exceeding the CCME criteria.

Table 2. *CCME industrial thresholds and mean background for soil and biomass contamination.*

METAL	CCME THRESHOLD	SOIL MBG	BIOMASS MBG
	mg/kg	***mg/kg***	***mg/kg***
Aluminium	-	9070	1040
Antimony	40	2	1
Arsenic	12	7	13.6
Barium	2000	177	73.4
Beryllium	8	40	40
Bismuth	-	20	20
Boron	-	10	180.8
Cadmium	22	2	2
Calcium	-	26483	16583
Chromium	87	15.6	6.1
Cobalt	300	7.7	2
Copper	91	12	12.5
Iron	-	19350	342
Lead	600	40	40

Table 2. *CCME industrial thresholds and mean background for soil and biomass contamination (continued).*

METAL	CCME THRESHOLD	SOIL MBG	BIOMASS MBG
Lithium	-	7.5	8
Magnesium	-	3870	2880
Manganese		-	111.3
Mercury	50	0.2	0.2
Molybdenum	40	2	3.6
Nickel	50	17.2	3.3
Phosphorus	-	772	4708
Potassium	-	1954	38196
Rubidium	-	10.9	14.5
Selenium	3.9	2	2
Silver	40	0.2	0.2
Sodium	-	400	400
Strontium	-	108	46.4
Sulphur	-	-	-
Tellurium	-	20	20
Thallium	1	4	4
Tin	300	3.6	7.3
Titanium	-	137	5.6
Uranium	-	0.7	0.8
Vanadium	130	22	8
Zinc	360	65	70
Zirconium	-	3.4	2

3.1 Grenade Range (#2)

Since 1997, the average annual number of M67 grenades fired in Range 2 has been 2500 except in 2003 and 2004 when the number was 0 and 188, respectively. Fifteen samples were collected in this area (see Figure 1 for the sampling description). RDX, and HMX, an impurity of RDX production, were detected in 15 and 12 samples, respectively, while TNT was observed in four samples, as detailed in Table 3. These three compounds come from Composition B, a formulation made of 60 % of RDX and 40 % of TNT present in the grenades.

Table 3. *Concentrations of HMX, RDX and TNT in samples collected in Range 2.*

SAMPLE	HMX	RDX	TNT
	mg/kg	***mg/kg***	***mg/kg***
A[1]	n.d.[2]	0.1	n.d.
B	0	0.5	n.d.
C	0.3	1.7	1.0
D	n.d.	0.2	n.d.
E	0	0.2	n.d.
F	0	0.2	n.d.
0-5 m	n.d.	0.1	n.d.
5-10 m	0	0.1	n.d.
10-15 m	0	0.3	n.d.
10-15 m DUP	0	0.3	n.d.
15-20 m	0.1	0.7	0.7
20-25 m	0.6	6.6	10.1
25-30 m	0.2	1.4	1.4
30-35 m	0.1	0.2	n.d.
35-40 m	0	0.1	n.d.

1: Sample A also showed a concentration of 0.1 mg/kg of NG.
2: n.d.= not detected

Figure 24 shows that the maximum concentration for these three compounds occurred within 20 and 25 m of the firing point, where values for RDX, HMX, and TNT were 6.7, 0.6, and 10.6 mg/kg, respectively. Most of the grenades were probably fired in this area. The results obtained for this hand grenade range are similar to other such ranges [4, 47]. Concentrations of HMX and RDX in the field duplicates were similar.

The results from metal analyses show a significant contamination by Zn. In fact, 9 out of 15 samples were contaminated with concentrations of Zn up to 1000 mg/kg while the CCME soil threshold is 360 mg/kg. Contamination was found in Regions B through F and the middle section up to 15 m. The metals-contaminated regions are not the same as the one contaminated by energetic materials (between 20 and 25 m as shown in Figure 24). Finally, the source of this contamination must be anthropogenic since the mean background of Zn is 64 mg/kg. Results also demonstrated that the same nine samples described previously were contaminated with copper and nickel with higher concentrations than the MBG. Finally, in biomass samples, Cu, Ni and Zn were found in concentrations exceeding the MBG. In soil samples, these three metals were found in concentrations higher than the MBG, while Zn was detected in concentrations higher that the CCME.

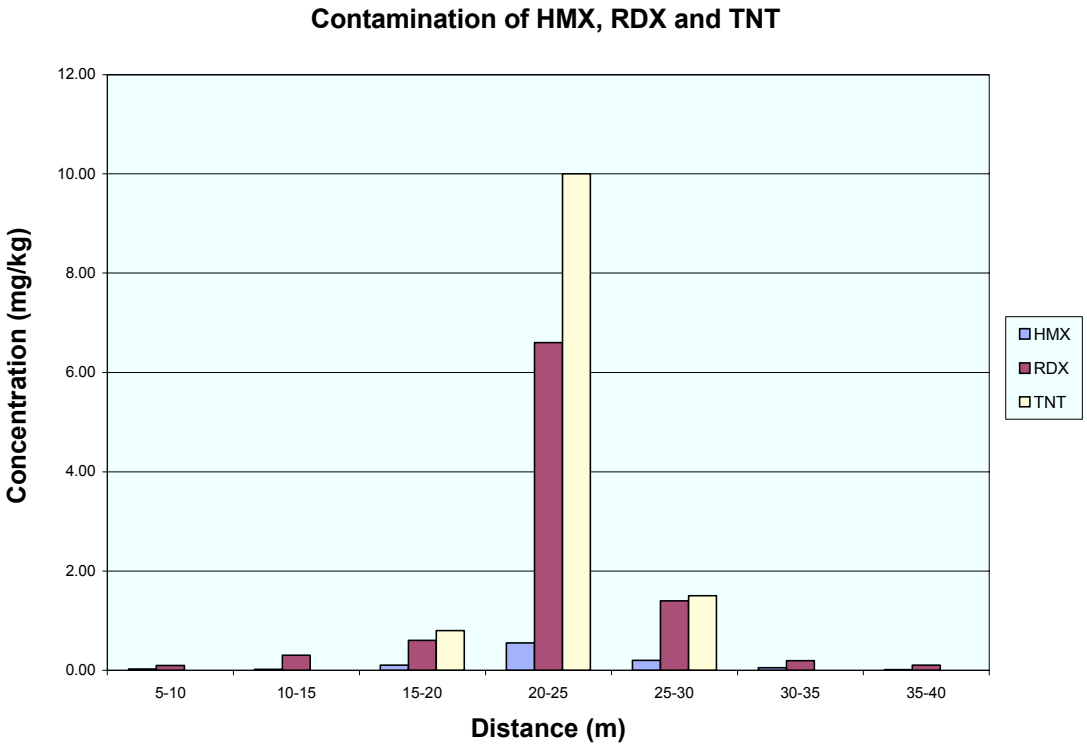

Figure 24. *Distribution of contaminants with distance from the firing point in Grenade Range.*

3.2 Light/Medium Mortar Range (#12)

During military training in 2001, 2002, and 2004, the number of 60-mm HE mortars fired in Range 12 was 501, 344, and 286, respectively. For the 12 samples analyzed at the firing position, NG was the only contaminant detected, which is characteristic of the use of double base propellants. Table 4 shows the results obtained behind the firing point (BFP) and in front of the firing point (FFP) (numbers correspond to the distance (m) of the sample from the firing point). The highest concentration was 700 mg/kg. No energetic materials were found in the target area.

From sampling around targets (see Figure 2), one sample showed concentration exceeding the CCME criteria for Zn and all samples demonstrated concentrations higher than the MBG for Cu and Zn. Two values for aluminium and nickel, and four values for total phosphorus exceed significantly the calculated MBG. This range will be resampled during phase II of the soil sampling campaign.

Table 4. *Concentrations of NG in samples collected in Range 12.*

SAMPLE	CONCENTRATION
	mg/kg
BFP[1] 0-5 m	698
BFP 0-5 m DUP	700
BFP 5-10 m	369
BFP 10-15 m	255
BFP 15-20 m	240
BFP 20-25 m	76
BFP 25-30 m	45
FFP[1] 0-5 m	101
FFP 5-10 m	7
FFP 5-10 m DUP	10
FFP 10-15 m	5
FFP 15-20 m	3
FFP 20-25 m	3
FFP 25-30 m	0.5

1: BFP and FFP mean behind and in front of the firing point, respectively.

3.3 Demolition Range (#14)

The demolition range is a site where many types of munitions can be destroyed by BIP procedures. The amount of C4 used to initiate the reaction is usually assumed to be high enough to ensure a high-order detonation. In some cases, the temperature, wind, weather, and condition of the munitions contribute to incomplete reactions resulting in low-order detonations and, consequently, contamination by explosives and metals. Results are summarized in Table 5. Thirteen samples were collected in the whole area. HMX was detected in 10 samples (max 0.6 mg/kg), RDX in 12 samples (max. 13.4 mg/kg), TNT in 10 samples (max.14 mg/kg), NG in three samples (max. 2.7 mg/kg), 2,4-DNT in five samples (max. 0.7 mg/kg), and 2-ADNT and 4-ADNT in three samples (max. 0.2 mg/kg). No metals concentration exceeding the CCME soil threshold criteria was found. However, three and seven samples contained concentration higher than the MGB for Zn and Cu, respectively, which indicated an accumulation of these metals from demolition activities in this range.

Table 5. *Concentrations of various energetic materials in samples collected at the Demolition Range (#14).*

SAMPLE	HMX	RDX	TNT	NG	2,4-DNT	2-ADNT	4-ADNT
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
DS-1 Moac[1] 1	0.1	1.6	0.1	n.d.[2]	n.d.	n.d.	n.d.
DS-1 Moac 2	0.6	6.5	2.5	n.d.	n.d.	n.d.	n.d.
DS-1 Moac 3	0.1	0.6	0.2	n.d.	n.d.	n.d.	n.d.
DS-2 Moac 1	n.d.	0.3	n.d.	n.d.	n.d.	n.d.	n.d.
DS-2 Moac 2	n.d.	0.5	n.d.	n.d.	n.d.	n.d.	n.d.
DS-2 Moac 3	0	0.6	n.d.	0.1	n.d.	n.d.	n.d.
DS-3 Moac 1	0.2	13.4	7.8	n.d.	0.2	n.d.	n.d.
DS-3 Moac 2	0.2	3.1	2.3	n.d.	n.d.	n.d.	n.d.
DS-3 Moac 3	0.3	10.6	3.9	0.1	0.2	0.2	0.1
DS-4 Moac 1	0.1	3.4	12.0	n.d.	0.8	0.2	0.2
DS-4 Moac 2	0.1	1.1	14.0	n.d.	0.4	0.1	0.1
DS-4 Moac 3	0.1	1.2	12.8	n.d.	0.6	0.1	0.1
DS-5 Moac	n.d.	n.d.	0.6	2.7	n.d.	n.d.	n.d.

1: MOAC= mother of all composites
2: n.d. = not detected

3.4 Armoured Fighting Vehicle (AFV) Static Range (#16)

In Range 16, many 5.56- and 7.62-mm bullets were fired (e.g. 197 957 bullets of 7.62-mm and 6 000 bullets of 0.5-mm were fired in 2001; 23 370 bullets of 5.56-mm were fired in 2004. Table 6 shows the results for energetic residues in front of the two firing points (FP1 and FP2) (numbers correspond to the distance (m) of the sample from the firing point), on a hot spot (HS) and on the two berms around the trails where dynamic targets were located. Nitroglycerin was detected in 14 samples at a maximum concentration of 92.7 mg/kg; 2,4-DNT was present in concentrations up to 10 mg/kg in 10 samples; and 2,6-DNT, an impurity of military grade 2,4-DNT, was detected in two samples at a lower concentration (max. 0.7 mg/kg). The 2,6-DNT was detected in the two samples showing the highest levels of 2,4-DNT. Finally, the maximum concentrations for these three contaminants were detected in the soil samples collected in the area between 10 and 20 m in front of the firing position. The two field duplicates gave similar results. No energetic materials were detected in the berms, indicating that they are used mostly as targets for small arms ammunition containing no explosive.

No metals concentration exceeding the CCME soil threshold criteria was found. When results were compared with the MGB, three and 14 samples showed higher concentration than the MGB, close to the CCME threshold for Zn and Cu mostly at the firing point, respectively. This trend shows that, in the future, these metal concentrations have a high probability of exceeding the CCME criteria.

For vegetation analyses, two samples collected in front of the concrete pad showed maximum concentrations of Cu and Pb of 19.8 and 21 mg/kg, respectively. Moreover, one sample at the berm collected at Range 16 showed a concentration of thallium of 4 mg/kg, higher than the CCME threshold (1 mg/kg).

3.5 Field Firing, Artillery, Mortar and Air Weapons Range (#17)

As explained in Section 3.6, Permanent Danger Area 4 is a huge area, which makes its characterization challenging. Sixteen samples were collected randomly and one hot spot was analyzed. All were analyzed for energetic materials while nine samples were analyzed for metals. Table 7 shows the results obtained at a firing position and in a fresh crater (see section 3.6 for the description of the sampling). No or low contamination of energetic materials was found in this area except for the hot spot (FP-HS). In fact, concentrations of 103 mg/kg of RDX and 18 mg/kg of TNT were found at the location of the hot spot which was a 25-mm long green British ammunition. The content of the munition was probably Composition B. Since the characterization was limited in time by the military training, the study will be continued and finished during the second phase of the soil campaign.

For metal analysis, two samples showed a concentration of nickel exceeding the CCME criteria with a maximum concentration of 398 mg/kg. Moreover, Cu and Zn were found with concentrations significantly higher than the MBG. No biomass sample was collected in this area.

Table 6. *Concentrations of NG, 2,4-DNT and 2,6-DNT in samples collected in Range 16.*

SAMPLE	NG	2,4-DNT	2,6-DNT
	mg/kg	***mg/kg***	***mg/kg***
FP1[1] 0-10 m	23.3	1.6	n.d.[2]
FP1 10-20 m	88.5	8.6	0.7
FP1 10-20 m DUP[3]	92.7	10.0	0.7
FP1 20-30 m	18.7	2.5	n.d.
FP1 30-40 m	4.5	0.6	n.d.
FP1 40-50 m	5.0	0.4	n.d.
FP2[1] 0-10 m	60.1	0.7	n.d.
FP2 0-10 m DUP	59.5	0.6	n.d.
FP2 10-20 m	34.5	n.d.	n.d.
FP2 20-30 m	5.7	n.d.	n.d.
FP2 30-40 m	4.4	0.2	n.d.
FP2 40-50 m	3.5	0.3	n.d.
FP2 HS[4]	0.2	n.d.	n.d.
Mt Berm 2-B	n.d.	n.d.	n.d.
Mt Berm 1-A	0.3	n.d.	n.d.
Mt Berm 2-A	n.d.	n.d.	n.d.
Mt Berm 1-B	n.d.	n.d.	n.d.

1: FP1 = firing point 1 and FP2 = firing point 2
2: n.d. = not detected
3: DUP = duplicate
4: HS = hot spot

Table 7. *Concentrations of various energetic materials in samples collected at Permanent Danger Area 4.*

SAMPLE	HMX	RDX	TNT	2-ADNT	4-ADNT
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***
FP[1]-HS[2]	0.2	103.5	18.4	5.7	7.8
FP-M-A	n.d.[3]	n.d.	n.d.	n.d.	n.d.
FP-M-B	n.d.	n.d.	n.d.	n.d.	n.d.
FP-M-C	n.d.	n.d.	n.d.	n.d.	n.d.
FP-M-D	n.d.	n.d.	n.d.	n.d.	n.d.
FP-M-Uxo	n.d.	0.1	n.d.	n.d.	n.d.
FP-Front-0-30 A-B	n.d.	n.d.	n.d.	n.d.	n.d.
FP-Front-0-30 C-D	n.d.	n.d.	n.d.	n.d.	n.d.
1	n.d.	n.d.	n.d.	n.d.	n.d.
2	n.d.	n.d.	n.d.	n.d.	n.d.
FC[2]-A	n.d.	n.d.	n.d.	n.d.	n.d.
FC-B	n.d.	n.d.	n.d.	n.d.	n.d.
FC-C	n.d.	n.d.	n.d.	n.d.	n.d.
FC-D	0.1	0.5	n.d.	n.d.	n.d.
FC-E	n.d.	n.d.	n.d.	n.d.	n.d.
FC-F	n.d.	n.d.	n.d.	n.d.	n.d.
FC-G	n.d.	n.d.	n.d.	n.d.	n.d.

1: FP = firing position
2: HS = hot spot
3: n.d. = not detected
4: FC = fresh crater

3.6 Platoon Field Firing Defensive Position (#21)

As shown in Table 8, the only contaminant found in the 13 samples collected at the firing point of Range 21 was NG, which is characteristic of the use of double base propellants (see Figure 11 for the sampling description). In fact, the samples from the six firing lines showed a maximum of 3 mg/kg in Line 1, while 12.5 mg/kg of NG was found into the mortar pit. Around targets, HMX, RDX, and TNT were found in the three samples with maximum

concentrations of 34, 7.5, and 4.6 mg/kg, respectively. Target 2 samples contained NG (1.8 mg/kg). Traces of NG in impact areas have been reported previously [47] and are the result of the incomplete burning of the propellant at impact. This last result will be verified during the second phase of the sampling campaign.

Table 8. *Concentrations of various energetic materials in samples collected at Range 21.*

SAMPLE	HMX	RDX	TNT	NG
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***
Firing position				
In MP[1]	n.d.[2]	n.d.	n.d.	23.2
Out MP	n.d.	0.2	n.d.	5.1
Line 1 Out MP	n.d.	n.d.	n.d.	1.0
Line 1 In MP	n.d.	n.d.	n.d.	1.9
Line 1 In MP DUP	n.d.	n.d.	n.d.	3.1
Line 2	n.d.	n.d.	n.d.	0.9
Line 3	n.d.	n.d.	n.d.	0.3
Line 3 DUP	n.d.	n.d.	n.d.	0.2
Line 4	n.d.	n.d.	n.d.	0.1
Line 5	n.d.	n.d.	n.d.	n.d.
Line 6	n.d.	n.d.	n.d.	0.2
Trench A	0.1	n.d.	n.d.	12.5
Trench B	n.d.	n.d.	n.d.	1.5
Target area				
T[3]1	5.2	7.5	0.2	n.d.
T2	0.1	0.4	4.6	1.8
T3	33.9	1.2	2.7	n.d.

1: MP = mortar pit
2: n.d. = not detected
3: T = target

The sample collected around Target 3 had a Cu concentration of 172 mg/kg, almost twice the CCME soil threshold (91 mg/kg). Fourteen samples show concentrations of Cu higher than the MBG but significantly lower than 91 mg/kg (CCME). Moreover, four samples (all samples of the target area, and one sample from the firing point) contained concentrations of Zn around 100 mg/kg, higher than the MBG but far from the CCME value (360 mg/kg). For biomass samples, Sb, Ni, Cu and Zn were found with concentrations higher than the MBG.

For biomass samples, Cu and Zn were found in concentrations higher than MBG and this result is in accordance with those obtained from soil samples, where these metals had been found in concentrations higher than the CCME criteria.

3.7 Grenade Launcher Range (#26)

At Range 26, the three firing positions and the target area were characterised. Results are shown in Table 9. The two composites of 50 increments collected behind (BFP) and in front of the firing position (FFP) showed that NG was found in higher concentration in front rather than behind the firing position. Moreover, the two holes were sampled inside (in-H) and outside (out-H). In both cases, the NG concentration was higher inside the hole. In the target area (T1-T3), HMX and RDX were observed in low concentrations.

The metal analysis was performed only for the two composites (BFP- and FFP-Moac) and around the three targets. No metal concentration exceeding the CCME criteria was detected. Around targets, Cu, Pb and Zn were found in concentrations higher than the MBG. No metal contamination exceeding MBG was also detected in the two collected biomass samples.

This site does not show high concentration of energetic materials and for this reason, the characterization of Range 26 will be performed again during phase II to confirm these results.

3.8 Vernonburg Site (Ammunition Dump)

No energetic materials contamination was found in the three collected samples at the Vernonburg site. These results will be confirmed during phase II. Finding no contamination around such a large number of dumped munitions was not expected. Our results tend to confirm that the munition pile located in Vernonburg is mainly composed of non-HE rounds. This should be interpreted carefully, however, because if munition casings were intact, leaching of HE may have been prevented.

All samples exhibited metal concentrations higher than the CCME soil threshold criteria for Cu (110, 149 and 255 mg/kg) and Zn (623, 7110 and 7220 mg/kg). The CCME soil threshold criteria are 91 and 360 mg/kg for Cu and Zn, respectively. Moreover, two out of three samples have concentrations of manganese significantly higher than MBG. The toxicity of this metal is difficult to interpret since no CCME threshold is available. Mercury is also detected in two samples but just one value is higher than the MBG. Mercury is detected only in a few ranges (Vernonburg and rifles ranges). Finally, one and three samples contained lead and tin in concentrations higher than MBG, respectively, but all results are far the CCME value.

Table 9. *Concentrations of HMX, RDX and NG in samples collected in Range 26.*

SAMPLE	HMX	RDX	NG
	mg/kg	***mg/kg***	***mg/kg***
BFP[1]-Moac	n.d.[2]	n.d.	0.2
FFP[3]-Moac	n.d.	n.d.	1.7
In H-A[4]	n.d.	n.d.	1.0
Out H-A	n.d.	n.d.	n.d.
In H-B[5]	n.d.	n.d.	0.7
Out H-B	n.d.	n.d.	0.1
T[6]1	n.d.	n.d.	n.d.
T2	0.1	1.0	n.d.
T3	0.1	0.2	n.d.
Bags	n.d.	n.d.	0.2

1: BFP = behind the firing point
2: n.d. = not detected
3: FFP = in front of the firing point
4 and 5: H-A and H-B mean hole A and hole B
6: T = target

3.9 Small Arms Ranges

3.9.1 500-Yard Conventional and 600 Meter Conventional Ranges (#1 and 8)

In Ranges 1 and 8, military training involved mainly 7.62- and 5.56-mm bullets. In 2002, 83 140 5.56-mm and 1 340 7.62-mm bullets were fired in Range 1, while in Range 8, 195 572 5.56-mm and 42 711 7.62-mm bullets were fired. The firing positions were sampled as described in section 3.10. As mentioned earlier, only the first two firing lines (100 and 200 m) were sampled to verify the extent of contamination. Results for Ranges 1 and 8 are reported in Tables 10 and 11, respectively. The name of the samples gives first the place where the sample was collected (FP means at the firing point), the distance of the firing line from the targets (100 or 200 m) and the numbers of the targets in front of which the sample was taken (ex. T 1-3 means in front of targets 1 to 3).

NG and 2,4-DNT were found in all samples. Concentrations of 2,4-DNT were significantly lower than concentrations of NG. The maximum concentrations of 2,4-DNT found in Ranges 1 and 8 were 0.5 and 1.1 mg/kg, respectively. Tables 10 and 11 also show that the difference between the sample and its duplicate can be important (field duplicates are identified by the letters DUP after the sample name). In fact, in Range 1, the difference between S-A1-R1 FP 200 T 4-6 and its duplicate for the concentration of NG is 14 mg/kg (60 percent), while in Range 8, the difference is 10 mg/kg (30 percent). The distance of the firing positions did not seem to have an influence on the contamination because the concentration at 200 m is sometimes higher than at 100 m.

In Range 1, the NG concentration is up to 22.9 mg/kg, while in Range 8, the highest NG concentration is 52.8 mg/kg. The high variation observed between field replicates tends to indicate that the sampling approach did not succeed in overcoming the high degree of heterogeneity associated with the dispersion of contaminants. Samples built of a larger number of composites should be collected in the future at this site.

Table 12 reports the numbers of metal concentrations in soil samples exceeding the MBG and the CCME criteria for Ranges 1 and 8. Pb and Cu were found in concentrations higher than the CCME soil threshold criteria (600 and 91 mg/kg, respectively). In fact, in Range 1, nine out of 12 samples taken in the target area were contaminated with Pb (616 to 66 100 mg/kg), while in Range 8, 11 out of 18 samples showed concentrations between 600 and 1 690 mg/kg. It is interesting to note that, in these ranges, only three and seven samples (Ranges 1 and 8, respectively), did not have Pb concentrations higher than the CCME soil threshold. Pb was not found at the firing positions for both ranges. In Ranges 1 and 8, copper concentrations exceeding the CCME soil threshold criteria were found in the target area for eight and nine samples, respectively. In the target area of Range 1, a maximum concentration of 6 740 mg/kg was found, while, for the same area in Range 8, a concentration of 21 900 mg/kg and an average of 150-200 mg/kg was determined for the eight other samples. In Range 1, two samples from the firing position at 100 m showed concentrations of Cu around 95 mg/kg, while in Range 8, concentrations up to 259 mg/kg were found for seven samples at 100 m and five samples at 200 m. The only other metal found in concentrations higher that the CCME soil threshold was Sb. In fact, in Range 1, four samples collected at the target area showed high Sb concentrations: 91, 474, 720 and 932 mg/kg. Sb is used at 2 percent level in Pb bullets to improve their hardness.

Most of the samples showing high concentrations of Cu, Pb, or/and Sb were in the upper sections (A and B). Section A was more contaminated than Section B, and Section C was less contaminated than the other two. The sand in Section A was the closest to the targets and, consequently, should receive more bullets than the other regions. As Section C is located at the extreme

bottom of the butt near the road, leaching of the contamination from the sections above is probably the only source of contamination in this section.

Biomass samples from the target area of Range 1 (small arms range) showed concentrations of Sb, Cu, and Pb higher than the MBGs, which were 1, 12.4, and 10 mg/kg, respectively. The contamination was found in the same three biomass samples with a maximum of 5, 23.3, and 144 mg/kg for Sb, Cu, and Pb, respectively. Results obtained from Range 8 do not show values higher than the MBGs.

Table 10. *Concentrations of NG and 2,4-DNT in samples collected in Range 1.*

SAMPLE	NG *mg/kg*	2,4-DNT *mg/kg*
FP[1] 100 m T[2] 1-3	21.7	0.4
FP 100 m T 4-6	17.9	0.4
FP 100 m T 7-9	21	0.5
FP 100 m T 10-12	9.4	0.2
FP 100 m T 10-12 DUP[3]	13.3	0.3
FP 200 m T 1-3	9.7	0.2
FP 200 m T 4-6	22.6	0.4
FP 200 m T 4-6 DUP	8.9	0.3
FP 200 m T 7-9	4.1	0.1
FP 200 m T 10-12	1.4	0

1: FP = firing point
2: T = target
3: DUP = duplicate

Table 11. *Concentrations of NG and 2,4-DNT in samples collected in Range 8.*

SAMPLE	NG	2,4-DNT
	mg/kg	*mg/kg*
FP[1] 100 m T[2] 1-4	15.5	0.3
FP100 m T 5-8	19.5	0.4
FP 100 m T 9-12	39.7	1.1
FP 100 m T 9-12 DUP	29.2	0.9
FP 100 m T 13-16	52.8	0.8
FP 100 m T 17-20	49.0	1.0
FP 100 m T 21-24	19.7	0.5
FP 200 m T 1-4	32.9	0.9
FP 200 m T 5-8	45.4	1.2
FP 200 m T 9-12	24.8	0.7
FP 200 m T 9-12 DUP	36.6	1.1
FP 200 m T 13-16	13.9	0.3
FP 200 m T 17-20	8.92	0.2
FP 200 m T 21-24	10.1	0.1

1: FP = firing point
2: T = target

3.9.1.1 Toxicity characteristic leaching procedure (TCLP)

TCLP gives a good indication of the concentration of metal that can be leached to the aqueous phase. The results showed no concentrations above the detection limits except of Pb. The highest concentrations of Pb (790, 580, 270 and 120 mg/l) were obtained from samples collected in the target area of Range 1. The maximum value (790 mg/l) exceeds the CCME criteria and all were higher than the MBGs.

Table 12. *Numbers of samples for which the metal concentration values exceeded CCME and MBG threshold in Ranges 1 and 8 in the firing positions and the target area.*

METAL	RANGE 1		RANGE 8	
	> CCME[1]	***> MBG[2, 3]***	***> CCME[1]***	***> MBG[2, 3]***
Aluminium	-	-	-	5 (10400)
Antimony	5 (932)	22 (30.4)	-	29 (17)
Arsenic	-	2 (11)	-	-
Barium	-	-	-	19 (227)
Chromium	-	-	-	10 (21.5)
Cobalt	-	-	-	25 (12.2)
Copper	10 (6740)	21 (71.5)	22 (21900)	34 (84.3)
Iron	-	-	-	2 (20400)
Lead	8 (66100)	21 (372)	11 (3230)	31 (441)
Lithium	-	-	-	26 (132.9)
Magnesium	-	-	-	23 (7780)
Nickel	-	-	-	25 (29.7)
Total Phosphorus	-	-	-	7 (1080)
Potassium	-	-	-	9 (2640)
Rubidium	-	-	-	8 (12.5)
Silver	-	4 (2.34)	-	-
Tin	-	4 (57.4)	-	-
Uranium	-	-	-	23 (1.1)
Vanadium	-	-	-	14 (30)
Zinc	1 (715)	5 (190)	1 (2750)	31 (129)
Zirconium	-	-	-	19 (5.1)

1: The bracket contains the maximum value (in mg/kg) exceeding the CCME threshold
2: The number of samples included those exceeding the MBG and, consequently, the CCME
3: The bracket contains the maximum value (in mg/kg) exceeding the MBG, without considering values exceeding the CCME

3.9.2 25-Meter Outdoor Range (#24) (Shooting Range Pistol)

The samples taken at the firing positions of Range 24 were analyzed for energetic materials and metals, while the sand butt was only characterised for metals. In the firing positions, NG was found up to a concentration of 6.7 mg/kg (see Table 13). The result seemed to vary with the distance of the firing position; the farthest firing positions were the least contaminated.

The sample collected from the most elevated part of the sand butt had significant concentrations of Cu (246 mg/kg) and Pb (6 720 mg/kg). The CCME soil threshold criteria are 91 and 600 mg/kg for Cu and Pb, respectively. During training, bullets are probably fired principally into the upper part of the butt.

Table 13. *Concentrations of NG found in samples collected in Range 24.*

SAMPLE	CONCENTRATION
	mg/kg
FP[1] 10 m	6.7
FP 15 m	1.2
FP 20 m	0.4
FP 25 m	0.5

1: FP = firing point

3.10 Anti-Tank Ranges (#13 and 22)

Several types of munitions are fired in anti-tank Ranges 13 and 22. The M72 light anti-tank weapon (LAW) (66-mm), practice AT4 anti-tank rocket (84-mm) and the HE 60-mm mortar are commonly used. Table 14 shows some data corresponding to the type and the number of munitions fired for the past four years.

Table 14. *Approximate number of munitions fired in anti-tank ranges # 13 and 22.*

RANGE 13	2001	2002	2004
M72 LAW rockets	294	205	72
RANGE 22			
HE 60-mm mortars	92	0	0
M72 LAW rockets	393	373	0
HE AT4 rockets	114	84	0
Practice AT4 rockets	114	937	28

3.10.1 Hand-Held Anti-Tank (Stationary Targets) (#13)

Table 15 lists the results obtained at the firing positions and the target area for Range 13. For the firing position sampling, the name of the sample begins with the location of the sample, i.e. behind (BFP) or in front of (FFP) the firing position, followed by numbers corresponding to the distance (m) of the sample from the firing point. For the target area, the name of the sample corresponds to the target number. The complete sampling description was given in section 3.11. The principal contaminant at the firing position was NG with concentrations up to 4 453.1 mg/kg. The concentration behind the firing point did not show a trend with distance. However, the contamination was more important behind than in front of the firing point, as observed at similar sites [22]. This concentration is due to the strong back blast associated with the firing of these types of weapons. In front of the firing point, the concentrations decreased with distance from the firing positions as expected. For example, the amount of NG found between 0 and 5 m was higher than the concentration between 25 and 30 m in front of the firing point. HMX was also detected between 5 and 30 m in front of the firing point with a maximum concentration of 3.8 mg/kg. This result is unusual because HMX is not present in the propellant formulation.

HMX, RDX, TNT, NG, 2-ADNT and 4-ADNT were detected around the targets; the results are presented in Table 15 and Figure 25. High concentrations of HMX were detected (up to 1 616 mg/kg). The small quantities of RDX were associated with the use of HMX. TNT was also present with a maximum concentration of 390 mg/kg around Target 4. In general, the measured TNT concentration is lower because TNT is soluble in water and its metabolite transformation starts rapidly. For example, in Gagetown [22], the anti-tank target area showed concentrations of 22.8 mg/kg of TNT. The presence of a concentration of 390 mg/kg of TNT in Wainwright might indicate a recent low-order rupture of munitions in the sampling area, and TNT would still be present in a higher proportion if limited rainfall had

occurred since the dispersion of octol. The highest HMX concentration was also detected around this target (1 616 mg/kg). Similar results were obtained in 1996 in the Wainwright anti-tank ranges characterization study [5]. In fact, HMX and TNT were found with maximum concentrations of 3 700 and 880 mg/kg, respectively. Finally, small quantities of the TNT transformation products, 2-ADNT and 4-ADNT, were found (maximum of 5.8 mg/kg) around targets. NG was also detected in this area. In phase II, sampling around those targets will be repeated to confirm these results and verify whether the TNT/HMX ratio will evolve with time, as predicted. Figure 25 shows the variation of concentration with the distance from the target. Concentrations of HMX, RDX, TNT, and NG were higher directly around the target than at a 5-m radius from the target.

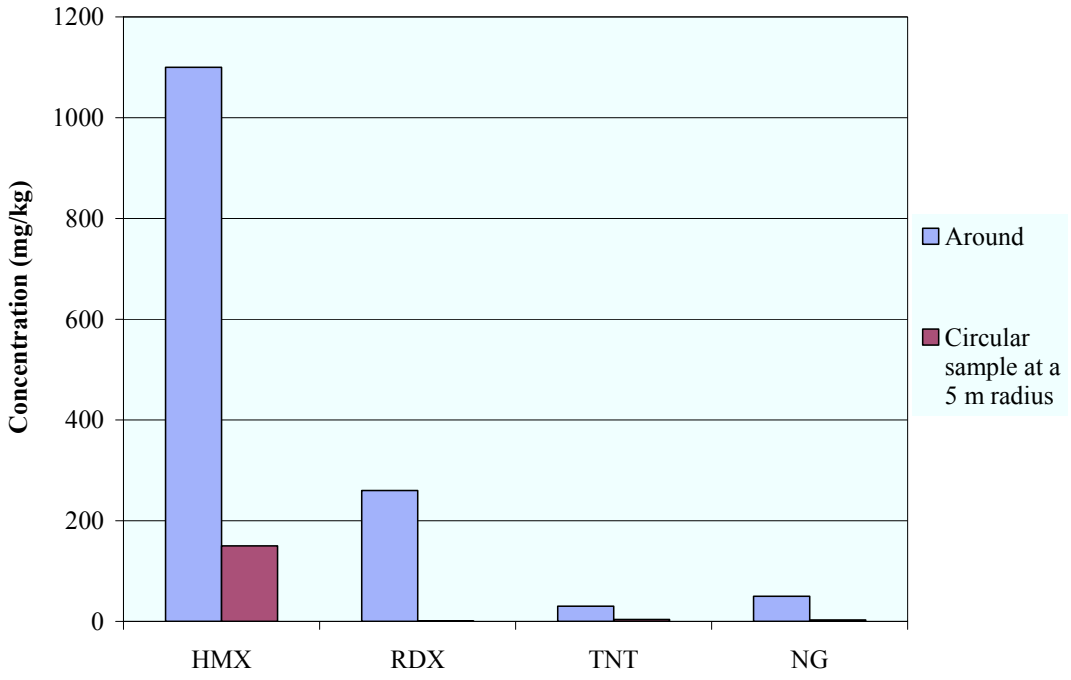

Figure 25. *Contamination around the target in Anti-tank Range #13.*

Table 15. *Concentrations (mg/kg) of energetic materials found behind (BFP) and in front of (FFP) the firing point in anti-tank Range #13.*

POSITION[1]	HMX	RDX	TNT	NG	2-ADNT	4-ADNT
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
Firing positions						
BFP[1] 0-5 m	n.d.[2]	n.d.	n.d.	2520.1	n.d.	n.d.
BFP 5-10 m	n.d.	n.d.	n.d.	1748.2	n.d.	n.d.
BFP 10-15 m	n.d.	n.d.	n.d.	2333.8	n.d.	n.d.
BFP 10-15 m DUP	n.d.	n.d.	n.d.	4453.1	n.d.	n.d.
BFP 15-20 m	n.d.	n.d.	n.d.	906.3	n.d.	n.d.
BFP 20-25 m	n.d.	n.d.	n.d.	1469.5	n.d.	n.d.
BFP 25-30 m	n.d.	n.d.	n.d.	637.2	n.d.	n.d.
FFP 0-5 m	n.d.	n.d.	n.d.	272.0	n.d.	n.d.
FFP[3] 0-5 m DUP	n.d.	n.d.	n.d.	136.6	n.d.	n.d.
FFP 5-10 m	2.4	n.d.	0.4	108.8	n.d.	n.d.
FFP 10-15 m	0.6	n.d.	n.d.	28.2	n.d.	n.d.
FFP 15-20 m	0.5	n.d.	n.d.	13.6	n.d.	n.d.
FFP 20-25 m	3.8	n.d.	n.d.	6.5	n.d.	n.d.
FFP 25-30 m	2.9	n.d.	n.d.	2.9	n.d.	n.d.
Target area						
T[4]1	453.8	3.2	7.7	22.1	1	1.1
T1-DUP	293.5	1	3.8	10.7	n.d.	n.d.
T2	1078.8	2.2	67.9	10.8	3.1	3.1
T3-Close	1192.4	2.6	27.8	53.8	3.3	3.1
T3-Far	137.9	0.6	3.2	1.9	n.d.	n.d.
T4	1615.9	14.1	389.7	2.9	5.7	5.7

1: BFP = behind the firing point
2: n.d. = not detected
3: FFP = in front of the firing point
4: T = target

Five metals with concentrations higher than the CCME soil threshold criteria were detected in samples collected around the targets. Cr was found in two samples with concentrations of 100 and 139 mg/kg, Cu in six samples with a minimum and a maximum of 445 and 10 400 mg/kg, Zn in four samples with concentrations between 412 and 1 190 mg/kg, Mo in two samples with concentrations of 44 and 105 mg/kg, and Ni in four samples with concentrations varying between 55 and 253 mg/kg. Finally, two samples collected around target 1 showed significant concentrations of cadmium (22 and 26 mg/kg); the CCME soil threshold for this metal is 22 mg/kg.

3.10.2 Hand-Held Anti-Tank Weapon (#22)

Table 16 shows the results obtained at the firing position and at the target area of Range 22, and the same terminology as in Table 15 was used. As for Range 13, HMX, RDX, TNT, and NG were found around the four sampled targets of Range 22. Concentrations of HMX and RDX were less than in Range 13. This last observation was also made in 1996 [5]. Concentrations of HMX and TNT around targets were detected up to 58 and 3 mg/kg, as mentioned in Table 16, while NG was found with concentrations of 35 mg/kg. In 1996, the results obtained for HMX and TNT were 290 and 68 mg/kg, respectively.

As expected, no HMX was found at the firing point of this range. As in Range 13, the concentrations of NG were greater behind than in front of the firing point. The explanation given for Range 13 is also valid here. However, the contamination for Range 22 was less than for Range 13. The maximum concentration of NG in Range 22 was 700 mg/kg compared to 4453 mg/kg in Range 13.

In Range 22, the following six metals were found with concentrations higher than the CCME soil threshold criteria: Sb, Cr, Ni, Cu, Pb, and Zn. In the target area, Sb and Cr were found in just one sample, each with concentrations of 59 and 94 mg/kg, respectively. Ni and Pb were detected in two samples with a maximum concentration of 54 and 1810 mg/kg, respectively, while Cu was present in four samples (691 to 1 680 mg/kg). Finally, three samples contained high concentrations of Zn at 302, 530 and 848 mg/kg.

3.10.2.1 Vertical Soil Profiling

As explained in sub-section 3.11.1, two holes were dug behind the firing point to perform vertical soil profiling. Most of the samples collected in the first hole showed detectable concentrations of NG. However, establishing a trend as a function of the depth was not possible, as shown at Table 17. For hole A, the average concentrations of NG at the surface (between 0 and 10 cm), between 30 and 40 cm, and at the bottom (50-60 cm) are 36, 0.5

Table 16. *Concentrations (mg/kg) of energetic materials found behind (BFP) and in front of (FFP) the firing point in anti-tank Range #22.*

POSITION	HMX	RDX	TNT	NG	2-ADNT	4-ADNT
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
Firing positions						
BFP[1] 0-5 m	n.d.[2]	n.d.	n.d.	698	n.d.	n.d.
BFP 0-5 m DUP	n.d.	n.d.	n.d.	700	n.d.	n.d.
BFP 5-10 m	n.d.	n.d.	n.d.	369	n.d.	n.d.
BFP 10-15 m	n.d.	n.d.	n.d.	255	n.d.	n.d.
BFP 15-20 m	n.d.	n.d.	n.d.	240	n.d.	n.d.
BFP 20-25 m	n.d.	n.d.	n.d.	76	n.d.	n.d.
BFP 25-30 m	n.d.	n.d.	n.d.	45	n.d.	n.d.
FFP[3] 0-5 m	n.d.	n.d.	n.d.	101	n.d.	n.d.
FFP 5-10 m	n.d.	n.d.	n.d.	7	n.d.	n.d.
FFP 5-10 m DUP	n.d.	n.d.	0.4	10	n.d.	n.d.
FFP 10-15 m	n.d.	n.d.	n.d.	5	n.d.	n.d.
FFP 15-20 m	n.d.	n.d.	n.d.	3	n.d.	n.d.
FFP 20-25 m	n.d.	n.d.	n.d.	3	n.d.	n.d.
FFP 25-30 m	n.d.	n.d.	n.d.	0.5	n.d.	n.d.
Target area						
T[4]1	58	0.4	3	35	0.2	0.4
T2	36	0.1	2	21	0.2	0.2
T3	14	n.d.	0.4	3	0.1	0.1
T4	31	0.2	1	16	n.d.	n.d.

1: BFP = behind the firing point
2: n.d. = not detected
3: FFP = in front of the firing point
4: T = target

and 6.8 mg/kg. All samples collected in this hole were contaminated with NG except one (between 30 and 40 cm). In the second hole (hole B), NG was found in two layers with a concentration equal to 0.2 mg/kg. Additional profiling should be conducted in the same area to improve confidence in the data.

Table 17. *Concentrations of NG in samples collected by vertical sampling in Range 22.*

SAMPLE	CONCENTRATION
HOLE A	***mg/kg***
BFP[1]A VS[2] 40-50 cm	1
BFPA VS 0-10 cm	36
BFPA VS 30-40 cm	0.5
BFPA VS 30-40 dup cm	n.d.[3]
BFPA VS 20-30 cm	0.3
BFPA VS 10-20 cm	0.6
BFPA VS 50-60 cm	7
HOLE B	
BFPB VS 0-10 cm	0.2
BFPB VS 40-50 cm	n.d.
BFPB VS 50-60 cm	n.d.
BFPB VS 10-20 cm	0.2
BFPB VS 30-40 cm	n.d.
BFPB VS 20-30 cm	n.d.

1: BFP = behind the firing point
2: VS = vertical sampling
3: n.d. = not detected

3.11 Area 3A

Results obtained for energetic materials from Jeep Hill are listed in Table 18. The three composites of 50 increments named MOAC 1 to 3 collected in this area showed that a high concentration (70.4 mg/kg) of TNT was found in this region. Since just one result was obtained with this magnitude, this region will be sampled again during phase II of the soil sampling campaign. As for metals, Cu and Zn were found with concentrations higher than the CCME criteria with maximum concentrations of 35.8 and 70.5 mg/kg, respectively.

Table 18. *Concentrations of TNT, RDX and NG determined by HPLC in samples collected at Jeep Hill.*

SAMPLE	TNT	RDX	NG
	mg/kg	***mg/kg***	***mg/kg***
Jeep Hill MOAC[1] 1[2]	70.4	0.3	0.7
Jeep Hill MOAC 2[3]	5.7	0.7	n.d.[2]
Jeep Hill MOAC 3	0.4	3.5	1.3
Jeep Hill Crater	0.3	n.d.	n.d.

1: MOAC = mother of all composites
2: Samples showed low concentration of HMX (0.05 mg/kg)
3: n.d. = not detected.

A linear sampling strategy was also applied in Area 3A. The detail of the two samples collected at 40% of the surface from the end of Range 16 was given in section 3.12. No energetic material and metal exceeding CCME and MBG were found in these samples. Moreover, the two biomass samples collected showed concentrations of barium and nickel higher than the MBG.

4. Conclusion

In the context of sustainable training, various firing ranges in CFB/ASU Wainwright were assessed for contamination by energetic materials and metals. This paper reports the results obtained for the first phase of the soil and biomass campaign performed in the summer of 2004 where 14 ranges were sampled. The second and last phase will be done in the summer of 2005 and the report will be published soon.

In the grenade range, the maximum concentrations of RDX (6.7 mg/kg) and TNT (10.6 mg/kg) were found in the rectangular area located 20 to 25 m in front of the firing position. Data from other grenade range studies showed similar results [47]. It would be normal to find more RDX than TNT at the surface, since degradation and transformation is greater for TNT than for RDX [47]. As RDX is less soluble in water and does not interact well with soil, its concentration at the surface should be higher than TNT. The higher concentrations of TNT than those of RDX in this case can probably be explained by recent detonations of munitions containing Composition B (RDX/TNT 60/40) in the training area; the TNT did not have enough time to interact with the soil and remained intact on the surface. The second phase of the campaign will verify whether the concentration of TNT is still higher than that of RDX after a few months. The highest levels of metal analytes were found between 0 and 15 m from the firing position, where concentrations of Zn up to 1 020 mg/kg were detected.

In the demolition range, seven compounds were detected in the soil (HMX, RDX, TNT, NG, 2,4-DNT, 2-ADNT and 4-ADNT), while concentrations lower than the CCME threshold were detected for all metal analytes. RDX and TNT were the two most important contaminants in this area with maximum concentrations of approximately 14 mg/kg for both. For RDX, this value is similar to those obtained for other ranges studied in this work. For TNT, however, this value is low when compared with the result obtained for Range 13 where 390 mg/kg of TNT was found in the target area.

All samples from the small arms ranges showed the presence of NG up to 52.8 mg/kg. However, the firing positions in the anti-tank ranges were the most contaminated. A maximum concentration of 4 453.1 mg/kg was found behind the firing positions; the zone in front of the firing positions showed lower concentrations (maximum of 136.6 mg/kg). 2,4-DNT was also found at the firing point of Ranges 1, 8, and 16 at concentrations up to 0.5, 1.1, and 10 mg/kg, respectively. When the concentration of 2,4-DNT was around 10 mg/kg, 2,6-DNT was also detected at very low concentrations (maximum of 0.7 mg/kg in Range 16). HMX detected (3.8 mg/kg) in front of the firing point in Range 13 will be verified in phase II, since the presence of HMX outside of the impact area is unusual.

NG was found in several ranges at the various firing points sampled. For example, in Range 12 a maximum of 4 mg/kg of NG was detected, while in Range 16 concentrations up to 92.7 mg/kg were found at the firing point. In Ranges 21 and 24, 12.5 and 7 mg/kg of NG were found, respectively, always at the firing point. In the target area, HMX, RDX and TNT were the major contaminants as observed in similar cases [47]. Range 21 showed concentrations of 34, 7.5 and 4.6 mg/kg for HMX, RDX and TNT, respectively. In anti-tank ranges, the maximum concentrations of HMX, RDX, and TNT were 1 192, 14, and 390 mg/kg,

respectively. The concentrations of contaminants were significantly higher closer to the target (see Table 15). NG was also detected in the target area of the two anti-tank ranges (13 and 22) and Range 21, which showed concentrations of 54, 35, and 1.8 mg/kg, respectively. This result can be explained by the incomplete combustion of the propellant. The distance of the targets from the firing point did not influence the magnitude of the contamination. In fact, the highest concentrations of contaminants were sometimes found at the farthest targets.

The target area for Ranges 13 and 22, the two anti-tank ranges, showed higher concentrations of HMX than those of TNT. In fact, HMX and TNT should be in the proportion of 70/30 in the soil, as in the munitions; however, the results showed a ratio of HMX to TNT between 98/2 and 80/20. This can be partially explained by the fast degradation rate and strong binding capacity of TNT and its metabolites. TNT thus vanishes rapidly from the surface soil, contrary to HMX, which is less soluble. The vertical sampling study done in Range 21 showed that NG was found at a depth of 60 cm, but no trend was observed with depth.

The highest concentrations of Zn were found in Range 2 (up to 1 000 mg/kg 0-15 m from the firing position) and in anti-tank Range 13 (1 190 mg/kg). Pb up to 66 100 mg/kg was found at the target area of small arms Ranges 1 and 8. In Range 24 (small arms range), 6 720 mg/kg of lead was found in the sand butt, which is the target. Samples from the dump site and the anti-tank range showed maximum concentrations of Cu of 7 220 and 10 400 mg/kg, respectively, while lower concentrations were found in Range 21 (172 mg/kg) and in Range 24 (246 mg/kg). Sb was also detected in small arms and anti-tank ranges with a maximum of 932 and 59 mg/kg, respectively. Finally, Cr, Ni, Mo, and Cd were detected in Anti-tank Range #13 with maximum concentrations of 139, 105, 253 and 26 mg/kg, respectively.

Leachate testing of the soil samples collected in the target zones of small arms ranges showed high concentrations of Pb (up to 790 mg/kg). This result means that lead could migrate into the groundwater. Water in proximity to these firing points must be closely monitored.

In summary, this study demonstrated that the accumulation of energetic materials and metals due to firing activities in CFB/ASU Wainwright is comparable to what was observed in similar ranges across Canada. The most impacted range was Anti-tank Range #13. High concentrations of energetic materials were found at the firing position (NG) and around targets (HMX and TNT). The high levels of NG at the firing position represent a concern for DND since military personnel can be exposed to this compound. The deposition pattern of gun propellant residues in firing positions has been studied, and remediation methods are under consideration. The highest concentration of Pb was detected in Range 1, a small arms range. Metal levels higher than the MBG were found in three biomass samples from Range 1 (Sb, Cu, and Pb), in two from Range 16 (Cu and Pb), and in one from the Vernonburg dump ammunition site (Cu). DRDC Valcartier will conduct phase II of the study to complete the characterization of the surface soil and the vegetation for metals and energetic materials. This campaign will also allow the sampling of additional ranges and confirmation of the results obtained during this first phase.

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Annex A □ GPS Positions

Table A1. *GPS positions of soil and vegetation backgrounds.*

SOIL AND VEGETATION BACKGROUND	GPS POSITIONS
1	0403631-5849303
2	0402538-5848516
3	0401147-5846679
4	0498173-5846922
5	0495987-5846016
6	0495253-5843540
7	0494710-5841163
8	0493869-5838840
9	0495482-5838687
10	0496411-5836978
11	0498454-5836222
12	0499879-5834952
13	0501029-5833337
14	0503716-5833337
15	0506138-5833283
16	0508023-5833020
17	0508541-5835631
18	0509721-5837024
19	0507133-5840000
20	0506771-5846863
21	0415300-5833265

Table A2. *GPS positions in Grenade Range #2 (see Figure 1).*

POSITIONS	GPS POSITIONS
a	0506334-5846977
b	0506315-5846983
c	0506317-5846987
d	0506298-5846992
e	0506299-5846997
f	0506304-5847015
g	0506305-5847020
h	0506325-5847015
i	0506326-5847020
j	0506347-5847013
k	0506343-5847005
l	0506338-5846985

Table A3. *GPS positions of firing positions and targets in Range 12.*

POSITIONS	GPS POSITIONS
Bags 1	0503590-5845679
Bags 2	0503589-5845691
Bags 3	0503589-5845704
Bags 4	0503530-5845717
Target 1	0503881-5845826
Target 2	0503881-5845826
Target 3/Hot spot	0504070-5845952

Table A4. *GPS positions of demolition areas in Range 14 (see Figure 4).*

POSITIONS	GPS POSITIONS
Square 1	a: 0505081-5844112
	b: 0505056-5844127
	c: 0505040-5844098
	d: 0505069-5844076
Square 2	e: 0505085-5844066
	f: 0505136-5844027
	g: 0505148-5844053
	h: 0505098-5844086
Square 3	i: 0505163-5844185
	j: 0505186-5844221
	k: 0505183-5844175
	l: 0505203-5844213
Square 4	m: 0505190-5844173
	n: 0505211-5844211
	o: 0505210-5844151
	p: 0505237-5844193

Table A5. *Dimensions of demolition areas in Range 14 (see Figure 4).*

POSITIONS	GPS POSITIONS
Square 1	a-b: 34 m
	b-c: 31 m
Square 2	e-f : 62 m
	f-g : 27 m
Square 3	i-j: 43 m
	k-i: 19 m
	k-l: 43 m
	j-l: 19 m
Square 4	m-n: 45 m
	n-p: 30 m
	p-o: 50 m
	m-o: 30 m

Table A6. *GPS positions in Range 16 (see Figure 7).*

	PAD 1	PAD 2
Positions	***GPS Positions***	***GPS Positions***
a	0496804-5845342	0496519-5845006
b	0496791-5845365	0496506-5845026
c	0496847-5845395	0496558-5845058
d	0496860-5845372	0496569-5845040
e	0496843-5845365	0496557-5845027
f	0496849-5845354	0496564-5845017
g	0496853-5845346	0496565-5845009
h	0496858-5845335	0496570-5844999
i	0496863-5845326	0496576-5844990
j	0496866-5845316	0496581-5844980
k	0496848-5845305	0496560-5844970
l	0496838-5845312	0496555-5844978
m	0496835-5845321	0496550-5844985
n	0496831-5845331	0496545-5844994
o	0496826-5845340	0496540-5845003
p	0496821-5845352	0496536-5845006

Table A7. *GPS positions of rails in Range 16*

	GPS POSITIONS
Rail A	
Beginning	0497073-5845214
End	0497025-5845179
Rail B	
Beginning	0497446-5844973
End	0496831-5844704

Table A8. *GPS positions of the seven fresh craters sampled in the danger permanent Area 4.*

POSITIONS	GPS POSITIONS
A	0521209-5833185
B	0521199-5833185
C	0521199-5833186
D	0521213-5833179
E	0521200-5833205
F	0521203-5833206
G	0521177-5833176

Table A9. *GPS positions of the mortar pit, the trench, the lines and the targets in Range 21.*

	GPS POSITIONS
Mortar Pit	0500195-5846371
Trench Beginning	0500171-5846380
Middle	0500081-5846403
End	0499987-5846390
Lines	
1	0500155-5846374
2	0500125-5846384
3	0500090-5846395
4	0500067-5846390
5	0500040-5846386
6	050000-5846386
Targets	
1	0500286-5846094
2	0500225-5846075
3	0499932-5845397

Table A10. *GPS positions of firing positions and targets in Range 26.*

	GPS POSITIONS
Hole A	0499122-5846694
Hole B	0499109-5846694
Bags	0499094-5846690
Target 1	0499121-5846509
Target 2	0499099-5846547
Target 3	0499086-5846415

Table A11. *GPS positions of targets located at the extremities and of two firing positions in Ranges 1 and 8.*

RANGE 1	**GPS POSITIONS**
Targets	
1	0506006-5852842
12	0506003-5852880
Firing positions	
93 m-beginning	0506119-5852844
93 m-end	0506122-5852844
200 m-beginning	0506215-5852846
200 m-end	0506211-5852884
RANGE 8	**GPS POSITIONS**
Targets	
1	0504779-5848786
24	0504863-5848789
Firing positions	
100 m-beginning	0504864-5848931
100 m-end	0504779-5848936
200 m-beginning	0504863-5849032
200 m-end	0504782-5849033

Table A12. *GPS positions of the sand butt and the firing positions in Range 24.*

	GPS POSITIONS
Butt Sand	0506780-5853320
Firing Positions	
10 m	0506788-5853305
15 m	0506788-5853305
20 m	0506787-5853304
25 m	0506788-5853279

Table A13. *GPS positions of the firing positions and targets in Range 13 (see Figures 18 and 19).*

POSITIONS	**GPS POSITIONS**
A	0503811-5845261
B	0503806-5845312
C	0503792-5845308
D	0503771-5845304
E	0503771-5845295
F	0503823-5845288
G	0503828-5845306
Targets	
T1	0503918-5845272
T2	0504005-5845292
T3	0504073-5845194
T4	0503965-5845234

Table A14. *GPS positions of the firing positions and targets in Range 22.*

POSITIONS	GPS POSITIONS
d	0501383-5846188
e	0501386-5846191
f	0501389-5846196
g	0501389-5846200
h	0501391-5846205
i	0501393-5846210
j	0501395-5846215
k	0501411-5846176
l	0501413-5846180
m	0501413-5846185
n	0501416-5846188
o	0501419-5846193
p	0501420-5846198
q	0501423-5846203
Firing positions	
A	0501410-5846179
B	0501397-5846184
C	0501386-5846188
Targets	
T1	0501360-5846094
T2	0501335-5846036
T3	0501242-5845806
T4	0501182-5845815

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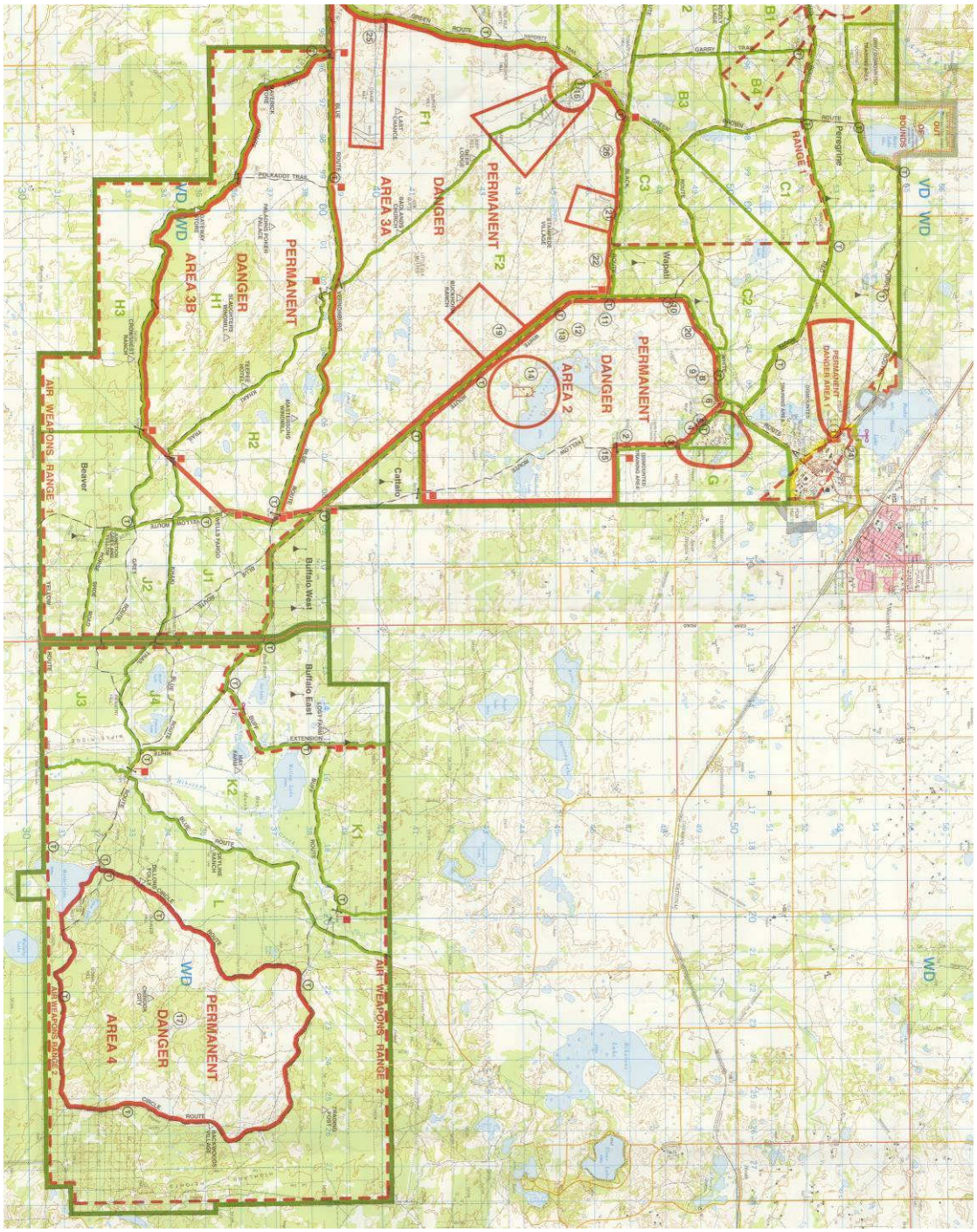
Annex B □ CFB/ASU Map



Map of CFB/ASU Wainwright

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Annex C □ Metal Concentrations in Soil

Table C1. *Concentrations of various metals in soil determined by ICP-MS*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R2 A	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5
R2 B	6850	< 0.5	4	121	< 10	< 5.0	3.9	0.99	9790	13.9
R2 C	7650	< 0.5	4	124	< 10	< 5.0	3.8	0.73	7600	13.9
R2 D	7820	< 0.5	4	145	< 10	< 5.0	8.2	1.45	9370	**17.5**
R2 E	6930	< 0.5	4	124	< 10	< 5.0	4.2	1.08	8540	**16.4**
R2 F	6370	< 0.5	4	118	< 10	< 5.0	3.7	0.96	8140	13.4
R2 0-5	5450	< 0.5	7	99	< 10	< 5.0	2.8	0.95	9060	13.7
R2 5-10	6310	< 0.5	4	110	< 10	< 5.0	3.4	0.93	7470	14.0
R2 10-15	4850	< 0.5	4	110	< 10	< 5.0	3.5	0.82	8900	13.7
R2 10-15 DUP	5420	< 0.5	4	123	< 10	< 5.0	3.5	0.92	8460	13.0
R2 15-20	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5
R2 20-25	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5
R2 25-30	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5
R2 30-35	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5
R2 35-40	< 100	< 0.5	< 1	< 0.5	< 10	< 5.0	< 0.5	< 0.50	< 100	< 0.5

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R12 T1	**11100**	< 0.5	5	154	< 10	< 5.0	8.1	0.82	5180	**18.2**
R12 T2	6790	0.6	3	121	< 10	< 5.0	9.3	0.91	4630	11.4
R12 T3	6360	< 0.5	3	100	< 10	< 5.0	7.3	0.81	2950	10.3
R12 HS 0504070-5845925	5780	1	4	87.9	< 10	< 5.0	4.3	< 0.50	6280	10.4
R12 Crater near T1	**13800**	< 0.5	6	134	< 10	< 5.0	**11**	< 0.50	9750	**21**
R14 DS-1 Moac 1	5170	< 0.5	3	56.6	< 10	< 5.0	2.1	< 0.50	3430	7.2
R14 DS-1 Moac 2	4700	< 0.5	3	57.8	< 10	< 5.0	1.8	< 0.50	2800	7.2
R14 DS-1 Moac 3	4860	< 0.5	3	55.2	< 10	< 5.0	2.1	< 0.50	3110	7.4
R14 DS-2 Moac 1	3920	< 0.5	2	58.1	< 10	< 5.0	2.1	< 0.50	4560	6.2
R14 DS-2 Moac 2	4610	< 0.5	3	59.5	< 10	< 5.0	2.2	< 0.50	5930	7.4
R14 DS-2 Moac 3	4530	< 0.5	3	70	< 10	< 5.0	2.9	< 0.50	7280	7.5
R14 DS-3 Moac 1	3460	< 0.5	3	53.6	< 10	< 5.0	2.5	< 0.50	5090	5.9
R14 DS-3 Moac 2	3680	< 0.5	3	61.3	< 10	< 5.0	2.2	< 0.50	5280	6.5
R14 DS-3 Moac 3	3420	< 0.5	3	51.2	< 10	< 5.0	2.2	< 0.50	4830	6.1
R14 DS-4 Moac 1	3570	< 0.5	3	51.6	< 10	< 5.0	2.1	< 0.50	5550	6

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R14 DS-4 Moac 2	3840	< 0.5	3	54	< 10	< 5.0	2.8	< 0.50	5320	6.7
R14 DS-4 Moac 3	3390	< 0.5	3	54.3	< 10	< 5.0	2.8	< 0.50	5290	6.3
R14 DS-5 Moac	3970	< 0.5	2	49.2	< 10	< 5.0	2.3	< 0.50	1820	6
R16 FP 1 0-10	2500	0.6	2	64.2	< 10	< 5.0	1.2	< 0.50	1260	4.2
R16 FP 1 10-20	2540	< 0.5	2	76.3	< 10	< 5.0	1.2	< 0.50	1250	4.3
R16 FP 1 10-20 DUP	2180	0.5	2	67.9	< 10	< 5.0	1	< 0.50	1150	3.9
R16 FP 1 20-30	2430	< 0.5	2	53.3	< 10	< 5.0	0.9	< 0.50	846	3.7
R16 FP 1 30-40	2410	0.5	2	62.4	< 10	< 5.0	1.1	< 0.50	883	3.7
R16 FP 1 40-50	2380	< 0.5	3	44.6	< 10	< 5.0	0.7	< 0.50	746	3.5
R16 FP 2 0-10	1580	0.6	3	36.6	< 10	< 5.0	1.6	< 0.50	2980	3.1
R16 FP 2 0-10 DUP	1280	< 0.5	2	32.9	< 10	< 5.0	0.7	< 0.50	2240	2.6
R16 FP 2 10-20	1420	< 0.5	3	37.4	< 10	< 5.0	0.5	< 0.50	3600	3.3
R16 FP 2 20-30	1520	< 0.5	3	46.4	< 10	< 5.0	0.6	< 0.50	1810	2.6
R16 FP 2 30-40	1780	0.6	2	40	< 10	< 5.0	1.2	< 0.50	1830	3.3
R16 FP 2 40-50	1660	0.6	2	42.1	< 10	< 5.0	1	< 0.50	1550	2.9

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***
R16 FP 2 HS	1650	0.6	4	66.7	< 10	< 5.0	1.3	< 0.50	9080	4.2
R16 MT Berm 1-A	2140	< 0.5	3	54.6	< 10	< 5.0	1	< 0.50	1640	3.7
R16 MT Berm 1-B	2870	< 0.5	3	67.8	< 10	< 5.0	13	< 0.50	1440	3.9
R16 MT Berm 2-A	1920	< 0.5	3	75.7	< 10	< 5.0	1.1	< 0.50	1790	2.8
R16 MT Berm 2-B	1760	< 0.5	2	42.9	< 10	< 5.0	0.7	< 0.50	2440	2.8
R17 1	3860	< 0.5	2	70.2	< 10	< 5.0	4.5	1.37	1520	5.2
R17 2	4020	< 0.5	3	90.3	< 10	< 5.0	4.5	0.5	1680	4.8
R17 FC-A	2990	< 0.5	1	38	< 10	< 5.0	4.8	< 0.50	966	4.1
R17 FC-B	4570	< 0.5	< 1	56	< 10	< 5.0	6.4	< 0.50	1140	6.4
R17 FC-C	4270	< 0.5	< 1	47.7	< 10	< 5.0	4.3	< 0.50	696	5.5
R17 FC-D	4740	< 0.5	< 1	69.7	< 10	< 5.0	4.3	< 0.50	1460	5.5
R17 FC-E	3090	< 0.5	1	33.8	< 10	< 5.0	4.2	< 0.50	950	4.3
R17 FC-F	3410	< 0.5	2	41.4	< 10	< 5.0	4.4	< 0.50	935	4.4
R17 FC-G	3050	< 0.5	2	42.7	< 10	< 5.0	3.8	< 0.50	893	4

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R21 In MP	3850	< 0.5	3	46.8	< 10	< 5.0	1.6	< 0.50	1080	5
R21 Out MP	2810	< 0.5	2	49.4	< 10	< 5.0	1.1	< 0.50	1110	4.2
R21 Line 1-In MP	2760	< 0.5	2	42.6	< 10	< 5.0	1.4	< 0.50	2860	4.0
R21 Line 1-In MP DUP	2420	< 0.5	2	36.7	< 10	< 5.0	1.2	< 0.50	3500	3.7
R21 Line 1-Out MP	1730	0.7	2	33.4	< 10	< 5.0	1.2	< 0.50	4000	3.2
R21 Line 2	1960	< 0.5	2	39.3	< 10	< 5.0	0.9	< 0.50	2080	3.7
R21 Line 3	1620	< 0.5	3	46.6	< 10	< 5.0	1.5	< 0.50	3120	2.9
R21 Line 3 DUP	1930	< 0.5	3	36.2	< 10	< 5.0	1.6	< 0.50	3830	3.4
R21 Line 4	2140	< 0.5	2	38.2	< 10	< 5.0	1.3	< 0.50	3040	3.6
R21 Line 5	1960	< 0.5	4	34.6	< 10	< 5.0	1.2	< 0.50	1770	3.2
R21 Line 6	2380	< 0.5	4	49.2	< 10	< 5.0	1.3	< 0.50	2580	3.8
R21 T1	3100	1.1	1	44.5	< 10	< 5.0	1.9	< 0.50	1100	4.6
R21 T2	3340	**6.3**	2	67.6	< 10	< 5.0	1.5	< 0.50	1380	9
R21 T3	4350	**10.4**	2	107	< 10	< 5.0	5.6	**3.96**	2980	10.8
R21 Trench A	2350	< 0.5	2	45.3	< 10	< 5.0	4.7	< 0.50	4050	3.9
R21 Trench B	2460	< 0.5	2	44.9	< 10	< 5.0	4.8	< 0.50	2100	3.9

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R26 BFP Moac	2790	< 0.5	2	42.6	< 10	< 5.0	4.3	< 0.50	995	4.3
R26 FFP Moac	3310	< 0.5	2	44.3	< 10	< 5.0	3.3	< 0.50	1100	4.5
R26 T1	2370	0.9	2	49.1	< 10	< 5.0	1.2	< 0.50	792	8.4
R26 T2	2550	< 0.5	2	52.9	< 10	< 5.0	1.5	< 0.50	1370	6.4
R26 T3	3400	< 0.5	2	48.6	< 10	< 5.0	4.4	< 0.50	1450	5
Vernonburg Moac 1	3390	< 0.5	2	68.1	< 10	< 5.0	5.7	3.08	1590	7
Vernonburg Moac 2	2390	< 0.5	2	59.6	< 10	< 5.0	4.8	1.21	1660	8.6
Vernonburg Moac 3	2960	< 0.5	2	52.4	< 10	< 5.0	4.7	0.76	1350	4.5
Jeephill Moac 1	2470	< 0.5	2	31.6	< 10	< 5.0	3.6	< 0.50	709	4
Jeephill Moac 2	1800	< 0.5	2	26.4	< 10	< 5.0	3.9	< 0.50	537	2.8
Jeephill Moac 3	2010	< 0.5	2	28.6	< 10	< 5.0	3.6	< 0.50	626	3.6
Jeephill crater	2420	< 0.5	1	34.5	< 10	< 5.0	0.6	< 0.50	593	3.3
A3A-LS-40% Crater	2170	< 0.5	2	42.1	< 10	< 5.0	4	< 0.50	884	3.4

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 T 1-3 A	3650	**720**	**10**	51.8	< 10	5.8	5.4	< 0.50	1790	5.4
R1 T 1-3 B	4360	**18.9**	3	63.6	< 10	< 5.0	4.8	< 0.50	2160	6.9
R1 T 1-3 C	4830	**170**	4	142	< 10	< 5.0	7.4	< 0.50	7540	10.2
R1 T 4-6 A	3470	**932**	**11**	48.8	< 10	5.5	4.5	< 0.50	1290	5.0
R1 T 4-6 B	3830	**30.4**	2	47.2	< 10	< 5.0	4.6	< 0.50	1410	5.9
R1 T 4-6 B DUP	3390	**10.8**	2	44.6	< 10	< 5.0	4.2	< 0.50	1340	4.7
R1 T 4-6 C	3040	**13.9**	2	44.6	< 10	< 5.0	5.2	< 0.50	1510	5.4
R1 T 7-9 A	3430	**474**	4	43.9	< 10	< 5.0	4.6	< 0.50	1190	5.2
R1 T 7-9 B	3950	**9.6**	2	46.7	< 10	< 5.0	4.6	< 0.50	1420	6.5
R1 T 7-9 C	3290	**2.9**	2	39.1	< 10	< 5.0	4.7	< 0.50	996	5.0
R1 T 10-12 A	4050	**90.5**	3	48.7	< 10	< 5.0	4.7	< 0.50	1300	6.0
R1 T 10-12 B	2940	**2.4**	2	36.7	< 10	< 5.0	4.1	< 0.50	950	4.7
R1 T 10-12 C	2730	**3**	2	29.1	< 10	< 5.0	4.2	< 0.50	775	4.3
R1 FP 100 T 1-3	3290	**5.8**	2	75.7	< 10	< 5.0	4.1	< 0.50	2430	7.9
R1 FP 100 T 4-6	4170	**7.4**	2	92.1	< 10	< 5.0	4.8	< 0.50	2120	6.5
R1 FP 100 T 7-9	4270	**5.7**	3	89.9	< 10	< 5.0	5	< 0.50	2240	6.7

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 FP 100 T 10-12	4310	**3.7**	2	75.5	< 10	< 5.0	4.7	< 0.50	2290	7.2
R1 FP 100 T 10-12 DUP	3890	**3.8**	2	85.6	< 10	< 5.0	4.8	< 0.50	2220	6.8
R1 FP 200 T 1-3	6170	**3.1**	3	94.5	< 10	< 5.0	5.8	< 0.50	3180	9.7
R1 FP 200 T 4-6	5630	**3.9**	3	97.6	< 10	< 5.0	5.6	< 0.50	3110	8.7
R1 FP 200 T 4-6 DUP	3390	**2.6**	2	59.3	< 10	< 5.0	4.2	< 0.50	1540	5.7
R1 FP 200 T 7-9	4170	**28.9**	3	63.4	< 10	< 5.0	3	< 0.50	1800	7.0
R1 FP 200 T 10-12	1210	< 0.5	< 1	21.8	< 10	< 5.0	1.3	< 0.50	582	1.5
R8 T 1-4 A	6890	**11.9**	5	149	< 10	< 5.0	6.2	< 0.50	15300	12.5
R8 T 1-4 A DUP	6800	**10.6**	1	160	< 10	< 5.0	3.7	< 0.50	16000	12.7
R8 T1-4 B	**9250**	**3.6**	2	**181**	< 10	< 5.0	5.6	< 0.50	16300	**16.7**
R8 T1-4 C	7320	0.6	4	147	< 10	< 5.0	7.2	< 0.50	13900	13.6
R8 T 5-8 A	7850	**17.4**	3	**181**	< 10	< 5.0	5.5	< 0.50	19200	14.8
R8 T 5-8 B	8530	**11**	2	**180**	< 10	< 5.0	5.0	< 0.50	18100	**15.7**
R8 T 5-8 C	**9970**	< 0.5	3	**207**	< 10	< 5.0	6.8	< 0.50	25700	**21.5**
R8 T 9-12 A	7470	**11.4**	2	177	< 10	< 5.0	4.3	< 0.50	17300	13.4

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 T 9-12 B	7420	6	2	177	< 10	< 5.0	4.6	< 0.50	16800	13.5
R8 T 9-12 C	7490	0.6	5	155	< 10	< 5.0	7	< 0.50	15600	14.5
R8 T 13-16 A	9230	12.7	2	207	< 10	< 5.0	5.7	< 0.50	20200	15.8
R8 T 13-16 B	10400	6.6	2	200	< 10	< 5.0	6.4	< 0.50	19500	18.3
R8 T 13-16 B DUP	8850	6.1	3	193	< 10	< 5.0	4.9	< 0.50	19600	16.3
R8 T 13-16 C	7060	3.2	2	163	< 10	< 5.0	5.6	< 0.50	20100	17.0
R8 T 17-20 A	8510	7.4	3	186	< 10	< 5.0	6	< 0.50	21000	15.8
R8 T 17-20 B	7380	5.2	4	148	< 10	< 5.0	6	< 0.50	13600	13.1
R8 T 17-20 C	7940	< 0.5	2	149	< 10	< 5.0	3.4	< 0.50	16600	14.1
R8 T 21-24 A	7220	5.3	2	169	< 10	< 5.0	4.5	< 0.50	16100	13.6
R8 T 21-24 B	7150	8	2	178	< 10	< 5.0	4.4	< 0.50	17300	13.3
R8 T 21-24 C	6230	2.6	4	130	< 10	< 5.0	7.1	< 0.50	14100	11.5
R8 FP 100 T 1-4	5250	8.9	4	144	< 10	< 5.0	5.1	< 0.50	6170	9.2
R8 FP 100 T 5-8	4760	9	3	148	< 10	< 5.0	5.3	< 0.50	5290	8.2
R8 FP 100 T 9-12	7420	15	4	206	< 10	< 5.0	5.0	< 0.50	6620	11.8
R8 FP 100 T 9-12 DUP	8460	12.3	5	227	< 10	< 5.0	6.5	< 0.50	7750	14.1

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 FP 100 T 13-16	6760	**15**	4	**195**	< 10	< 5.0	5.6	< 0.50	4610	11.5
R8 FP 100 T 17-20	7590	**14.1**	4	**221**	< 10	< 5.0	6.4	< 0.50	5050	12.4
R8 FP 100 T 21-24	8900	**6.4**	4	176	< 10	< 5.0	5.1	< 0.50	3330	13.8
R8 FP 200 T 1-4	7230	**10.8**	4	**210**	< 10	< 5.0	6.1	< 0.50	6090	12.0
R8 FP 200 T 5-8	7210	**10.1**	4	**198**	< 10	< 5.0	5.7	< 0.50	8020	12.4
R8 FP 200 T 9-12	7530	**7**	4	**211**	< 10	< 5.0	7.1	< 0.50	8930	12.5
R8 FP 200 T 9-12 DUP	7160	**6.3**	4	**196**	< 10	< 5.0	6.1	< 0.50	7370	11.5
R8 FP 200 T 13-16	7580	**6**	5	**206**	< 10	< 5.0	6.4	< 0.50	12000	13.5
R8 FP 200 T 17-20	**9790**	**3.4**	5	**213**	< 10	< 5.0	7.6	< 0.50	10200	**15.9**
R8 FP 200 T 21-24	**9670**	1.9	4	176	< 10	< 5.0	8.4	< 0.50	10300	**16.1**
R24 FP 10	4530	< 0.5	3	102	< 10	< 5.0	4.6	< 0.50	8710	7.4
R24 FP 15	6480	< 0.5	5	122	< 10	< 5.0	6.2	< 0.50	10400	10.8
R24 FP 20	7370	< 0.5	5	162	< 10	< 5.0	6.7	0.62	12100	13.3
R24 FP 25	6000	< 0.5	4	105	< 10	< 5.0	5.6	< 0.50	10400	10.2

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C1. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R24-BermA-Moac	6580	< 0.5	< 1	106	< 10	< 5.0	7.6	< 0.50	17200	11.9
R24-BermBT-Moac	2480	**18.5**	< 1	69.6	< 10	< 5.0	6	< 0.50	20400	6.6
R13 T1	**24900**	**18.9**	6	**202**	< 10	**39.2**	5.3	**26.4**	2760	**139**
R13 T1 DUP	**18100**	**8**	4	**189**	< 10	**44**	8.5	**22.0**	4860	**65.7**
R13 T2	**14600**	**3.5**	4	112	< 10	< 5.0	**11.4**	**3.81**	5370	**47.9**
R13 T3-close	**23900**	**16.4**	7	**196**	< 10	10	7.2	**15.9**	8650	**100**
R13 T3-far	8230	1	5	121	< 10	< 5.0	7.7	**2.06**	7470	13.7
R13 T4	8810	0.8	3	86.4	< 10	< 5.0	5.5	**3.46**	4150	**19.9**
R22 T1	**10400**	**4.9**	**8**	127	< 10	5.2	**10.9**	< 0.50	15700	**93.6**
R22 T2	7970	**18.2**	2	132	< 10	17.3	2.8	**2.49**	1460	**31.7**
R22 T3	**14900**	**26.2**	2	90.9	< 10	**32.5**	6.8	**7.41**	2230	**27.7**
R22 T4	**17500**	**59**	7	**182**	< 10	**24.9**	9.2	**8.05**	14200	**33.3**

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C2. *Concentrations of various metals in soil determined by ICP-MS.*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R2 A	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8
R2 B	6.7	**38.3**	13100	20	7.4	3170	317	< 0.05	< 0.5	**24.3**
R2 C	7.5	**29**	14200	16	**7.6**	2910	378	< 0.05	< 0.5	**23.3**
R2 D	7.1	**57.7**	15500	30	7.1	3020	400	< 0.05	< 0.5	**31.6**
R2 E	6.4	**45.7**	13900	24	6.7	2850	322	< 0.05	< 0.5	**25.8**
R2 F	6.5	**32.9**	12500	19	6.8	2790	404	< 0.05	< 0.5	**22.8**
R2 0-5	6.0	**66.6**	12900	15	5.8	2650	312	< 0.05	< 0.5	**19.5**
R2 5-10	6.2	**48.7**	13300	18	5.9	2550	298	< 0.05	< 0.5	**22.2**
R2 10-15	5.5	**48.5**	12300	18	5.9	2680	253	< 0.05	< 0.5	**21.8**
R2 10-15 DUP	5.8	**47.9**	12500	29	6.2	2710	281	< 0.05	< 0.5	**24**
R2 15-20	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8
R2 20-25	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8
R2 25-30	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8
R2 30-35	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8
R2 35-40	< 0.5	< 0.5	< 100	< 10	< 2.0	< 100	< 0.2	< 0.05	< 0.5	< 0.8

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R12 T1	**8.8**	**27.5**	17500	35	**9.3**	2980	512	< 0.05	0.7	**19.7**
R12 T2	5.7	**27.7**	10800	19	4.8	1740	378	< 0.05	0.6	12.5
R12 T3	5.2	**45.4**	9320	17	4.6	1390	388	< 0.05	< 0.5	9.7
R12 HS 0504070-5845925	4.1	**30.6**	8040	22	4.5	1630	227	< 0.05	< 0.5	9.9
R12 Crater near T1	**10.2**	**23**	**20900**	11	**12.4**	**3970**	479	< 0.05	0.7	**24.9**
R14 DS-1 Moac 1	4.8	10	8010	< 10	5.2	1520	200	< 0.05	< 0.5	10.2
R14 DS-1 Moac 2	4.3	**14.1**	7610	< 10	4.7	1350	198	< 0.05	< 0.5	10.2
R14 DS-1 Moac 3	4.7	8.7	7940	< 10	5	1490	233	< 0.05	< 0.5	11.2
R14 DS-2 Moac 1	3.9	9.4	6960	< 10	4.2	1450	174	< 0.05	< 0.5	9
R14 DS-2 Moac 2	4.5	11.2	7690	< 10	4.5	1720	193	< 0.05	< 0.5	10.1
R14 DS-2 Moac 3	4.5	10.5	8630	< 10	5.5	1980	216	< 0.05	< 0.5	11.2
R14 DS-3 Moac 1	3.8	**19.2**	6980	10	3.5	1450	187	< 0.05	< 0.5	9
R14 DS-3 Moac 2	4.4	**26.8**	7790	13	3.9	1470	232	< 0.05	< 0.5	10.3
R14 DS-3 Moac 3	4	**20.4**	7440	10	3.8	1400	192	< 0.05	< 0.5	9.4
R14 DS-4 Moac 1	4	**22.5**	7070	12	3.6	1570	179	< 0.05	< 0.5	9.3

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R14 DS-4 Moac 2	3.8	23.7	7260	11	3.2	1330	182	< 0.05	< 0.5	8.9
R14 DS-4 Moac 3	3.7	25.5	6610	14	3.4	1320	189	< 0.05	< 0.5	8.6
R14 DS-5 Moac	3.5	11	4670	< 10	3	1210	159	< 0.05	< 0.5	6.7
R16 FP 1 0-10	3.1	42.5	4040	13	2.1	706	145	< 0.05	< 0.5	6.6
R16 FP 1 10-20	3	35.5	4090	17	2.1	725	133	< 0.05	< 0.5	6.8
R16 FP 1 10-20 DUP	2.6	38.3	4080	32	< 2.0	628	117	< 0.05	< 0.5	7
R16 FP 1 20-30	2.6	21.1	3930	15	< 2.0	629	108	< 0.05	< 0.5	5.6
R16 FP 1 30-40	2.5	27.7	3870	29	2.1	606	105	< 0.05	< 0.5	5.7
R16 FP 1 40-50	2.8	13.4	4270	22	< 2.0	608	130	< 0.05	< 0.5	6.3
R16 FP 2 0-10	2.6	17.1	6390	11	< 2.0	721	173	< 0.05	< 0.5	6.8
R16 FP 2 0-10 DUP	2.4	14.6	5200	< 10	< 2.0	660	154	< 0.05	< 0.5	6.1
R16 FP 2 10-20	2.7	10.5	4360	< 10	< 2.0	634	203	< 0.05	< 0.5	7.2
R16 FP 2 20-30	2.9	20.3	5610	< 10	< 2.0	556	556	< 0.05	< 0.5	8.8
R16 FP 2 30-40	2.7	63	5010	14	< 2.0	754	754	< 0.05	< 0.5	6
R16 FP 2 40-50	2.5	42	4280	11	2.3	611	611	< 0.05	< 0.5	7.6

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R16 FP 2 HS	3.7	**34**	11500	68	2.1	1750	567	< 0.05	< 0.5	10.9
R16 MT Berm 1-A	2.9	**16.1**	7700	18	< 2.0	649	260	< 0.05	< 0.5	6
R16 MT Berm 1-B	3.1	**57**	7590	26	2.1	670	268	< 0.05	< 0.5	6
R16 MT Berm 2-A	2.4	7.8	7040	< 10	< 2.0	649	556	< 0.05	< 0.5	7.1
R16 MT Berm 2-B	2.4	7.7	4650	< 10	< 2.0	696	257	< 0.05	< 0.5	5.1
R17 1	2.8	**34.3**	4390	< 10	2.7	814	131	< 0.05	< 0.5	6.7
R17 2	3.1	**18.9**	5290	< 10	2.8	841	165	< 0.05	< 0.5	7.2
R17 FC-A	1.5	6.7	2960	< 10	2.7	697	31.1	< 0.05	< 0.5	**112**
R17 FC-B	1.9	7.6	2910	< 10	3.2	775	27.3	< 0.05	< 0.5	**398**
R17 FC-C	1.5	8.4	2830	< 10	2.7	7690	26.4	< 0.05	< 0.5	7.8
R17 FC-D	1.5	7.7	2850	< 10	3.3	777	27.4	< 0.05	< 0.5	8.8
R17 FC-E	1.8	7.4	3310	< 10	2.5	777	35.7	< 0.05	< 0.5	6.3
R17 FC-F	2.7	**12.9**	4240	< 10	2.7	828	84.8	< 0.05	< 0.5	7.2
R17 FC-G	2.6	7.4	4110	< 10	2.7	769	82.3	< 0.05	< 0.5	6.6

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R21 In MP	3.6	14.9	6300	< 10	3.1	937	139	< 0.05	< 0.5	8.3
R21 Out MP	3.1	22.5	4980	< 10	2.6	836	118	< 0.05	< 0.5	6.8
R21 Line 1-In MP	3.1	24.6	4730	< 10	2.5	1100	140	< 0.05	< 0.5	7.6
R21 Line 1-In MP DUP	3	20.2	6120	< 10	2.3	1300	139	< 0.05	< 0.5	7.7
R21 Line 1-Out MP	2.4	28.4	5860	< 10	< 2.0	964	138	< 0.05	< 0.5	5.8
R21 Line 2	2.6	12.3	4230	< 10	< 2.0	796	135	< 0.05	< 0.5	6.6
R21 Line 3	3.2	11	6470	< 10	< 2.0	741	167	< 0.05	< 0.5	7.4
R21 Line 3 DUP	3.4	12.2	6580	< 10	2	1050	169	< 0.05	< 0.5	8.2
R21 Line 4	3	13.1	4720	< 10	2.1	845	130	< 0.05	< 0.5	6.7
R21 Line 5	3.3	17.7	5620	< 10	< 2.0	775	129	< 0.05	< 0.5	7.9
R21 Line 6	3.6	20	6860	< 10	2.2	948	240	< 0.05	< 0.5	9.1
R21 T1	2.9	10.2	3940	25	2.3	739	140	< 0.05	< 0.5	5.5
R21 T2	3.4	28.5	4270	192	2.1	745	174	< 0.05	< 0.5	7
R21 T3	4.5	172	6410	297	2.8	840	231	< 0.05	0.6	8
R21 Trench A	3.3	15	5840	< 10	2.9	1360	181	< 0.05	< 0.5	7.7
R21 Trench B	3.2	13.2	4680	< 10	2.4	864	133	< 0.05	< 0.5	7.1

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R26 BFP Moac	3	6.5	4310	< 10	2	707	126	< 0.05	< 0.5	6.3
R26 FFP Moac	3.2	6.1	4690	< 10	2.8	839	128	< 0.05	< 0.5	7.7
R26 T1	2.8	21.4	3870	93	2.3	596	141	< 0.05	< 0.5	5.1
R26 T2	2.8	30.7	3750	24	2.2	694	149	< 0.05	< 0.5	5.7
R26 T3	2.9	26.2	4680	< 10	2.6	779	138	< 0.05	< 0.5	6.8
Vernonburg Moac 1	3	149	10800	70	2.5	755	4540	< 0.05	0.7	8.7
Vernonburg Moac 2	2.9	110	8080	26	2.2	652	1200	0.40	0.7	10.6
Vernonburg Moac 3	2.7	255	5470	16	2.7	807	697	0.15	< 0.5	6.6
Jeephill Moac 1	2.3	35.8	4020	< 10	2.2	601	78.8	< 0.05	< 0.5	6.9
Jeephill Moac 2	2.2	10.2	3910	< 10	< 2.0	457	85.1	< 0.05	< 0.5	6.4
Jeephill Moac 3	2	11.1	4080	< 10	< 2.0	498	69.5	< 0.05	< 0.5	6.1
Jeephill crater	1.9	15.2	3210	< 10	< 2.0	501	68.8	< 0.05	< 0.5	4.3
A3A-LS-40% Crater	2.2	9	3730	< 10	2	552	102	< 0.05	< 0.5	5.2

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 T 1-3 A	3.1	1360	7550	66100	3.1	1110	111	< 0.05	< 0.5	7.6
R1 T 1-3 B	3.9	125	9140	1350	3.6	1440	181	< 0.05	< 0.5	9.5
R1 T 1-3 C	5.9	331	13500	7460	5.5	2870	340	0.07	< 0.5	16
R1 T 4-6 A	3.1	1300	6870	36700	2.7	1010	103	< 0.05	< 0.5	7.4
R1 T 4-6 B	3.5	102	7820	110	3.3	1100	113	< 0.05	< 0.5	8.2
R1 T 4-6 B DUP	3.0	92.8	7290	728	3.1	1070	104	< 0.05	< 0.5	7.7
R1 T 4-6 C	3.6	35	8140	372	3.3	1260	112	< 0.05	0.5	8.4
R1 T 7-9 A	3.1	6740	7150	16300	2.7	959	108	0.15	< 0.5	7.5
R1 T 7-9 B	3.1	55.1	7650	616	3.1	1070	109	< 0.05	< 0.5	7.4
R1 T 7-9 C	2.8	14.7	7230	78	2.9	929	93.5	< 0.05	< 0.5	7.3
R1 T 10-12 A	3.2	500	7500	4310	3.1	1020	117	0.85	< 0.5	8
R1 T 10-12 B	2.9	24.6	7170	113	2.7	789	37.4	< 0.05	< 0.5	6.2
R1 T 10-12 C	2.5	8.3	5790	46	2.3	766	73.6	< 0.05	< 0.5	4.9
R1 FP 100 T 1-3	3.8	92.9	5640	100	3.2	979	192	< 0.05	< 0.5	7.1
R1 FP 100 T 4-6	3.9	95.4	6960	125	3.5	1080	222	< 0.05	< 0.5	8.1
R1 FP 100 T 7-9	4	71.5	7750	73	3.7	1070	227	< 0.05	< 0.5	7.8

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 FP 100 T 10-12	4	44.3	7960	43	3.7	1110	228	< 0.05	< 0.5	7.8
R1 FP 100 T 10-12 DUP	3.8	49.4	7060	55	3.4	1040	238	< 0.05	< 0.5	7.3
R1 FP 200 T 1-3	4.8	39.6	9750	33	5.1	1510	275	< 0.05	< 0.5	10.6
R1 FP 200 T 4-6	5	53	9110	67	4.6	1460	278	< 0.05	< 0.5	10
R1 FP 200 T 4-6 DUP	3.1	44.3	4810	46	2.9	916	179	< 0.05	< 0.5	6.6
R1 FP 200 T 7-9	3.9	62.1	6640	261	3.4	1150	184	< 0.05	< 0.5	7.8
R1 FP 200 T 10-12	1.1	4.5	1820	< 10	< 2.0	325	57.3	< 0.05	< 0.5	2.2
R8 T 1-4 A	8.1	151	17700	940	9.6	5680	407	< 0.05	0.5	21
R8 T 1-4 A DUP	9.1	171	14800	1110	10.2	6290	362	< 0.05	< 0.5	21.8
R8 T1-4 B	10.1	61.5	17200	254	11.9	6180	521	< 0.05	< 0.5	25.4
R8 T1-4 C	8.2	18.1	18500	43	10.6	5050	432	< 0.05	< 0.5	19.9
R8 T 5-8 A	9.8	208	16000	3230	12.2	6710	423	< 0.05	< 0.5	23.9
R8 T 5-8 B	9.9	195	16300	1080	11.4	6730	513	< 0.05	< 0.5	25.5
R8 T 5-8 C	11.1	22.1	20100	32	14.9	7620	552	< 0.05	< 0.5	29.7
R8 T 9-12 A	9.6	161	15300	1690	11.4	6550	416	< 0.05	< 0.5	23.1

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 T 9-12 B	10	105	15800	606	12.6	6460	427	< 0.05	< 0.5	23.8
R8 T 9-12 C	8.7	17.4	20400	41	11.1	5360	478	< 0.05	< 0.5	21.5
R8 T 13-16 A	12.2	21900	19100	1170	132.9	7780	482	< 0.05	< 0.5	28.9
R8 T 13-16 B	10.6	98.2	19300	955	14.1	7680	466	< 0.05	< 0.5	27.6
R8 T 13-16 B DUP	10.5	84.3	17600	894	12.3	7170	470	< 0.05	< 0.5	27
R8 T 13-16 C	9.1	26.5	16400	622	11.8	6000	421	< 0.05	< 0.5	21.6
R8 T 17-20 A	10.3	147	16900	628	13.1	6520	466	< 0.05	< 0.5	24.4
R8 T 17-20 B	8.6	60.6	17000	331	9.2	5750	410	< 0.05	< 0.5	20.2
R8 T 17-20 C	9.3	15.2	16600	22	9.7	5070	484	< 0.05	< 0.5	22.6
R8 T 21-24 A	9.5	118	15400	402	11.7	5940	396	0.06	< 0.5	22.7
R8 T 21-24 B	10.3	52.4	15800	441	12.3	6670	427	< 0.05	< 0.5	24.1
R8 T 21-24 C	7.3	28	16700	113	8.7	5090	389	< 0.05	< 0.5	17.9
R8 FP 100 T 1-4	5.8	157	10500	129	4.9	2160	391	< 0.05	< 0.5	13
R8 FP 100 T 5-8	5.6	125	9660	119	5.1	1950	331	< 0.05	< 0.5	12.1
R8 FP 100 T 9-12	7.9	170	13100	202	6.7	2380	482	< 0.05	0.6	15.1
R8 FP 100 T 9-12 DUP	8.7	226	14900	193	7.6	2700	606	< 0.05	0.7	17.3

Table C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 FP 100 T 13-16	6.2	**200**	11300	**185**	5.6	1940	393	< 0.05	0.5	13.4
R8 FP 100 T 17-20	7	**259**	12200	**185**	6.3	2150	457	< 0.05	0.7	13.5
R8 FP 100 T 21-24	7.1	**111**	13100	**96**	6	1840	445	< 0.05	0.8	12.8
R8 FP 200 T 1-4	7.2	**209**	13300	**167**	7	2660	490	< 0.05	0.6	15.4
R8 FP 200 T 5-8	7.4	**175**	13500	**164**	**7.6**	3070	476	< 0.05	< 0.5	15.9
R8 FP 200 T 9-12	**7.9**	**137**	14400	**112**	**7.9**	3180	553	< 0.05	0.6	**17.6**
R8 FP 200 T 9-12 DUP	7.7	**138**	13500	**115**	7.4	2890	504	< 0.05	< 0.5	16.3
R8 FP 200 T 13-16	**8.1**	**104**	15100	**128**	**9.7**	**4540**	457	< 0.05	0.5	**18.8**
R8 FP 200 T 17-20	**9.4**	**77.9**	17100	**46**	**11**	**4410**	535	< 0.05	0.6	**20.8**
R8 FP 200 T 21-24	**8**	**58**	15500	30	**10.4**	**4120**	469	< 0.05	0.5	**18.4**
R24 FP 10	4.4	8.6	9750	< 10	4.8	2550	270	< 0.05	< 0.5	12
R24 FP 15	6.6	**13.7**	13200	< 10	6.6	3350	401	< 0.05	0.5	16.4
R24 FP 20	7.6	**17.6**	15400	10	**7.8**	**4410**	425	< 0.05	0.5	**19.4**

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

7able C2. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R24 FP 25	5.9	**12.1**	12000	12	5.9	2970	335	< 0.05	< 0.5	15.1
R24-BermA-Moac	7.1	**12.6**	14700	25	6.8	3760	415	< 0.05	< 0.5	17
R24-BermBT-Moac	3.9	**246**	13100	**6720**	2.8	**6400**	428	< 0.05	< 0.5	9
R13 T1	**8.1**	**10400**	**55500**	**447**	2.8	1150	**757**	< 0.05	**105**	**253**
R13 T1 DUP	7	**4700**	**29700**	**292**	6.1	1800	458	< 0.05	**44.1**	**93.7**
R13 T2	6.3	**1820**	**22200**	**147**	6.3	2200	359	< 0.05	**21.8**	**55.2**
R13 T3-close	**8.7**	**4170**	**23300**	**863**	6.7	2690	476	< 0.05	**20.3**	**83.7**
R13 T3-far	**8.3**	**445**	13500	34	**7.9**	2990	298	< 0.05	1.1	23
R13 T4	6.5	**488**	11400	**54**	7.2	1880	158	< 0.05	1.5	**18.9**
R22 T1	4.9	**1680**	12300	**97**	3.9	1910	244	< 0.05	**6.8**	**54.1**
R22 T2	4.4	**837**	8440	**488**	2.2	842	220	< 0.05	**5**	**26.8**
R22 T3	2.8	**950**	8390	**777**	< 2.0	810	188	< 0.05	**2.5**	**29.3**
R22 T4	**11.3**	**691**	**22700**	**1810**	**11.3**	**4200**	547	< 0.05	**4.4**	**51.2**

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Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C3. *Concentrations of various metals in soil determined by ICP-MS.*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R2 A	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0
R2 B	328	1080	8.4	< 0.5	0.07	< 100	26	-	< 5.0
R2 C	337	1150	9.7	< 0.5	0.07	< 100	26	-	< 5.0
R2 D	394	1370	9.6	< 0.5	0.07	< 100	28.8	-	< 5.0
R2 E	389	1180	8.8	< 0.5	0.05	109	25.9	-	< 5.0
R2 F	367	1160	8.2	< 0.5	0.06	< 100	24.8	-	< 5.0
R2 0-5	349	961	6.9	< 0.5	< 0.05	< 100	24	-	< 5.0
R2 5-10	349	1050	7.8	< 0.5	0.05	< 100	23.3	-	< 5.0
R2 10-15	315	927	6.8	< 0.5	< 0.05	175	24.2	-	< 5.0
R2 10-15 DUP	315	1020	7.3	< 0.5	0.06	189	24.8	-	< 5.0
R2 15-20	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0
R2 20-25	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0
R2 25-30	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0
R2 30-35	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0
R2 35-40	< 10	< 100	< 0.5	< 0.5	< 0.05	< 100	< 0.1	-	< 5.0

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Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R12 T1	**937**	**2720**	**13.9**	< 0.5	0.17	< 100	27	-	< 5.0
R12 T2	**1980**	1850	7.3	< 0.5	0.05	< 100	22.4	-	< 5.0
R12 T3	**1050**	1630	7.3	< 0.5	< 0.05	< 100	19	-	< 5.0
R12 HS 0504070-5845925	**30000**	1170	6.5	< 0.5	< 0.05	< 100	21.5	-	< 5.0
R12 Crater near T1	575	**2450**	**16.2**	< 0.5	0.1	< 100	30.7	-	< 5.0
R14 DS-1 Moac 1	330	961	5.5	< 0.5	< 0.05	< 100	12.6	-	< 5.0
R14 DS-1 Moac 2	308	921	5.1	< 0.5	< 0.05	< 100	12.5	-	< 5.0
R14 DS-1 Moac 3	274	858	5.3	< 0.5	< 0.05	< 100	11.9	-	< 5.0
R14 DS-2 Moac 1	223	719	4.7	< 0.5	< 0.05	< 100	15.2	-	< 5.0
R14 DS-2 Moac 2	274	822	5.1	< 0.5	< 0.05	< 100	18.8	-	< 5.0
R14 DS-2 Moac 3	233	778	5.5	< 0.5	< 0.05	< 100	21.5	-	< 5.0
R14 DS-3 Moac 1	224	860	4.4	< 0.5	< 0.05	< 100	13.9	-	< 5.0
R14 DS-3 Moac 2	269	894	4.7	< 0.5	< 0.05	< 100	14.9	-	< 5.0
R14 DS-3 Moac 3	231	840	4.3	< 0.5	< 0.05	< 100	12.9	-	< 5.0
R14 DS-4 Moac 1	238	917	4.7	< 0.5	< 0.05	< 100	13.9	-	< 5.0

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Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R14 DS-4 Moac 2	301	1000	4.3	< 0.5	< 0.05	< 100	15.7	-	< 5.0
R14 DS-4 Moac 3	240	912	4.1	< 0.5	< 0.05	< 100	14.5	-	< 5.0
R14 DS-5 Moac	331	1000	4.3	< 0.5	< 0.05	< 100	16.5	-	< 5.0
R16 FP 1 0-10	229	488	3.1	< 0.5	< 0.05	< 100	6.5	-	< 5.0
R16 FP 1 10-20	218	442	2.9	< 0.5	< 0.05	< 100	7.7	-	< 5.0
R16 FP 1 10-20 DUP	217	404	2.6	< 0.5	< 0.05	< 100	7	-	< 5.0
R16 FP 1 20-30	176	391	2.4	< 0.5	< 0.05	< 100	6.1	-	< 5.0
R16 FP 1 30-40	186	414	2.5	< 0.5	< 0.05	< 100	7	-	< 5.0
R16 FP 1 40-50	181	375	2.4	< 0.5	< 0.05	< 100	5.6	-	< 5.0
R16 FP 2 0-10	172	283	1.9	< 0.5	< 0.05	< 100	6.3	-	< 5.0
R16 FP 2 0-10 DUP	148	219	1.5	< 0.5	< 0.05	< 100	3.9	-	< 5.0
R16 FP 2 10-20	162	280	1.5	< 0.5	< 0.05	< 100	7.5	-	< 5.0
R16 FP 2 20-30	186	274	1.8	< 0.5	< 0.05	< 100	5.1	-	< 5.0
R16 FP 2 30-40	199	358	2	< 0.5	< 0.05	< 100	5.5	-	< 5.0
R16 FP 2 40-50	208	331	1.7	< 0.5	< 0.05	< 100	5.9	-	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R16 FP 2 HS	247	391	2.5	< 0.5	< 0.05	171	9.8	-	< 5.0
R16 MT Berm 1-A	252	516	2.9	< 0.5	< 0.05	< 100	7.6	-	< 5.0
R16 MT Berm 1-B	320	637	3.5	< 0.5	< 0.05	< 100	9.3	-	< 5.0
R16 MT Berm 2-A	202	336	2.2	< 0.5	< 0.05	< 100	5.8	-	< 5.0
R16 MT Berm 2-B	190	349	2	< 0.5	< 0.05	< 100	5.6	-	< 5.0
R17 1	271	644	3.3	< 0.5	< 0.05	< 100	10.8	-	< 5.0
R17 2	336	765	3.9	< 0.5	< 0.05	< 100	12.3	-	< 5.0
R17 FC-A	151	368	3.3	< 0.5	0.15	< 100	5.1	-	< 5.0
R17 FC-B	132	434	3.6	< 0.5	**0.56**	< 100	7.8	-	< 5.0
R17 FC-C	130	423	3.6	< 0.5	< 0.05	< 100	6.8	-	< 5.0
R17 FC-D	147	407	3.7	< 0.5	< 0.05	< 100	6.6	-	< 5.0
R17 FC-E	192	434	2.9	< 0.5	< 0.05	< 100	5.2	-	< 5.0
R17 FC-F	225	474	3	< 0.5	< 0.05	< 100	6	-	< 5.0
R17 FC-G	220	395	2.7	< 0.5	< 0.05	< 100	6.1	-	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R21 In MP	240	543	3.5	< 0.5	< 0.05	< 100	6.8	-	< 5.0
R21 Out MP	209	565	3.1	< 0.5	< 0.05	< 100	6.2	-	< 5.0
R21 Line 1-In MP	210	381	2.7	< 0.5	< 0.05	108	6.1	-	< 5.0
R21 Line 1-In MP DUP	176	366	2.5	< 0.5	< 0.05	118	6.2	-	< 5.0
R21 Line 1-Out MP	202	414	2.1	< 0.5	< 0.05	< 100	8.1	-	< 5.0
R21 Line 2	147	355	2.1	< 0.5	< 0.05	< 100	5.5	-	< 5.0
R21 Line 3	372	354	2	< 0.5	< 0.05	< 100	10.9	-	< 5.0
R21 Line 3 DUP	185	402	2.2	< 0.5	< 0.05	< 100	6	-	< 5.0
R21 Line 4	215	420	2.5	< 0.5	< 0.05	< 100	8.5	-	< 5.0
R21 Line 5	241	343	2	< 0.5	< 0.05	< 100	4.5	-	< 5.0
R21 Line 6	225	480	2.6	< 0.5	< 0.05	< 100	6.5	-	< 5.0
R21 T1	251	761	3.6	< 0.5	< 0.05	< 100	6.1	-	< 5.0
R21 T2	406	834	3.9	< 0.5	< 0.05	< 100	9.2	-	< 5.0
R21 T3	361	854	3.8	< 0.5	0.17	< 100	21.6	-	< 5.0
R21 Trench A	207	548	3.1	< 0.5	< 0.05	< 100	7.8	-	< 5.0
R21 Trench B	303	493	2.9	< 0.5	< 0.05	< 100	8.6	-	< 5.0

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Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R26 BFP Moac	203	561	3	< 0.5	< 0.05	< 100	6	-	< 5.0
R26 FFP Moac	222	520	3	< 0.5	< 0.05	< 100	6.2	-	< 5.0
R26 T1	205	563	3.2	< 0.5	< 0.05	< 100	6.6	-	< 5.0
R26 T2	274	661	2.8	< 0.5	< 0.05	< 100	7.8	-	< 5.0
R26 T3	317	740	3.3	< 0.5	< 0.05	< 100	7.2	-	< 5.0
Vernonburg Moac 1	404	648	3.2	< 0.5	0.05	< 100	6.8	-	< 5.0
Vernonburg Moac 2	332	501	2.2	< 0.5	< 0.05	< 100	5.7	-	< 5.0
Vernonburg Moac 3	321	577	2.7	< 0.5	< 0.05	< 100	6.1	-	< 5.0
Jeephill Moac 1	140	333	2	< 0.5	0.06	< 100	5.6	-	< 5.0
Jeephill Moac 2	124	271	1.6	< 0.5	< 0.05	< 100	4.5	-	< 5.0
Jeephill Moac 3	137	291	1.6	< 0.5	< 0.05	< 100	5.1	-	< 5.0
Jeephill crater	157	383	2.2	< 0.5	< 0.05	< 100	6	-	< 5.0
A3A-LS-40% Crater	197	421	2.2	< 0.5	< 0.05	< 100	5.1	-	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 T 1-3 A	208	757	4.1	< 0.5	**2.34**	< 100	21	-	< 5.0
R1 T 1-3 B	250	649	4.8	< 0.5	0.12	< 100	9.5	-	< 5.0
R1 T 1-3 C	339	921	7.2	< 0.5	0.08	< 100	20.8	-	< 5.0
R1 T 4-6 A	256	665	3.7	< 0.5	**2.27**	< 100	9.6	-	< 5.0
R1 T 4-6 B	219	543	4.3	< 0.5	0.1	< 100	17.5	-	< 5.0
R1 T 4-6 B DUP	200	495	3.5	< 0.5	0.07	< 100	6.6	-	< 5.0
R1 T 4-6 C	205	472	4	< 0.5	< 0.05	134	8.3	-	< 5.0
R1 T 7-9 A	232	641	3.3	< 0.5	**0.74**	< 100	8.8	-	< 5.0
R1 T 7-9 B	223	576	4.4	< 0.5	0.05	< 100	7.8	-	< 5.0
R1 T 7-9 C	208	433	3.4	< 0.5	< 0.05	< 100	6.3	-	< 5.0
R1 T 10-12 A	240	756	4.2	< 0.5	**0.27**	< 100	8.7	-	< 5.0
R1 T 10-12 B	200	472	3.3	< 0.5	< 0.05	< 100	5.9	-	< 5.0
R1 T 10-12 C	218	396	2.8	< 0.5	< 0.05	< 100	4.7	-	< 5.0
R1 FP 100 T 1-3	318	1060	4.7	< 0.5	< 0.05	< 100	9.1	-	< 5.0
R1 FP 100 T 4-6	360	1240	5.6	< 0.5	< 0.05	< 100	10.1	-	< 5.0
R1 FP 100 T 7-9	385	1130	5.5	< 0.5	< 0.05	< 100	11.1	-	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 FP 100 T 10-12	384	1190	5.5	< 0.5	< 0.05	< 100	11	-	< 5.0
R1 FP 100 T 10-12 DUP	464	1350	5.1	< 0.5	< 0.05	< 100	10.7	-	< 5.0
R1 FP 200 T 1-3	403	1550	7.7	< 0.5	< 0.05	< 100	14.7	-	< 5.0
R1 FP 200 T 4-6	427	1450	7.5	< 0.5	< 0.05	< 100	14.1	-	< 5.0
R1 FP 200 T 4-6 DUP	312	1040	4.6	< 0.5	< 0.05	< 100	7.7	-	< 5.0
R1 FP 200 T 7-9	348	1070	5.4	< 0.5	< 0.05	< 100	10	-	< 5.0
R1 FP 200 T 10-12	139	221	1.4	< 0.5	< 0.05	< 100	2.7	-	< 5.0
R8 T 1-4 A	326	1060	9.9	< 0.5	0.1	< 100	51.2	< 100	< 5.0
R8 T 1-4 A DUP	412	1040	9.3	< 0.5	0.15	< 100	59.8	< 100	< 5.0
R8 T1-4 B	520	1470	11.4	< 0.5	0.11	< 100	53.6	< 100	< 5.0
R8 T1-4 C	360	1180	9.7	< 0.5	0.08	< 100	39.1	< 100	< 5.0
R8 T 5-8 A	466	1150	10.8	< 0.5	0.19	< 100	62.4	< 100	< 5.0
R8 T 5-8 B	465	1300	10.8	< 0.5	0.15	< 100	56.9	< 100	< 5.0
R8 T 5-8 C	510	1560	12.2	< 0.5	0.1	134	62.3	< 100	< 5.0
R8 T 9-12 A	457	1130	9.6	< 0.5	0.15	< 100	53.7	< 100	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 T 9-12 B	447	1120	10.5	< 0.5	0.12	< 100	52.7	< 100	< 5.0
R8 T 9-12 C	400	1310	10	< 0.5	0.08	< 100	42.3	< 100	< 5.0
R8 T 13-16 A	513	1410	12.1	< 0.5	0.63	< 100	65.9	< 100	< 5.0
R8 T 13-16 B	476	1370	12.5	< 0.5	0.14	< 100	58.7	< 100	< 5.0
R8 T 13-16 B DUP	465	1200	11.4	< 0.5	0.14	< 100	59.5	< 100	< 5.0
R8 T 13-16 C	494	1340	9.5	< 0.5	0.09	< 100	45.9	< 100	< 5.0
R8 T 17-20 A	479	1390	12	< 0.5	0.12	< 100	68.3	< 100	< 5.0
R8 T 17-20 B	381	1080	9.9	< 0.5	0.09	< 100	43.6	< 100	< 5.0
R8 T 17-20 C	404	1300	9.6	< 0.5	0.09	< 100	39.4	< 100	< 5.0
R8 T 21-24 A	442	1110	9.9	< 0.5	0.11	< 100	58.5	< 100	< 5.0
R8 T 21-24 B	448	1090	10.3	< 0.5	0.12	< 100	53.7	< 100	< 5.0
R8 T 21-24 C	333	994	8	< 0.5	0.07	< 100	35	< 100	< 5.0
R8 FP 100 T 1-4	645	1690	6.7	< 0.5	0.06	< 100	25.8	-	< 5.0
R8 FP 100 T 5-8	583	1490	6.4	< 0.5	0.06	< 100	22.8	-	< 5.0
R8 FP 100 T 9-12	878	2040	9.2	< 0.5	0.08	< 100	29.4	-	< 5.0
R8 FP 100 T 9-12 DUP	957	2400	10.4	< 0.5	0.08	< 100	32.3	-	< 5.0

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 FP 100 T 13-16	**774**	**1970**	8.3	0.5	0.07	< 100	21	-	< 5.0
R8 FP 100 T 17-20	**1000**	**2400**	9	< 0.5	0.08	< 100	24.7	-	< 5.0
R8 FP 100 T 21-24	**1080**	**2640**	10.6	< 0.5	0.07	< 100	21.7	-	< 5.0
R8 FP 200 T 1-4	755	1940	9.1	< 0.5	0.08	< 100	26.2	-	< 5.0
R8 FP 200 T 5-8	758	**1980**	9.2	< 0.5	0.07	< 100	31.2	-	< 5.0
R8 FP 200 T 9-12	**813**	**1980**	9.4	< 0.5	0.08	< 100	37	-	< 5.0
R8 FP 200 T 9-12 DUP	724	1910	9.1	< 0.5	0.08	< 100	31.6	-	< 5.0
R8 FP 200 T 13-16	714	1850	10.5	< 0.5	0.1	< 100	45.2	-	< 5.0
R8 FP 100 T 17-20	**824**	**2460**	**11.9**	< 0.5	0.1	< 100	41.2	-	< 5.0
R8 FP 100 T 21-24	718	**2220**	**11.3**	< 0.5	0.08	< 100	40	-	< 5.0
								-	< 5.0
R24 FP 10	457	778	< 0.5	< 0.5	0.06	< 100	19	-	< 5.0
R24 FP 15	656	1190	5.9	0.9	0.08	< 100	26.4	-	< 5.0
R24 FP 20	**1040**	1540	7.4	< 0.5	0.1	< 100	31.6	-	< 5.0

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C3. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R24 FP 25	608	1160	5.9	< 0.5	0.07	< 100	27.6	-	< 5.0
R24-BermA-Moac	550	1420	7.1	< 0.5	0.07	< 100	38.6	-	< 5.0
R24-BermBT-Moac	316	524	3.4	< 0.5	0.17	121	20.8	-	< 5.0
R13 T1	200	564	3.1	< 0.5	**14.1**	< 100	34	-	< 5.0
R13 T1 DUP	315	1200	6	< 0.5	**13**	< 100	54.2	-	< 5.0
R13 T2	274	1090	7.1	< 0.5	**4.63**	< 100	37.8	-	< 5.0
R13 T3-close	321	1270	7.5	< 0.5	**11.1**	< 100	40.3	-	< 5.0
R13 T3-far	435	1400	8	< 0.5	**2.56**	< 100	30.6	-	< 5.0
R13 T4	326	1300	6.5	< 0.5	**1.46**	< 100	59.2	-	< 5.0
R22 T1	393	842	3.5	< 0.5	**4.73**	255	54.9	-	< 5.0
R22 T2	347	772	3.9	< 0.5	**5.06**	< 100	31.7	-	< 5.0
R22 T3	302	582	2.5	< 0.5	**1.71**	< 100	39.3	-	< 5.0
R22 T4	622	1630	**12.2**	< 0.5	**0.5**	112	74.6	-	< 5.0

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS.*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***
R2 A	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5
R2 B	< 1	0.5	56	0.4	19	**689**	2.8
R2 C	< 1	0.4	57	0.4	21	**426**	2.8
R2 D	< 1	0.8	69	0.6	21	**1020**	3
R2 E	< 1	0.7	77	0.5	19	**801**	3.3
R2 F	< 1	0.4	60	0.4	17	**688**	2.7
R2 0-5	< 1	0.3	50	0.4	15	**401**	2.4
R2 5-10	< 1	0.9	60	0.5	16	**797**	2.8
R2 10-15	< 1	0.6	49	0.5	15	**637**	1.9
R2 10-15 DUP	< 1	0.6	54	0.5	16	**746**	2.4
R2 15-20	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5
R2 20-25	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5
R2 25-30	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5
R2 30-35	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5
R2 35-40	< 1	< 0.1	< 1	< 0.2	< 2	< 0.5	< 0.5

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R12 T1	< 1	1.9	91	0.6	30	101	4.2
R12 T2	< 1	3.6	68	0.6	17	289	2.8
R12 T3	< 1	0.5	60	0.5	14	134	2.3
R12 HS 0504070-5845925	< 1	1.4	61	0.4	13	586	1.2
R12 Crater near T1	< 1	0.8	100	0.7	36	115	4.6
R14 DS-1 Moac 1	< 1	0.3	48	0.3	13	30.5	2.1
R14 DS-1 Moac 2	< 1	0.2	37	0.3	12	33.6	2.2
R14 DS-1 Moac 3	< 1	0.2	40	0.4	13	27.7	1.8
R14 DS-2 Moac 1	< 1	0.2	39	0.3	11	27.6	1.3
R14 DS-2 Moac 2	< 1	0.2	40	0.4	12	33.2	1.9
R14 DS-2 Moac 3	< 1	0.1	44	0.4	13	28.8	1.4
R14 DS-3 Moac 1	< 1	0.5	43	0.3	10	53.2	1.3
R14 DS-3 Moac 2	< 1	0.5	41	0.3	10	66	1.6
R14 DS-3 Moac 3	< 1	0.4	43	0.3	10	54.2	1.4
R14 DS-4 Moac 1	< 1	0.8	47	0.3	10	63.9	1.4

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R14 DS-4 Moac 2	< 1	0.5	51	0.3	11	63.5	1.4
R14 DS-4 Moac 3	< 1	0.5	42	0.2	9	**77.2**	1.5
R14 DS-5 Moac	< 1	0.2	36	0.3	9	**101**	2
R16 FP 1 0-10	< 1	2.3	26	0.3	6	45.9	0.9
R16 FP 1 10-20	< 1	1.6	24	0.2	7	41.4	0.7
R16 FP 1 10-20 DUP	< 1	2.9	24	0.2	5	**91.9**	0.7
R16 FP 1 20-30	< 1	1.1	27	0.2	6	29.6	0.6
R16 FP 1 30-40	< 1	0.9	31	0.2	7	41	0.6
R16 FP 1 40-50	< 1	0.8	27	0.2	7	28.9	0.5
R16 FP 2 0-10	< 1	2	34	0.3	6	36.5	0.8
R16 FP 2 0-10 DUP	< 1	0.8	23	< 0.2	5	25.2	< 0.5
R16 FP 2 10-20	< 1	0.7	28	0.2	5	44.4	0.5
R16 FP 2 20-30	< 1	0.5	35	0.2	5	25.8	0.6
R16 FP 2 30-40	< 1	0.8	38	< 0.2	6	21.8	0.8
R16 FP 2 40-50	< 1	1.1	29	0.2	6	28.2	0.6

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R16 FP 2 HS	< 1	2.3	61	0.3	9	**206**	0.9
R16 MT Berm 1-A	< 1	0.4	35	0.2	7	34.8	1.2
R16 MT Berm 1-B	< 1	0.5	44	< 0.2	8	**71.9**	1.8
R16 MT Berm 2-A	< 1	0.7	35	0.2	7	28.4	0.7
R16 MT Berm 2-B	< 1	0.3	27	< 0.2	6	25.8	0.8
R17 1	< 1	1.4	42	0.3	8	**162**	0.8
R17 2	< 1	0.2	39	0.3	9	**126**	1.1
R17 FC-A	< 1	0.6	33	< 0.2	6	**66.6**	< 0.5
R17 FC-B	< 1	1.4	33	0.3	10	54.3	< 0.5
R17 FC-C	< 1	0.9	30	0.3	9	51.9	< 0.5
R17 FC-D	< 1	0.7	24	0.4	12	52.5	0.6
R17 FC-E	< 1	0.4	31	< 0.2	7	55	0.5
R17 FC-F	< 1	0.4	31	0.2	8	58.3	0.5
R17 FC-G	< 1	0.3	32	0.2	8	54.2	0.5

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R21 In MP	< 1	0.2	36	0.3	10	59.2	1.3
R21 Out MP	< 1	0.1	24	0.2	8	23.8	1
R21 Line 1-In MP	< 1	0.1	35	0.3	7	54.9	0.9
R21 Line 1-In MP DUP	< 1	0.1	33	0.2	7	59.5	0.8
R21 Line 1-Out MP	< 1	< 0.1	32	0.2	6	22.1	< 0.5
R21 Line 2	< 1	0.2	23	< 0.2	6	18.5	< 0.5
R21 Line 3	< 1	0.3	32	0.3	6	52.8	0.9
R21 Line 3 DUP	< 1	0.1	36	0.2	7	54.7	0.9
R21 Line 4	< 1	0.4	28	0.2	6	59.4	0.8
R21 Line 5	< 1	< 0.1	24	0.2	8	58.2	0.7
R21 Line 6	< 1	0.1	33	0.2	8	**65.1**	0.8
R21 T1	< 1	0.8	37	0.2	7	**86.3**	0.9
R21 T2	< 1	0.4	36	0.3	8	**117**	1.2
R21 T3	< 1	2.2	40	0.3	8	**118**	1.3
R21 Trench A	< 1	0.6	35	0.3	7	58.7	0.7
R21 Trench B	< 1	0.5	28	0.3	7	63.5	0.8

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R26 BFP Moac	< 1	0.2	26	< 0.2	7	21.1	0.8
R26 FFP Moac	< 1	0.6	25	0.3	8	27.4	1
R26 T1	< 1	0.9	24	0.2	6	62.2	0.7
R26 T2	< 1	0.4	25	0.2	6	38.1	0.7
R26 T3	< 1	0.8	40	0.3	8	**65.1**	1
Vernonburg Moac 1	< 1	**19**	41	0.2	7	**7110**	0.6
Vernonburg Moac 2	< 1	**4.5**	28	< 0.2	6	**7220**	0.6
Vernonburg Moac 3	< 1	**6.6**	31	0.2	7	**623**	0.7
Jeephill Moac 1	< 1	1.2	23	< 0.2	6	**70.5**	0.6
Jeephill Moac 2	< 1	0.5	29	< 0.2	5	46.7	0.7
Jeephill Moac 3	< 1	0.4	22	< 0.2	6	51	0.6
Jeephill crater	< 1	0.5	25	< 0.2	6	41.1	< 0.5
A3A-LS-40% Crater	< 1	0.3	25	< 0.2	6	**595**	0.6

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 T 1-3 A	< 1	57.4	50	0.2	10	190	< 0.5
R1 T 1-3 B	< 1	1.4	37	0.3	11	53.6	0.6
R1 T 1-3 C	< 1	0.6	44	0.4	15	117	1.1
R1 T 4-6 A	< 1	26	46	0.2	9	169	< 0.5
R1 T 4-6 B	< 1	0.8	52	0.3	10	46.2	0.6
R1 T 4-6 B DUP	< 1	2.1	31	0.2	9	40.9	3
R1 T 4-6 C	< 1	3.3	35	0.2	9	41.2	0.6
R1 T 7-9 A	< 1	7.5	34	0.2	9	715	0.5
R1 T 7-9 B	< 1	1	57	0.3	10	41.3	< 0.5
R1 T 7-9 C	< 1	0.3	39	0.2	9	61.5	< 0.5
R1 T 10-12 A	< 1	4.6	52	0.2	11	88.4	< 0.5
R1 T 10-12 B	< 1	1.5	31	0.2	9	35.2	< 0.5
R1 T 10-12 C	< 1	0.8	32	< 0.2	8	30.5	< 0.5
R1 FP 100 T 1-3	< 1	1.5	40	0.4	9	48.5	1.5
R1 FP 100 T 4-6	< 1	1.5	49	0.4	11	53.4	1.6
R1 FP 100 T 7-9	< 1	1.2	53	0.4	12	47.1	1.6

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R1 FP 100 T 10-12	< 1	1.1	53	0.4	12	46.3	1.5
R1 FP 100 T 10-12 DUP	< 1	0.9	53	0.4	10	57.7	1.4
R1 FP 200 T 1-3	< 1	1	62	0.5	15	53.1	2.3
R1 FP 200 T 4-6	< 1	1.2	60	0.6	14	52.9	2
R1 FP 200 T 4-6 DUP	< 1	0.9	41	0.3	8	46	1.1
R1 FP 200 T 7-9	< 1	0.5	48	0.3	11	39	1.8
R1 FP 200 T 10-12	< 1	0.1	17	< 0.2	3	11.2	< 0.5
R8 T 1-4 A	< 1	0.8	47	**0.8**	22	**66.9**	1.6
R8 T 1-4 A DUP	< 1	0.2	48	**0.9**	21	**79**	2.9
R8 T1-4 B	< 1	< 0.1	58	**0.9**	**24**	**81.7**	**4.5**
R8 T1-4 C	< 1	0.4	51	0.7	22	52.3	2.3
R8 T 5-8 A	< 1	1.7	57	**0.9**	**24**	**92**	3.3
R8 T 5-8 B	< 1	0.3	58	**1**	**25**	**96.4**	**3.7**
R8 T 5-8 C	< 1	< 0.1	80	**1.1**	**30**	**88.4**	**4.1**
R8 T 9-12 A	< 1	0.2	52	**0.9**	22	**82.1**	3

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 T 9-12 B	< 1	< 0.1	51	1	22	77.1	4.6
R8 T 9-12 C	< 1	0.5	55	0.7	23	66.5	1.7
R8 T 13-16 A	< 1	0.7	61	1.1	28	2750	3.6
R8 T 13-16 B	< 1	< 0.1	67	1	29	85.6	4
R8 T 13-16 B DUP	< 1	< 0.1	56	1	26	84.9	3.5
R8 T 13-16 C	< 1	< 0.1	65	1	22	123	2.8
R8 T 17-20 A	< 1	< 0.1	63	1	25	88.3	3.9
R8 T 17-20 B	< 1	0.6	54	0.8	22	54.1	2.2
R8 T 17-20 C	< 1	< 0.1	54	0.6	24	77.7	3.5
R8 T 21-24 A	< 1	< 0.1	51	0.9	21	77.2	3.2
R8 T 21-24 B	< 1	< 0.1	52	0.9	23	71.3	3.1
R8 T 21-24 C	< 1	0.4	45	0.7	19	97.2	1.8
R8 FP 100 T 1-4	< 1	1.9	60	0.5	15	101	3.1
R8 FP 100 T 5-8	< 1	1.4	55	0.6	14	62.6	2.7
R8 FP 100 T 9-12	< 1	2.4	83	0.7	20	116	4.6
R8 FP 100 T 9-12 DUP	< 1	2.9	87	0.8	23	129	4.9

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R8 FP 100 T 13-16	< 1	2.8	80	0.7	17	**118**	3.2
R8 FP 100 T 17-20	< 1	3.6	82	0.7	20	**124**	**3.5**
R8 FP 100 T 21-24	< 1	1.3	99	0.6	22	**87.5**	3.3
R8 FP 200 T 1-4	< 1	3	78	**0.9**	19	**118**	**3.9**
R8 FP 200 T 5-8	< 1	1.8	73	0.7	20	**79.9**	**3.7**
R8 FP 200 T 9-12	< 1	2.2	76	**1**	20	**113**	**4.5**
R8 FP 200 T 9-12 DUP	< 1	1.9	75	**0.8**	20	**111**	**4.5**
R8 FP 200 T 13-16	< 1	1.1	70	**1**	22	**75.1**	**4.3**
R8 FP 200 T 17-20	< 1	1.1	87	**1**	**26**	**112**	**5.1**
R8 FP 200 T 21-24	< 1	0.9	86	**0.9**	**26**	**99.4**	**4.3**
R24 FP 10	< 1	0.4	24	0.6	12	45.7	1.4
R24 FP 15	< 1	1.5	36	0.7	17	**68.7**	2.5
R24 FP 20	< 1	0.4	41	0.7	21	**76.7**	**3.6**

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

Table C4. *Concentrations of various metals in soil determined by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
R24 FP 25	< 1	1.1	35	0.6	16	**69.8**	2.4
R24-BermA-Moac	< 1	0.5	53	0.7	17	43.1	2.6
R24-BermBT-Moac	< 1	1.7	85	0.4	8	24.8	< 0.5
R13 T1	< 1	**42.1**	74	0.4	17	**1190**	1.6
R13 T1 DUP	< 1	**30**	65	0.6	16	**760**	2.5
R13 T2	< 1	**11.8**	63	0.4	16	**412**	2.6
R13 T3-close	< 1	**189**	74	0.5	22	**811**	2.7
R13 T3-far	< 1	**5.4**	63	0.6	20	**144**	2.5
R13 T4	< 1	**17.4**	42	**0.8**	16	**258**	**3.5**
R22 T1	< 1	**5.5**	**295**	0.3	19	**302**	2.8
R22 T2	< 1	**7.8**	51	0.3	8	**303**	2
R22 T3	< 1	**10.3**	41	< 0.2	6	**530**	2.4
R22 T4	< 1	**6**	104	0.6	**29**	**848**	**5.4**

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts
Values in red: Results above the CCME threshold value for industrial soils are highlighted in red bold fonts

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Annex D □ Metal Concentrations in Biomass

Table D1. *Metal concentrations in biomass samples analyzed by ICP-MS.*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A2-R2	102	< 0.5	< 1	27.6	< 10	< 5.0	8	< 0.50	5520	4.5
B-R16-FP1-0-10	< 100	< 0.5	< 1	68.6	< 10	< 5.0	4.7	< 0.50	2900	2.6
B-R16-FP1-10-20	< 100	< 0.5	< 1	38.7	< 10	< 5.0	3.7	< 0.50	1960	2.4
B-R16-FP2-0-10	< 100	< 0.5	< 1	134	< 10	< 5.0	25.7	< 0.50	32200	2.3
B-R16-FP2-10-20	143	< 0.5	< 1	29.1	< 10	< 5.0	14.3	< 0.50	5900	2.4
B-R16 MT BERM1	< 100	< 0.5	< 1	30.6	< 10	< 5.0	13.5	< 0.50	3810	4.1
B-R16 MT BERM2	205	< 0.5	7	39.7	< 10	< 5.0	9	< 0.50	6350	6.1
B-A3A-R21-TARGETS	< 100	2.7	< 1	61.7	< 10	< 5.0	23.5	< 0.50	6530	3.9
B-A3A-R21-Trench	< 100	< 0.5	< 1	16.7	< 10	< 5.0	15.9	< 0.50	5510	4
B-A3A-R21-OUT (Front)	< 100	< 0.5	< 1	46.2	< 10	< 5.0	12.1	< 0.50	6110	3.7
B-A3A-R21-OUT (Back)	< 100	< 0.5	< 1	41	< 10	< 5.0	11.6	< 0.50	5640	3.6
B-A3A-R26-FP	< 100	< 0.5	< 1	30.7	< 10	< 5.0	3.5	< 0.50	3490	4.1
B-A3A-R26-T	< 100	< 0.5	< 1	31.7	< 10	< 5.0	4.6	< 0.50	3100	3.3
B-A3A-Vernonburg	< 100	< 0.5	1	61.8	< 10	< 5.0	33.5	1.61	19000	5.1
B-A3A-LS-40%-A	< 100	< 0.5	< 1	75.8	< 10	< 5.0	14.7	< 0.50	7500	3.9
B-A3A-LS-40%-B	< 100	< 0.5	< 1	68.2	< 10	< 5.0	21.6	< 0.50	10500	4.1

Table D1. *Metal concentrations in biomass samples analyzed by ICP-MS (continued).*

SAMPLE	ALUMINUM	ANTIMONY	ARSENIC	BARIUM	BERYLLIUM	BISMUTH	BORON	CADMIUM	CALCIUM	CHROMIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A1-R1-T-1-3	< 100	**3.2**	< 1	28.6	< 10	< 5.0	8.6	< 0.50	6940	1.7
B-A1-R1-T-1-3 DUP	< 100	< 0.5	< 1	12.1	< 10	< 5.0	10.8	< 0.50	2770	1.8
B-A1-R1-T-4-6	< 100	**3.5**	< 1	48.2	< 10	< 5.0	29.2	< 0.50	12000	2
B-A1-R1-T-7-9	112	**5.2**	< 1	20.5	< 10	< 5.0	6.2	< 0.50	1880	2.3
B-A1-R1-T-10-12	< 100	< 0.5	< 1	12	< 10	< 5.0	6.2	< 0.50	1640	1.9
B-A2-R8-T-1-4	< 100	< 0.5	4	2.9	< 10	< 5.0	5.2	< 0.50	2020	5.2
B-A2-R8-T-5-8	< 100	< 0.5	3	4.9	< 10	< 5.0	10.8	< 0.50	2810	5.4
B-A2-R8-T-9-12	< 100	< 0.5	5	6.1	< 10	< 5.0	6.4	< 0.50	2380	5
B-A2-R8-T-13-16	< 100	< 0.5	< 1	1	< 10	< 5.0	7.9	< 0.50	1440	4.4
B-A2-R8-T-21-24	< 100	< 0.5	2	7.3	< 10	< 5.0	11	< 0.50	2870	5
B-A3A-R22-T2	< 100	< 0.5	< 1	27.4	< 10	< 5.0	7.4	< 0.50	5500	4

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts

Table D2. *Metal concentrations in biomass samples analyzed by ICP-MS.*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A2-R2	< 0.5	13.6	237	< 10	< 2.0	2230	64.8	< 0.05	1	5.7
B-R16-FP1-0-10	< 0.5	19.8	148	21	< 2.0	599	30	< 0.05	0.6	< 0.8
B-R16-FP1-10-20	< 0.5	14.9	198	12	< 2.0	508	65.1	< 0.05	< 0.5	< 0.8
B-R16 MT BERM1	< 0.5	14.2	146	< 10	< 2.0	1080	75.1	< 0.05	1.3	< 0.8
B-R16 MT BERM2	< 0.5	8.2	401	< 10	< 2.0	1640	108	< 0.05	1.9	0.9
B-R16-FP2-0-10	< 0.5	5.9	< 100	< 10	< 2.0	2700	77.9	< 0.05	< 0.5	1.8
B-R16-FP2-10-20	< 0.5	9.6	369	< 10	< 2.0	1030	51.3	< 0.05	0.6	2.9
B-A3A-R21-TARGETS	< 0.5	11.3	103	36	< 2.0	2110	95.8	< 0.05	0.5	4.3
B-A3A-R21-Trench	< 0.5	11.7	< 100	< 10	< 2.0	1960	31.1	< 0.05	1.2	1.4
B-A3A-R21-OUT (Front)	< 0.5	13.1	120	< 10	< 2.0	1390	44.2	< 0.05	0.6	< 0.8
B-A3A-R21-OUT (Back)	< 0.5	10.7	204	< 10	< 2.0	1150	45.7	< 0.05	0.7	0.9
B-A3A-Vernonburg	< 0.5	15.1	117	< 10	< 2.0	1940	67.6	< 0.05	< 0.5	2.6
B-A3A-LS-40%-A	< 0.5	7.6	141	< 10	< 2.0	1370	88.3	< 0.05	< 0.5	4.6
B-A3A-LS-40%-B	< 0.5	5.7	159	< 10	< 2.0	2130	53.4	< 0.05	< 0.5	1.5

Table D2. *Metal concentrations in biomass samples analyzed by ICP-MS (continued).*

SAMPLE	COBALT	COPPER	IRON	LEAD	LITHIUM	MAGNESIUM	MANGANESE	MERCURY	MOLYBDENUM	NICKEL
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A3A-R26-FP	< 0.5	7.8	< 100	< 10	< 2.0	1150	29.1	< 0.05	0.7	1.4
B-A3A-R26-T	< 0.5	3.6	< 100	< 10	< 2.0	967	67.2	< 0.05	< 0.5	2.6
B-A1-R1-T-1-3	< 0.5	**17.9**	142	**109**	< 2.0	1430	14.2	< 0.05	1.6	0.9
B-A1-R1-T-1-3 DUP	< 0.5	6.7	< 100	< 10	< 2.0	1020	29.9	< 0.05	1.2	1.5
B-A1-R1-T-4-6	< 0.5	**21**	155	**96**	< 2.0	2860	41.3	< 0.05	0.8	3.2
B-A1-R1-T-7-9	< 0.5	**23.3**	181	**144**	< 2.0	523	31.7	< 0.05	0.8	< 0.8
B-A1-R1-T-10-12	< 0.5	3.7	< 100	< 10	< 2.0	663	39.3	< 0.05	< 0.5	< 0.8
B-A2-R8-T-1-4	< 0.5	6.9	< 100	< 10	4	944	31.3	< 0.05	< 0.5	1.2
B-A2-R8-T-5-8	< 0.5	9.5	< 100	< 10	**9.3**	1240	49	< 0.05	0.7	< 0.8
B-A2-R8-T-9-12	< 0.5	8.6	< 100	< 10	< 2.0	962	46.8	< 0.05	0.5	< 0.8
B-A2-R8-T-13-16	< 0.5	7.1	< 100	< 10	< 2.0	819	23.8	< 0.05	0.7	1.7
B-A2-R8-T-21-24	< 0.5	8.7	< 100	< 10	< 2.0	1250	50.7	< 0.05	0.7	< 0.8
B-R24-FP-10	< 0.5	6.1	< 100	< 10	< 2.0	918	24.9	**0.85**	0.9	1.6
B-A3A-R22-T2	< 0.5	8.1	105	< 10	< 2.0	1310	43.3	< 0.05	< 0.5	2

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts

Table D3. *Metal concentrations in biomass samples analyzed by ICP-MS.*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A2-R2	3980	29200	13.4	1	< 0.05	< 100	21.6	-	< 5.0
B-R16-FP1-0-10	1280	9360	1.6	< 0.5	< 0.05	< 100	13.4	< 100	< 5.0
B-R16-FP1-10-20	769	4830	0.9	< 0.5	< 0.05	< 100	10.1	< 100	< 5.0
B-R16-FP2-0-10	1890	11000	13.1	< 0.5	< 0.05	< 100	64.4	< 100	< 5.0
B-R16-FP2-10-20	1570	10700	5.1	< 0.5	< 0.05	< 100	9.2	< 100	< 5.0
B-R16 MT BERM1	2270	20800	4.2	< 0.5	< 0.05	< 100	18.8	-	< 5.0
B-R16 MT BERM2	2820	21900	18	< 0.5	< 0.05	< 100	18.1	-	< 5.0
B-A3A-R21-TARGETS	3750	18900	2	< 0.5	< 0.05	< 100	29	-	< 5.0
B-A3A-R21-Trench	5050	45000	6.4	< 0.5	< 0.05	< 100	16.5	< 100	< 5.0
B-A3A-R21-OUT (Front)	4020	31500	2.1	< 0.5	< 0.05	< 100	17.4	< 100	< 5.0
B-A3A-R21-OUT (Back)	2390	22900	1.9	< 0.5	< 0.05	< 100	18.1	< 100	< 5.0
B-A3A-Vernonburg	6630	32700	5.4	< 0.5	< 0.05	< 100	43	-	< 5.0
B-A3A-LS-40%-A	3810	19200	2.6	< 0.5	< 0.05	< 100	34.1	< 100	< 5.0
B-A3A-LS-40%-B	3790	20200	2.6	< 0.5	< 0.05	< 100	37	-	< 5.0

Table D3. *Metal concentrations in biomass samples analyzed by ICP-MS (continued).*

SAMPLE	PHOSPHORUS TOTAL (P)	POTASSIUM	RUBIDIUM	SELENIUM	SILVER	SODIUM	STRONTIUM	SULPHUR	TELLURIUM
	mg/kg	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
B-A3A-R26-FP	3070	19800	1.4	< 0.5	< 0.05	< 100	11.1	-	< 5.0
B-A3A-R26-T	2320	13900	1.1	< 0.5	< 0.05	< 100	10.3	< 100	< 5.0
B-A1-R1-T-1-3	1480	13000	4.8	< 0.5	< 0.05	< 100	28.4	-	< 5.0
B-A1-R1-T-1-3 DUP	1790	21300	**18.3**	< 0.5	< 0.05	< 100	12.7	-	< 5.0
B-A1-R1-T-4-6	2050	14800	3.8	< 0.5	< 0.05	< 100	46.3	-	< 5.0
B-A1-R1-T-7-9	2120	10600	0.7	< 0.5	< 0.05	< 100	8.3	-	< 5.0
B-A1-R1-T-10-12	2800	17000	7.4	< 0.5	< 0.05	< 100	6.3	-	< 5.0
B-A2-R8-T-1-4	3280	30600	10.3	< 0.5	< 0.05	< 100	10.3	-	< 5.0
B-A2-R8-T-5-8	3990	34600	3.8	< 0.5	< 0.05	< 100	12.4	-	< 5.0
B-A2-R8-T-9-12	3020	31900	11.1	< 0.5	< 0.05	< 100	11.1	-	< 5.0
B-A2-R8-T-13-16	3740	26800	9	< 0.5	< 0.05	< 100	5.9	-	< 5.0
B-A2-R8-T-21-24	3640	34200	5	< 0.5	< 0.05	< 100	10.8	-	< 5.0
B-R24-FP-10	2780	22200	1.7	< 0.5	< 0.05	< 100	5.7	-	< 5.0
B-A3A-R22-T2	2820	19700	2.2	< 0.5	< 0.05	< 100	21.4	-	< 5.0

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts

Table D4. *Metal concentrations in biomass samples analyzed by ICP-MS.*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***
B-A2-R2	< 1	< 0.1	4	< 0.2	< 2	**86.6**	< 0.5
B-R16-FP1-0-10	< 1	1.2	2	< 0.2	< 2	34	< 0.5
B-R16-FP1-10-20	< 1	0.6	3	< 0.2	< 2	**99.4**	< 0.5
B-R16-FP2-0-10	< 1	0.4	2	< 0.2	< 2	26.9	< 0.5
B-R16-FP2-10-20	< 1	0.7	4	< 0.2	< 2	42.7	< 0.5
B-R16 MT BERM1	**4**	4.3	3	< 0.2	< 2	55.8	0.9
B-R16 MT BERM2	< 1	0.8	**6**	< 0.2	< 2	49.8	0.7
B-A3A-R21-TARGETS	1	1	2	< 0.2	< 2	53.5	< 0.5
B-A3A-R21-Trench	< 1	< 0.1	2	< 0.2	< 2	47.7	1
B-A3A-R21-OUT (Front)	< 1	< 0.1	2	< 0.2	< 2	**80.1**	**3.2**
B-A3A-R21-OUT (Back)	< 1	< 0.1	4	< 0.2	< 2	49.4	1.4
B-A3A-R26-FP	< 1	< 0.1	2	< 0.2	< 2	53	< 0.5
B-A3A-R26-T	< 1	< 0.1	1	< 0.2	< 2	40.9	0.7
B-A3A-Vernonburg	< 1	0.3	2	< 0.2	< 2	**215**	0.5
B-A3A-LS-40%-A	< 1	< 0.1	3	< 0.2	< 2	60.9	1
B-A3A-LS-40%-B	1	2.3	3	< 0.2	< 2	56.8	0.6

Table D4. *Metal concentrations in biomass samples analyzed by ICP-MS (continued).*

SAMPLE	THALLIUM	TIN	TITANIUM	URANIUM	VANADIUM	ZINC	ZIRCONIUM
	mg/kg	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***	***mg/kg***
B-A1-R1-T-1-3	< 1	0.5	2	< 0.2	< 2	37	< 0.5
B-A1-R1-T-1-3 DUP	< 1	0.8	< 1	< 0.2	< 2	64	< 0.5
B-A1-R1-T-4-6	< 1	0.5	2	< 0.2	< 2	39.6	< 0.5
B-A1-R1-T-7-9	< 1	0.7	2	< 0.2	< 2	72	0.6
B-A1-R1-T-10-12	< 1	0.3	< 1	< 0.2	< 2	62.6	< 0.5
B-A2-R8-T-1-4	< 1	1.2	2	< 0.2	< 2	30.2	0.7
B-A2-R8-T-5-8	< 1	1.7	2	< 0.2	< 2	46.3	1
B-A2-R8-T-9-12	< 1	1	2	< 0.2	< 2	31.8	0.5
B-A2-R8-T-13-16	< 1	3	2	< 0.2	< 2	30.2	1.2
B-A2-R8-T-21-24	< 1	2.1	2	< 0.2	< 2	29	1
B-R24-FP-10	< 1	0.3	1	< 0.2	< 2	42.4	< 0.5
B-A3A-R22-T2	< 1	< 0.1	2	< 0.2	< 2	54.1	< 0.5

Values in blue: Results above the mean value added to twice the standard deviation are highlighted in blue bold fonts

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List of symbols/abbreviations/acronyms/initialisms

ACN	Acetonitrile
ADNT	Amino-dinitrotoluene
AFV	Armoured fighting vehicle
BFP	Behind the firing position/point
BIP	Blown-in-place
CCME	Canadian Council of Ministers of the Environment
CFB/ASU	Canadian Forces Base/Area Support Unit
CFAD	Canadian Forces Ammunition Depot
CLAWR	Cold Lake Air Weapon Ranges
CRREL	Cold regions Research and Engineering Laboratory
DCC	Defence Construction Canada
DLE	Director Land Environment
DND	Department of National Defence
DNT	Dinitrotoluene
DoD	Department of Defence
DRDC	Defence Research and Development Canada
DUP	Duplicate
ECD	Electron capture detector
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
FC	Fresh crater

FFP	In front of the firing position/point
FP	Firing position/point
GC	Gas chromatography
GPS	Global positioning system
HE	High explosive
HMX	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	High performance liquid chromatography
HS	Hot spot
ICP/MS	Inductively coupled plasma/mass spectrometry
INRS-ETE	Institut National de la Recherche Scientifique Eau, Terre et Environnement
LAW	Light anti-tank weapon
MBG	Mean background
MOAC	Mother of all composites
MP	Mortar pit
NG	Nitroglycerin
OB/OD	Open burning/open detonation
NATO	North Atlantic Treaty Organisation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
SERDP	Strategic Environmental R&D Program
T	Target
TCLP	Toxicity Characteristic Leaching Procedure
TNT	2,4,6-trinitrotoluene
TTCP	The Technical Cooperation Program
UV	Ultraviolet

UK	United Kingdom
UXO	Unexploded ordnances

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Military training on fields and ranges at Canadian Force Bases is essential to prepare our troops for potential wars and/or peace missions. On the other hand, the growing concern of DND leaders and of the general population makes it necessary to evaluate the impacts of training on the environment. During the last 10 years, new methods of characterisation have been developed to assess the energetic materials contamination, which is different from the usual contamination in residential or industrial scenarios. The CFB/ASU Wainwright in Alberta was characterized to assess the contamination by metals and energetic materials into the soil and the biomass. This location was selected based on its intensive use by Canadian and allied troops and based on its potential for heavier training intensity in the future. Several types of training sites were visited such as grenade, rifle, battle run, small arms and anti-tank ranges. The different methods of characterisation were adapted for each situation, i.e. the type of fired ammunition, the concentration of contaminants, and the size and the pattern of the training sites. Soil and biomass samples were taken using a composite approach to be statistically representative. The metal analyses were performed at PSC laboratory in Edmonton and the energetic materials were analyzed at DRDC Valcartier. This work was realized in May-June 2004 and was supported by the Director Land Environment (DLE), Ottawa, Canada and the Strategic Environmental Research and Development Program (SERDP), Washington D.C., USA.

L□entra”nement militaire dans les secteurs d□entra”nement des bases des Forces canadiennes est essentiel pour pr□parer les troupes aux guerres potentielles et/ou aux missions de paix. D□autre part, l□int□r□t grandissant du MDN et de la population par rapport □ l□environnement rend n□cessaire l□□valuation de l□impact de l□entra”nement sur l□environnement. Au cours des 10 derni□res ann□es, de nouvelles m□thodes de caract□risation on □t□ d□velopp□es pour □valuer la contamination en mat□riaux □nerg□tiques, diff□rente des sc□narios habituels, i.e. r□sidentiel ou industriel. La caract□risation de BFC/USS Wainwright en Alberta a permis d□□valuer la contamination en m□taux et en mat□riaux □nerg□tiques dans les sols et la biomasse. Cette base a □t□ s□lectionn□e pour son utilisation intensive par les troupes canadiennes et □trang□res, et pour son utilisation future qui sera de plus en plus fr□quente. Plusieurs sites d□entra”nement ont □t□ visit□s comme le site de grenade, des armes de petits calibres et anti-chars, et diff□rentes m□thodes d□□chantillonnage adapt□es □ chaque situation ont □t□ utilis□es, i.e. le type de munitions tir□es, la concentration des contaminants, et la grandeur et la topologie du site d□entra”nement. Les □chantillons de sols et de biomasses ont □t□ pr□lev□s suivant une approche composite pour □tre statistiquement repr□sentatifs. Les analyses de m□taux ont □t□ effectu□es au laboratoire PSC □ Edmonton, tandis que les analyses de mat□riaux □nerg□tiques ont □t□ r□alis□es □ RDDC Valcartier. Ce travail a □t□ r□alis□ aux mois de mai et de juin 2004 et a □t□ support□ par DLE □ Ottawa et SERDP, □ Washington D.C., aux □tats-Unis.

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