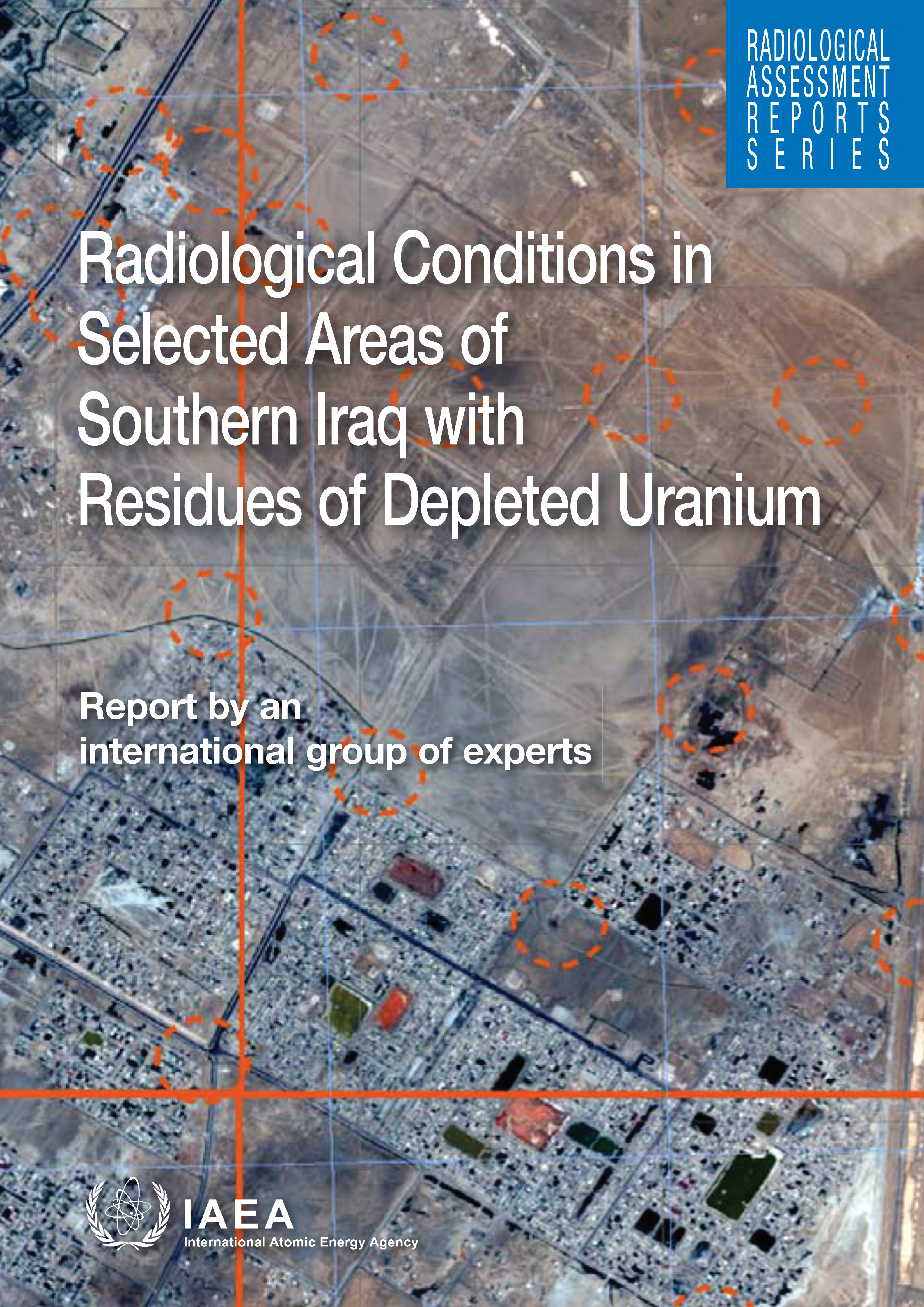

RADIOLOGICAL ASSESSMENT REPORTS SERIES

Radiological Conditions in Selected Areas of Southern Iraq with Residues of Depleted Uranium

Report by an international group of experts

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Cover:
A satellite image of an area in southern Iraq. The orange markings indicate sampling areas.
(Photograph courtesy of UNEP.)

RADIOLOGICAL CONDITIONS IN SELECTED AREAS OF SOUTHERN IRAQ WITH RESIDUES OF DEPLETED URANIUM

Report by an
international group of experts

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FOREWORD

Various locations around the world have been affected by radioactive residues at some time or another. Some of these residues are the result of peaceful activities; others from military actions, such as nuclear weapons testing and, in the more recent past, also from the use of depleted uranium in conventional munitions in conflicts.

Following these conflicts, questions have arisen regarding the possible radiological consequences of such residues for local populations and the environment, and the governments of the affected countries were obliged to respond. Many of these residues are in countries where the infrastructure and expertise necessary for evaluating the radiation risks posed by the residues, and for making decisions on remediation, are insufficient. In such cases, governments have felt it necessary to obtain outside help. In other cases, it has been considered to be socially and politically desirable to obtain independent expert opinions on the radiological conditions caused by such residues.

As a result, the IAEA has been requested by the governments of a number of Member States to provide assistance in this context. This assistance has been provided by the IAEA under its statutory obligation "to establish…standards of safety for protection of health…and to provide for the application of these standards…at the request of a State". In situations involving depleted uranium (DU) munitions, the IAEA conducted its activities in consultation and collaboration with other United Nations organizations, including the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).

In 2004, UNEP received a request from the Iraqi Ministry of Environment to perform an assessment in relation to the residues of DU munitions that exist at four selected areas in southern Iraq, left over from the 2003 conflict in Iraq. The IAEA was subsequently invited to undertake a radiological assessment of the results obtained through the sampling campaign and laboratory measurements conducted by UNEP.

For this purpose, the IAEA convened a team of experts who were involved in past similar radiological studies in different post-conflict situations involving DU. The team was led by P.R. Danesi, an external consultant; the IAEA technical officers were D. Telleria and D. Louvat, of the Division of Radiation, Waste and Transport Safety.

The information reported in Appendixes I, II and III was taken from documentation provided to the IAEA by UNEP. Particular acknowledgement is made of the contribution of M. Burger (Spiez Laboratory, Switzerland, and external consultant to UNEP), who made available to the IAEA the information reported in Tables 22–25, and who participated in several technical discussions.

This report describes the methods, assumptions and parameters used by the IAEA during the assessment of the post-conflict radiological conditions of the environment and populations using the results provided by UNEP from the 2006–2007 sampling campaigns, and presents results, findings and conclusions in connection therewith.

EDITORIAL NOTE

CONTENTS

SUMMARY

During the conflict in Iraq in 2003, depleted uranium (DU) munitions were employed by the Coalition Forces. As a result, residues of DU contaminated both localized areas of land and vehicles. The possible health effects of such residues on the Iraqi population living in the vicinity of the affected areas raised concerns in Iraq as well as in other parts of the world.

The United Nations Environment Programme (UNEP), after receiving a formal request from the Iraqi Minister of Environment, HE Mishkat Moumin, for a comprehensive field assessment to investigate the use of DU and its residual impacts, decided to train and equip national experts from the Radiation Protection Centre (RPC) of the Iraqi Ministry of Environment to undertake a sampling campaign for DU in Iraq. The IAEA was subsequently invited to become involved; its specific role was to undertake a radiological assessment of the results obtained through the sampling campaign.

RPC staff collected environmental samples at selected sites in southern Iraq during sampling campaigns conducted in 2006–2007. A total of 520 samples of soil, water, vegetation and smear samples were taken. The samples were collected at four locations in southern Iraq, namely, As Samawah, An Nasiriyah, Al Basrah and Az Zubayr. The samples were then shipped from Iraq to UNEP in Geneva, Switzerland, and analysed by the Spiez Laboratory in Switzerland.

In the subsequent radiation dose assessment performed by the IAEA, the following exposure pathways were considered:

(1) Inhalation of DU contaminated soil resuspended by the action of wind or human activities;
(2) Inhalation of resuspended DU dust inside military vehicles hit by DU munitions;
(3) Ingestion of DU contaminated soil;
(4) Ingestion of DU contaminated vegetables and drinking water;
(5) Direct contact with DU penetrators or DU fragments;
(6) Ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls);
(7) Inhalation and ingestion of DU during operations at scrap metal facilities involving military vehicles hit by DU munitions.

On the basis of assumptions on the habits of local residents, which were corroborated by the experts from the Iraqi RPC, and the results of measurements of environmental samples, the estimation of the radiological risk from DU was performed in a very conservative way. Assumptions concerning human habits and exposure scenarios were made such that radiation doses at the upper end of the possible range would result. From the data provided by the RPC/Spiez Laboratory, those data showing the highest DU contamination levels were mainly used.

In this report, it is concluded that the radiation doses from DU do not pose a radiological hazard to the population at the four studied locations in southern Iraq. The estimated annual committed effective radiation doses that could arise from exposure to DU residues are low, always less than 100 μSv/a and only to a few, if any, individuals, and therefore of little radiological concern. The estimated radiation doses are less than those received on average by individuals from natural sources of radiation in the environment (worldwide average 2.4 mSv/a), below internationally recommended dose limits for members of the public (1 mSv/a) and below the action level of 10 mSv/a set out in the IAEA Safety Standard on Remediation of Areas Contaminated by Past Activities and Accidents [1] to establish whether remedial actions are necessary.

The conclusions concerning the radiological impact are relevant to the locations investigated and cannot be directly extrapolated to other locations in Iraq where DU ammunition was used. However, it is likely that the general picture is not very different at other locations in Iraq where DU was used in the 2003 conflict. The conclusions reached in international studies of other situations where DU munitions were employed (Kuwait and the Balkans) were similar to those of this report and support the belief that the radiological impact of the residues from the firing of DU munitions is also likely to be low in other parts of Iraq.

The doses that could be accumulated by individuals who enter abandoned vehicles which have been hit by DU ammunition may be higher than those from DU in the environment due to the inhalation of residual dust containing DU inside the vehicles. It should be recognized that such vehicles may present an inhalation hazard and members of the public should be prevented from entering them.

In the absence of special facilities, it is not advisable for metal from vehicles hit by DU munitions to be used as scrap metal. Direct disposal as low level radioactive waste (LLRW) (without any decontamination) is to be preferred from a radiological perspective since it is associated with fewer potential exposure pathways.

Although very few DU penetrators or DU penetrator fragments were identified during the sampling campaign, it cannot be excluded that they might be found and collected by members of the public in areas where DU munitions were used. Although the radiation dose would become significant only if the person exposed were to be in direct contact with DU munitions or fragments for a considerable period of time, nevertheless, the handling of DU penetrators or fragments should be kept to a minimum, and protective gloves should be worn when DU munitions are being handled. DU fragments and penetrators should be considered and managed as LLRW.

1. INTRODUCTION

1.1. BACKGROUND TO THE PROJECT

During the conflict in Iraq in 2003, depleted uranium (DU) munitions were employed by the Coalition Forces. As a result, residues of DU contaminated localized areas of land and vehicles.

The possible health effects of DU residues on the Iraqi population living in the vicinity of the affected areas raised concerns in Iraq as well as in other parts of the world. Following a formal request in August 2004 from the Iraqi Minister of Environment, that a comprehensive field assessment be conducted in Iraq to investigate the use of DU and its residual impacts, the United Nations Environment Programme (UNEP), in association with the World Health Organization (WHO), submitted a proposal to the United Nations Development Group Iraq Trust Fund in late 2004. The proposal was not approved, but UNEP carried on with a scaled down plan of work, with the help of funding from the United Kingdom's Department for International Development.

The original plan of UNEP called for the deployment of international experts to Iraq to conduct the investigation. In June 2005, however, due to the continuously deteriorating security situation, UNEP decided instead to train and equip national experts from the Radiation Protection Centre (RPC) of the Iraqi Ministry of Environment to undertake the DU assessment locally.

On 6 April 2005, a meeting of UNEP, WHO and the IAEA was convened in Geneva to discuss, coordinate and plan work on DU in Iraq. The three organizations share a history of collaboration in the field of DU, for example, in Kuwait in 2001 [2]. At the meeting, UNEP, WHO and the IAEA agreed to collaborate with the Iraqi Ministry of Environment's RPC. WHO and the IAEA also agreed to actively participate in a programme of seminars and workshops organized by UNEP on the topic of DU. Both agencies subsequently took part in a UNEP seminar in Amman, Jordan, in May 2005, where they presented their latest findings in the field of radiation protection, DU and related health effects. This gave them the opportunity to meet and share their latest knowledge with other stakeholders.

In March 2006, a meeting involving the IAEA, UNEP and the RPC was held in Geneva to review the procedures and preliminary results of the first phase of the local expert DU assessment, and to offer feedback to the Iraqi experts. UNEP and the RPC also defined follow-up field activities and the second phase of the assessment. The IAEA was invited to undertake a radiological assessment based on data collected by the experts of the RPC in 2006 and 2007. This is the subject of the present report.

1.2. DU RESIDUES IN IRAQ

During the conflict in 2003, air attacks were mounted on selected Iraqi targets by US aircraft. In some of the air attacks, DU munitions were employed. Such munitions were also used by United Kingdom and US tanks in land battles, mainly against Iraqi T-type tanks.

The total amount of DU ammunition used during the conflict in 2003 is still unknown, but speculative figures from various studies cite the range as 170–1700 t. The United Kingdom Ministry of Defence has indicated that its forces deployed less than 1 t of DU ammunition during the 1991 Gulf War, and approximately 1.9 t in the 2003 conflict in Iraq. The ammunition was fired exclusively from tanks, as DU munitions were not used by the United Kingdom from aircraft in either conflict.

While it has not been disclosed where such ammunition was used in the 1991 conflict, the United Kingdom Ministry of Defence provided UNEP in June 2003 with the coordinates of DU firing points for its Challenger 2 tanks in the 2003 Iraq conflict. Up to now, the United States Government has not released information to UNEP on DU target coordinates for either the 1991 conflict or the 2003 one.

1.3. WORK PROGRAMME

For the purpose of the project, staff from the Iraqi RPC were trained by UNEP on DU radiological related issues. The main objectives of UNEP's DU capacity building project in Iraq were to: train RPC staff to undertake a field based assessment of DU using internationally approved protocols and modern equipment; provide RPC staff with precise information on sites to assess and types of samples to collect; supervise remotely the assessment and retrieve samples; analyse the field observations,

FIG. 1. Map of Iraq indicating the four investigated locations. This map is based on UN Map No. 3835, Rev. 4, January 2004. (The original was used with the kind permission of the UN Cartographic Section.)

monitoring results and samples to draw conclusions on the effectiveness of the capacity building activities; and review the results and provide recommendations to the Iraqi Ministry of Environment on follow-up actions.

The scope of the DU assessment performed by local experts in southern Iraq included the identification of areas where DU ammunition had been used; where contamination might be detected; and the implementation of a sampling programme for DU in soil, water, vegetation and on surfaces.

Environmental samples were collected by RPC staff from selected sites in southern Iraq in sampling campaigns carried out in 2006 and 2007. A total of 520 samples of soil, water, vegetation and smear samples were taken. The samples were collected at four locations in southern Iraq, namely, As Samawah, An Nasiriyah, Al Basrah and Az Zubayr (Fig. 1). Descriptions of the four locations and of the major battles that took place there are reported in Appendix I. The methods used for identifying the sampling locations and the sampling methodology employed are described in Appendix II. The information reported in the two appendixes was taken from documentation provided to the IAEA by UNEP.

The collected samples were analysed for their uranium content by the Spiez Laboratory, Switzerland, on behalf of UNEP. The results of the analyses were reported as weight of the four U isotopes, ^{238}U, ^{236}U, ^{235}U and ^{234}U per gram of dried sample (soil and vegetation samples), per millilitre of water (water samples), and per smear sample.

On the basis of this information, the IAEA assessed the radiological risk from DU to the local population living in the vicinity of the sites where the presence of DU had been identified.

2. BACKGROUND

In this section, the internationally accepted concepts and quantities relevant to the assessment of radiation dose to exposed humans are outlined and some basic information on uranium and DU is provided.

2.1. ACTIVITY AND RADIATION DOSE

The amount of a given radionuclide in a particular material is normally expressed in terms of activity, which is the rate at which nuclear transformations occur at a certain time. The unit of activity is the becquerel (Bq). Radionuclides can differ markedly in their physical characteristics (decay mode, radioactive half-life), and in their behaviour in the human body and in the environment. Consequently, the relative importance of different pathways of exposure to radiation is also dependent on the radionuclide of interest. Exposure can occur via external irradiation, when radionuclides are outside the human body, or via internal irradiation, following the intake of radionuclides via ingestion or inhalation. The potential harm to a person from exposure to radiation is expressed in terms of radiation dose — which is a measure of the energy deposited in tissue by radiation. The quantity ‘effective dose’ takes account of the varying radiation sensitivities of different organs and tissues to different types of radiation; its unit is the sievert (Sv). The radiation doses received as a result of the intake of radionuclides into the human body may be delivered over a considerable period of time after the intake and, in this report, they are assessed in terms of ‘committed effective doses’, this means the effective dose integrated to 50 years after intake for adults and 70 years after intake for children. The IAEA [3] and the International Commission on Radiological Protection (ICRP) [4, 5] have published coefficients relating intakes of radionuclides and the associated committed effective radiation doses. In practice, the annual radiation doses arising from the presence of radionuclides in the environment are at the level of millisievert (mSv), which is one thousandth of one sievert, or microsievert (μSv), which is one millionth of one sievert.

Exposure to any radioactive material, whether of natural or artificial origin, gives rise to an incremental risk of developing cancer. This risk is assumed to be proportional to the dose received [3, 6]. The additional risk of fatal cancer associated with a dose of 1 mSv is assumed to be about 1 in 20 000. This small increase in lifetime risk can be contrasted with the 1 in 5 risk of fatal cancer that people usually incur from all causes in their lives.

2.2. INTERNATIONAL SAFETY STANDARDS

The IAEA, together with other relevant international organizations, has established the basic requirements for protection against the risks associated with exposure to ionizing radiation; these are published in the Basic Safety Standards (BSS) [3]. The BSS are based primarily on the recommendations of the ICRP [6] and on the assessments of the health effects of radiation of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [7], and do not apply to non-ionizing radiation or to chemical or biological pollutants.

The BSS cover a wide range of situations that give rise to or could give rise to exposure to radiation, and are applicable to exposures from any combination of uranium isotopes, including those present in DU.

Another international safety standard provides requirements for the Remediation of Areas Contaminated by Past Activities and Accidents [1]. It recommends, as a generic reference level for aiding decisions on remediation, an individual existing annual effective dose of 10 mSv from all sources, including natural background radiation. In addition, it recommends an upper value of 100 mSv to any organ at which intervention would be justified under almost any circumstances.

To put it into perspective, the worldwide average annual effective dose from natural background radiation is 2.4 mSv, with a typical range of 1–20 mSv [7]. The most significant contribution to the worldwide average annual effective dose comes from exposure to radon and its decay products (1.15 mSv); exposure to terrestrial gamma rays and cosmic rays account for 0.48 mSv and 0.38 mSv, respectively; the contribution of the intake of natural radionuclides in air, food and water to the average dose is 0.31 mSv, mainly due to ^{40}K (0.17 mSv), ^{210}Po (0.086 mSv), ^{210}Pb (0.032 mSv) and ^{228}Ra (0.021 mSv); uranium isotopes contribute little to the dose.

2.3. URANIUM AND DU

Uranium is a naturally occurring radioactive element. In its pure form, it is a silver coloured heavy metal similar to lead, cadmium and tungsten. Like tungsten, it is very dense, with a density of about 19 g/cm^3. In its natural state, uranium consists of three isotopes (^{238}U, ^{235}U and ^{234}U). Other isotopes which can exist but are not found in natural uranium are ^{237}U, ^{236}U, ^{233}U and ^{232}U.

In the process of uranium enrichment, uranium is enriched in its ^{235}U content. The enriched uranium is mainly used in nuclear reactors to produce energy. During the uranium enrichment process, the fraction of ^{235}U is increased from its natural level (0.72% by mass) to 2% or more by mass. The uranium that remains after the enriched fraction has been removed has reduced concentrations of ^{235}U and ^{234}U. This by-product of the enrichment process is known as DU. Typically, the percentage concentration by mass of ^{235}U in DU used for military purposes is 0.2% [8].

The total specific activity of natural uranium (i.e. the activity per unit mass of natural uranium metal) is 25.4 Bq/mg. In nature, uranium isotopes are in radioactive equilibrium with the other isotopes, such as ^{234}Th, ^{231}Th, ^{226}Ra, ^{223}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po, created as a result of radioactive decay. In DU, only traces of decay products beyond ^{234}Th and ^{231}Th are present, as these decay products have not had time to form. The specific activity of DU is 14.2 Bq/mg.

Table 1 gives the half-lives and specific activities of the three isotopes of natural uranium and ^{236}U, and compares their relative abundance by mass in natural uranium and in DU.

There have been reports that the DU in munitions contains small amounts of other radionuclides, such as isotopes of americium and plutonium, as well as ^{236}U. The presence of these human-made radionuclides indicates that some of the DU has been obtained from uranium that had been irradiated in nuclear reactors and subsequently reprocessed. However, published information from other theatres of war, as well as the results of this study, indicate that the amounts of these isotopes present in DU are very small [9, 10]. Isotopes of natural uranium decay mainly by emitting alpha particles. The emissions of beta particles and gamma radiation are low. The average energies per transformation emitted by the isotopes of natural uranium are shown in Table 2.

TABLE 1. HALF-LIVES, SPECIFIC ACTIVITIES AND RELATIVE ABUNDANCES OF URANIUM ISOTOPES IN NATURAL URANIUM AND DU

Isotope	Half-life (a)	Specific activity (Bq/mg)	Isotopic abundance (%) by mass	
			Natural uranium	DU
^{238}U	4.51×10^9	12.44	99.28	99.8
^{236}U	2.34×10^7	2400	0	0.0003
^{235}U	7.1×10^{10}	80	0.72	0.2
^{234}U	2.47×10^5	230 700	0.0055	0.0007

TABLE 2. AVERAGE ENERGY PER TRANSFORMATION OF THE URANIUM ISOTOPES ^{238}U, ^{236}U, ^{235}U AND ^{234}U

Isotope	Average energy per transformation (MeV/Bq)		
	Alpha radiation	Beta radiation	Gamma radiation
^{238}U	4.26	0.01	0.001
^{236}U	4.57	0.011	0.05
^{235}U	4.47	0.048	0.154
^{234}U	4.84	0.0013	0.002

2.4. URANIUM IN NATURE

Uranium is found in trace amounts in all rocks and soil, in water and air, and in materials made from natural substances. It is a reactive metal, therefore, it is not present in metallic form in the environment, but as uranium compounds. The solubility of uranium compounds varies greatly. Uranium in the environment is dominated by uranium oxides such as UO_2, which is an anoxic insoluble compound found in minerals, and UO_3, a moderately soluble compound found in surface waters. The chemical form of the uranium compound determines how easily it can move through the environment, as well as how chemically toxic it is.

2.5. EXPOSURE ROUTES FOR DU

The radiation emitted from DU is predominantly in the form of alpha particles (Table 2). Alpha particles have a very limited range in tissue; they can barely penetrate the external layer of the skin, hence do not pose a hazard in terms of external irradiation. Alpha particles, however, are very energetic, and if emitted inside the body can damage nearby cells. Uranium is not transferred very effectively along food chains, and so inhalation is usually the route of intake that merits primary attention.

In a combat situation, the main radiological hazard associated with DU munitions is inhalation of the aerosols created when DU munitions hit an armoured target. Studies carried out at test ranges show that most of the DU aerosols created by the impact of penetrators against an armoured target settle within a short time of the impact and in close proximity to the site, although smaller particles may be carried to a distance of several hundred metres by the wind [11]. This investigation is concerned with the possible long term effects of DU residues on the population of Iraq; therefore, short term exposures (i.e. of military personnel during the conflict) are not considered.

A possible exposure pathway for those visiting or living in DU affected areas after the aerosols have settled is the inhalation of DU particles in soil that are resuspended through wind or human activities such as ploughing.

Inhalation of DU dust by individuals entering military or other abandoned vehicles hit by DU munitions is also an important exposure pathway.

Another possible pathway of exposure that merits consideration is the inadvertent or deliberate ingestion of soil. For example, farmers working in fields in which DU munitions were fired could inadvertently ingest small quantities of soil, as could small children in such an environment, who may eat small quantities of soil as they play.

Generally, a large proportion of DU munitions fired from aircraft miss their intended targets. The physical state of these munitions, once fired, varies from small fragments to whole intact penetrators, either totally or partially encased in their aluminium jackets. Individuals who find and handle such munitions could be exposed via external irradiation due to the beta particles and gamma rays emitted by the DU (Table 2).

Penetrators that do not hit the target corrode with time, forming fragments and particles containing DU oxides, which may range from several millimetres to less than a micrometre in size [13]. People may ingest or inhale some of the uranium oxides formed through this weathering process.

3. RADIATION EXPOSURE

3.1. GENERAL ASSESSMENT APPROACH

The assessment approach used in this study employed relatively simple methods based on cautious assumptions. Where approximations were made, they were such as to produce an overestimate of the health risks.

The estimates of committed effective doses from exposure to existing levels of DU in the environment were based on radionuclide concentrations measured in samples of environmental media collected for the study. The doses to ‘hypothetical’ individuals who reside, work (adults) or play (children) in the investigated areas were estimated. Doses from DU as well as from natural uranium found in the environment have been estimated for both adults and 10 year old children.

3.2. RADIATION EXPOSURE PATHWAYS CONSIDERED

The following exposure pathways were considered in the radiation dose assessments:

(1) Inhalation of soil resuspended by wind or human activities;
(2) Inhalation of resuspended dust inside abandoned military vehicles hit by DU munitions;
(3) Ingestion of soil;
(4) Ingestion of vegetables and drinking water;
(5) External exposure due to direct contact with DU penetrators or DU fragments;
(6) Ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls);
(7) Inhalation and ingestion of dust during scrap metal operations involving military vehicles hit by DU munitions (a combination of pathways (2) and (6)).

In addition, consideration has been given to the possible inhalation of DU dust during the re-melting of scrap metal from dismantled military vehicles hit by DU munitions.

External exposure as a result of DU in soil is insignificant and has not been included in the assessment.

3.3. LIMITATIONS OF THE ASSESSMENT

The assessment is based on site specific information, such as the measurements made at the specific location, the nature of the local terrain and the use to which the area is put (agricultural, urban). Extrapolation of the estimated radiation doses to other areas of Iraq not considered in this study is, in general, not appropriate. However, for certain estimated doses, extrapolation to other areas may be valid. These are the doses associated with the inhalation of resuspended dust inside abandoned military vehicles hit by DU munitions, direct contact with DU penetrators and fragments, and inhalation and ingestion during scrap metal recovery operations on military vehicles hit by DU munitions. These estimates were based on generic data and have a more general applicability.

4. METHODOLOGY USED FOR THE ESTIMATION OF DOSE

4.1. INHALATION OF DU CONTAMINATED SOIL RESUSPENDED BY WIND OR HUMAN ACTIVITIES

The estimation of radiation doses from the inhalation of resuspended material requires information on the concentration of the material in air. In this study, these concentrations were modelled, not measured, using a simple air dust loading approach expressed in the following equation:

$$C_{air,\ i} = SC_{soil,\ i}$$

where $C_{air,\ i}$ is the activity concentration of each uranium isotope in air (Bq/m^3), S is the dust loading factor (kg/m^3) and $C_{soil,\ i}$ is the activity concentration of each uranium isotope in soil (Bq/kg).

The dust loading approach has an advantage over more process oriented approaches in that it requires no data on the processes giving rise to airborne concentrations, for example, wind velocity and particle size. However, it tends to be conservative in assuming a constant airborne concentration of locally derived soil particles. The model also implies that the radionuclides inhaled are associated with the soil particles, which is likely to become realistic only after a longer period of time following the deposition event. Finally, the use of air concentrations derived from the dust loading model assumes that the size distribution of the DU particles associated with the soil is in the respirable range (less than 10 µm). In fact, in another similar assessment study, the presence of DU particles in the respirable range, being AMAD <10 µm (where AMAD refers to 'activity median aerodynamic diameter'), was experimentally confirmed [2].

The dust loading factor used in this assessment was evaluated on the basis of the information in Ref. [9], where dust loading factors of 2.0×10^{-6} kg/m^3 for wind driven resuspension and 3.0×10^{-5} kg/m^3 for human-made resuspension (agriculture, digging, driving) are reported. These values were based on measurements taken at the Emu and Maralinga nuclear test sites in Australia [14]. Since no information on dust loading factors was available for the investigated locations, an average value of $S = 1.6 \times 10^{-5}$ (kg/m^3) was assumed in the calculations.

The uranium isotope activity concentrations in soil were obtained by multiplying the measured concentrations expressed in mg/kg by the specific activities of ^{238}U, ^{236}U, ^{235}U and ^{234}U contained in column 3 of Table 1.

The next step in the dose assessment is the evaluation of the intake of air containing DU by an exposed individual at the DU contaminated location. Average inhalation rates of adults and children considered in the assessment were taken from Ref. [15] and are given in Table 3. The intake of DU contaminated air (m^3) by inhalation can be evaluated from knowledge of the time spent by hypothetical exposed individuals at the location.

The total amount of radioactivity (Bq) of each uranium isotope that a hypothetical individual would inhale is obtained by multiplying the intake (m^3) by the activity concentration in air, $C_{air,\ i}$ (Bq/m^3). This may be converted to radiation dose (Sv) using the dose coefficients in Table 4.

The dose coefficients for inhalation used in the calculations were taken from the BSS [3]. Dose coefficients for inhalation are available for three types of material, classified as type F, M and S, according to whether the absorption rate of the material into body fluids from the respiratory tract is considered to be fast (very soluble compounds), moderate or slow (insoluble compounds). The chemical composition of the DU particles produced from the oxidation of uranium in the DU munitions has been shown by experimental studies [16] to consist of 50% UO_2, and 50% U_3O_8 or a mixture of ⅔ UO_2 and ⅓ U_3O_8. As shown in Ref. [17], both of these forms can be considered as slightly soluble uranium oxides. Consequently, in this assessment, the inhalation dose coefficients used were those for compounds with a slow absorption rate (type S).

TABLE 3. AVERAGE INHALATION RATES

Age group	Inhalation rate (m^3/h)
Adults	0.84
Children (10 years old)	0.64

TABLE 4. DOSE COEFFICIENTS (COMMITTED EFFECTIVE DOSES) FOR INHALATION USED IN THE ASSESSMENT

Age group	Dose coefficient (Sv/Bq) for inhalation (type S)			
	^{238}U	^{236}U	^{235}U	^{234}U
Adults	8.0×10^{-6}	8.6×10^{-6}	8.4×10^{-6}	9.3×10^{-6}
Children (10 years old)	1.0×10^{-5}	1.1×10^{-5}	1.1×10^{-5}	1.2×10^{-5}

TABLE 5. ESTIMATED COMMITTED EFFECTIVE RADIATION DOSE DUE TO THE INHALATION OF DU INSIDE CONTAMINATED TANKS

Age group	Inhalation dose (mSv/mg DU in air)				
	^{238}U	^{236}U	^{235}U	^{234}U	Total
Adults	9.9×10^{-2}	6.2×10^{-5}	$1.3\ 10^{-3}$	1.5×10^{-2}	0.12
Children (10 years old)	1.2×10^{-1}	7.9×10^{-5}	1.8×10^{-3}	1.9×10^{-2}	0.14

4.2. INHALATION OF RESUSPENDED DUST INSIDE MILITARY VEHICLES HIT BY DU MUNITIONS

Dust inside abandoned vehicles which have been hit by DU munitions is not likely to be quickly dissipated, since in most cases there is no effective dispersion mechanism, for example, compared with the effect of wind in open locations. If such vehicles are entered by persons, the contaminated dust will be resuspended by their movements inside the vehicle, and if the persons are not wearing protective masks, the radiation doses received by them due to inhalation could be significant.

No direct measurements of resuspended dust inside DU contaminated tanks were made in the present study and doses have been estimated based on information from the literature. Marshall [18] has made estimates based on experimental data obtained in a US Army sponsored programme [19]. The tests consisted of firing 120 mm DU rounds at Abrams tanks and measuring resuspended DU concentrations in air inside the tanks after they were hit with the DU rounds. The average and maximum DU concentrations in air reported are 0.5 mg/m^3 and 1 mg/m^3, respectively.

For the purpose of calculating the inhalation radiation doses to persons entering contaminated tanks, the maximum observed concentration (1 mg/m^3) [18] was used, recognizing that it represents an upper estimate of the air concentration due to resuspension. The radiation doses received by adults and children when inhaling 1 mg of DU, obtained by using the dose coefficients of Table 4, are shown in Table 5.

Using the inhalation rates of Table 3, the estimated committed effective radiation doses to hypothetical persons spending 10 h in a year inside a contaminated vehicle would be about 1 mSv for adults and 900 µSv for 10 year old children. These dose estimates are based on conservative assumptions and are likely to be higher than would be received in practice. They are higher than most of those evaluated for persons exposed as a result of the contamination found on the ground at various sites, and are comparable to the global natural radiation background (2.4 mSv/a) and the internationally recommended dose limits for members of the public (1 mSv/a).

4.3. INGESTION OF SOIL

The methodology used for assessing this pathway is essentially the same as the one used in Refs [2, 20]. The dose due to each of the four isotopes present can be calculated by multiplying the activity concentration in soil (Bq/kg) by the ingestion rate of soil (kg/a) and the dose coefficient for ingestion (Sv/Bq). The total dose is the sum of the doses due to each uranium isotope.

TABLE 6. INGESTION DOSE COEFFICIENTS (COMMITTED EFFECTIVE DOSE) AND SOIL INGESTION RATES

Age group	Dose coefficients for ingestion (f_1 = 0.04) (Sv/Bq)				Soil ingestion rate (kg/a)
	^{238}U	^{236}U	^{235}U	^{234}U	
Adults	4.4×10^{-8}	4.6×10^{-8}	4.6×10^{-8}	4.9×10^{-8}	0.0183
Children (10 years old)	6.6×10^{-8}	7.0×10^{-8}	7.0×10^{-8}	7.4×10^{-8}	0.0365

The ingestion dose coefficients and the soil ingestion rates, taken from Refs [3, 21], respectively, are set out in Table 6.

4.4. INGESTION OF VEGETABLES AND DRINKING WATER

4.4.1. Vegetables

The methodology for evaluating the radiation doses from the ingestion of vegetables is the same as the one described in Ref. [2]. Although the vegetation collected during sampling was not typical of that normally consumed by humans, in the absence of any other relevant data, it is assumed that the concentrations measured in the samples collected are representative of the values in edible vegetation. An adult ingestion rate of 300 kg/a, the value generally used for edible vegetables [2], is assumed.

The activity intake due to the ingestion of each of the four uranium isotopes can be obtained by multiplying the ingestion rate (kg/a) by the activity concentrations measured in the vegetation (Bq/kg). By multiplying the activity intake of each radioisotope by the corresponding ingestion dose coefficient (Table 6), the dose due to each isotope can be calculated. The total ingestion dose is the sum of the doses due to the four isotopes.

4.4.2. Water

The methodology for evaluating the radiation doses from the ingestion of water is the same as the one described in Ref. [2]. It is assumed that the average amount of water drunk by an individual in a year is 1000 L (~2.7 L/d). The activity in Bq of each uranium isotope ingested in one year is then equal to the product of the activity concentration in water (Bq/L) and the annual ingestion rate (L/a). By multiplying this value by the relevant ingestion dose coefficient (Table 6), the radiation dose due to each of the uranium isotopes is obtained. The overall radiation dose is calculated by adding the doses from each of the four isotopes.

4.5. DIRECT CONTACT WITH DU PENETRATORS OR DU FRAGMENTS

Although very few DU penetrators or DU penetrator fragments were identified during the sampling campaigns, the possibility cannot be excluded that such pieces or fragments might still be found and collected by members of the public in areas where DU munitions were used. Individuals handling DU penetrators or fragments could be exposed to external radiation. The exposure of individuals who find and handle DU munitions is mainly due to beta particles and low energy gamma rays, and can become significant only if the person exposed is in direct contact with DU munitions or fragments for a considerable period of time.

The contact dose rate to the skin from typical DU ammunitions is about 2.3 mSv/h [12]. At this dose rate, it is unlikely that even prolonged contact with a DU penetrator would lead to serious skin burns (erythema) or any other acute radiation effect.

4.6. INGESTION OF DU CONTAMINATED DUST FROM FLAT SURFACES (METAL, CONCRETE, WALLS)

The amount of dust or soil from DU contaminated flat surfaces (metal, concrete, walls) that could be ingested by an individual is difficult to estimate in the absence of appropriate data. However, the smear samples collected during the sampling campaign from flat surfaces, ranging from 10 cm × 10 cm to 50 cm × 50 cm, can provide a useful qualitative indication of: (a) the presence of DU in the area; (b) the presence of removable DU contamination from a surface; and (c) the order of magnitude of the surface contamination. The information is of a qualitative nature because of the uncertainties in the nature of the surface from which the smear samples were taken and, among other things, the variability of the pressure exerted by persons taking the smear sample.

Nevertheless, a conservative estimation of the doses from ingestion of DU from the sampled surfaces was made based on the following assumptions:

— The smear samples where the highest total uranium mass was measured are representative of all the smear samples taken in this area;
— The reported primary analytical data, expressed as the total mass of each uranium isotope present in the smear test, actually represents the mass of each uranium isotope present on the sampled surface;
— The total mass is completely collected from the surface by an individual touching the surface with his/her hands;
— The total mass is then fully ingested by this individual;
— The individual touches surfaces having the same highest uranium isotope concentration of 100 times per year.

The total dose due to each of the four uranium isotopes can then be calculated by multiplying the measured activity (Bq) of the uranium isotope taken from the sampled surface by 100 and by the dose coefficient for ingestion of the uranium isotope (Sv/Bq). The total dose is the sum of the doses from each isotope.

4.7. INHALATION AND INGESTION OF DU DURING SCRAP METAL OPERATIONS FOR MILITARY VEHICLES HIT BY DU MUNITIONS

The calculation of the possible doses received during the various processes involved in manipulating scrap metal from contaminated military vehicles can be assessed by a combination of the pathways previously discussed, that is, inhalation of resuspended dust inside military vehicles hit by DU munitions and ingestion of DU contaminated dust from flat surfaces.

5. CONSIDERATION OF THE POSSIBLE HAZARDS ASSOCIATED WITH THE RE-MELTING OF SCRAP METAL FROM DISMANTLED MILITARY VEHICLES

The radiological concern in melting radioactive contaminated metal scrap is that the melting process can create potential exposure pathways. Four main possibilities exist in the melting of ferrous scrap:

(1) The contaminant element can stay in the metal (e.g. cobalt and ruthenium).
(2) The contaminant element can enter the slag (e.g. lanthanides and actinides).
(3) The contaminant element can become associated with the furnace dust and be collected with the fly ash (e.g. caesium).
(4) The contaminant element can pass through all filtration/retention processes to enter the air in the local environment (e.g. iodine) [23].

In the case of uranium, about 95% of it by weight goes into slag and about 5% accompanies the furnace dust or fly ash. Thus, radiation exposure may occur during: the transport of the metal to the melter; the cutting process; the transfer of off-gases to the bag house; the processing of the dust; and the processing of the slag.

For ensuring radiation protection, it is important that the melting facilities are properly equipped so that radiation exposure is minimized. This requires special facilities and equipment that is not likely to be present in normal scrap metal melters. For these reasons, it is not advisable for metal from vehicles hit by DU munitions to be used as scrap metal unless such special facilities are available. In the absence of such facilities, direct disposal as LLRW (without any decontamination) is to be preferred from a radiological perspective, since it is associated with fewer potential exposure pathways.

6. EVALUATION OF THE RADIATION DOSES AT THE FOUR INVESTIGATED LOCATIONS

A description of the four investigated locations (As Samawah, An Nasiriyah, Al Basrah and Az Zubayr) and of the battles that took place there is given in Appendix I. At each location a number of selected areas, nominated areas of interest (AOI), were investigated. These are also described in Appendix I. The criteria used to identify these areas and the sampling methodology employed are described in Appendix II.

The results of the analyses conducted by the Spiez Laboratory are reported in Appendix III: Table 45 Soil Samples; Table 46 Water Samples; Table 47 Vegetation Samples; and Table 48 Surface Samples (Smears).

Unless otherwise specified, the estimated radiation doses are committed effective doses calculated for intakes in an assumed period of one year using the measured radionuclide concentrations in the samples (Appendix III) and the habit data summarized in Appendix IV.

The overall radiation doses were calculated by adding the individual doses from each of the four isotopes (^{238}U, ^{236}U, ^{235}U and ^{234}U) present in the samples. The doses due only to DU were calculated by first calculating the percentage of DU present in the sample using the equation given in Appendix III. This assumes that the isotope ratio $^{235}U/^{238}U$ of DU is 0.002.

In most instances, the dose calculations were based on the samples having the highest DU concentrations.

The doses were calculated for both adults and 10 year old children.

6.1. AS SAMAWAH

6.1.1. Doses due to the inhalation of soil resuspended by wind or human activities

At this location, 70 soil samples were collected in five selected AOIs. At each AOI, several soil samples were collected, but DU was not detected in any of the samples. Nevertheless, for the sake of comparison, the dose due to inhalation of natural uranium resuspended from the soil at this location was calculated. For this purpose, the sample in which the highest uranium concentration was measured (‘SAMA-bombarded tank-soil-10 (2nd Mission)’) was used. The time spent outdoors in a year by hypothetical individuals at this location was assumed to be 3650 h. This occupancy corresponds to adults and children spending about 10 h each day of the year out of doors. By using the previously reported values of the inhalation rates for adults and children, the following annual air inhalation rates are obtained (Table 7).

The estimated radiation doses to adults and children due to inhalation of the uranium isotopes present in air are reported in Table 8.

TABLE 7. ASSUMED ANNUAL INHALATION RATES

Age group	Annual inhalation rate (m^3/a)
Adults	3070
Children (10 years old)	2340

TABLE 8. AS SAMAWAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INHALATION OF RESUSPENDED SOIL CONTAINING ONLY NATURAL URANIUM (*no DU was detected*)

Quantity	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in soil sample ‘SAMA-bombarded tank-soil-10’ (2nd Mission)	2.21	—	1.57×10^{-2}	1.18×10^{-4}	2.23	
Annual dose (µSv) to adults	11	—	0.52	12	24	0
Annual dose (µSv) to children (10 years old)	10	—	0.52	12	23	0

For a perspective on the values reported in Table 8, the estimated radiation dose (to both adults and children spending a large portion of their time out of doors) due to the inhalation of uranium naturally present in soil (i.e. DU is absent) at this location is about 1% of the global average annual effective dose due to natural radiation (~2.4 mSv) [7]. In fact, the doses due to resuspended natural uranium in soil are likely to be much lower owing to the conservative nature of the dust loading modelling approach (see Section 4.1).

6.1.2. Doses due to the ingestion of soil

As no DU was detected in any of the soil samples collected, no calculation of radiation dose due to ingestion was performed.

6.1.3. Doses due to the ingestion of vegetables and drinking water

6.1.3.1. Vegetables

At this AOI, 15 samples of vegetation (of an unknown type) were collected. In three samples, traces of DU were detected. However, the analysing laboratory (Spiez Laboratory) reported that the presence of DU was most likely to be due to cross-contamination. As a conservative approach, it was assumed that the values are real. The annual radiation doses due to the ingestion of this vegetation were calculated using the concentrations measured in sample 'SAMA-103-vegetation-A'. The estimated doses are reported in Table 9.

6.1.3.2. Water

At this AOI, ten water samples were collected. No DU was detected in any of the samples.

6.1.4. Doses due to the ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls)

Fifty-seven smear samples were collected at this location. For many of the samples, the analytical laboratory reported that there was evidence of cross-contamination which most likely occurred during the sample packaging. Seventeen smear samples were taken from parts of tanks and artillery cannons still on the railway train where they were hit by DU ammunition during the conflict. The highest DU percentage (18%) was measured in a sample taken from a wall, namely, sample 'SAMA-409-smear-W-A'. The estimation of the radiation dose due to ingestion was made using this sample. It must be emphasized again that this is a very unlikely 'worst case' situation, as it implies that a person (child or adult) could have his/her hands in contact with the contaminated surface on 100 occasions in a year, and that all uranium collected by the surface smear is equivalently transferred to his/her hands, and that all of the transferred material is ingested. The radiation doses are reported in Table 10.

6.2. AN NASIRIYAH

6.2.1. Doses due to the inhalation of soil resuspended by wind or human activities

At this location, samples were collected in 13 out of the 15 selected AOIs. The total number of soil samples collected was 106. DU was detected in 12 samples. In all AOIs, several soil samples were collected with the exception of the AOI denominated as 'additional points', where only two samples were collected, namely, at a scrapyard of destroyed

TABLE 9. AS SAMAWAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INGESTION OF VEGETATION *(10.5% DU)*

Quantity	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg dry weight) in sample 'SAMA-103-vegetation-A'	7.20×10^{-2}	1.63×10^{-7}	4.73×10^{-4}	4.01×10^{-6}	7.25×10^{-2}	
Annual dose (μSv) to adults	11.7	0.0054	0.51	13.5	~ 26	~ 2
Annual dose (μSv) to children (10 years old)	17.7	0.0081	0.78	20.4	~ 39	~ 3

TABLE 10. AS SAMAWAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INGESTION OF URANIUM ISOTOPES PRESENT ON THE MOST DU CONTAMINATED SURFACE MEASURED *(18% DU)*

Quantity	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Amount (mg) present in sample 'SAMA-409-smear-W-A'	2.65×10^{-5}	5.03×10^{-10}	1.84×10^{-7}	1.55×10^{-9}	2.67×10^{-5}	
Annual dose (µSv) to adults	1.5×10^{-3}	5.6×10^{-6}	6.8×10^{-5}	1.8×10^{-3}	$\sim 3 \times 10^{-3}$	1×10^{-4}
Annual dose (µSv) to children (10 years old)	2.2×10^{-3}	8.5×10^{-6}	1.0×10^{-4}	2.6×10^{-3}	$\sim 5 \times 10^{-3}$	2×10^{-4}

TABLE 11. AN NASIRIYAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INHALATION OF RESUSPENDED SOIL

Quantity	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in soil sample 'Nasir-soil-02-09'	2.10	3×10^{-6}	13.8×10^{-3}	1.11×10^{-4}	2.11	
Annual dose (µSv) to adults	10	0.0030	0.45	12	~ 22	~ 1
Annual dose (µSv) to children (10 years old)	9.8	0.0030	0.45	11	~ 22	~ 1

military vehicles ('Nasir-soil-scraps') and near a tank hit by DU ammunition ('Nasir-soil bombed tank'). Owing to the unique nature of these two samples, they are not considered to be representative of the average composition of the soil that could become resuspended. For this reason, they have not been included in the calculation of the annual doses attributable to soil resuspension. However, it must be observed that, even if they had been included, the resulting doses would not have been substantially changed. In physical terms, this means that, in the case of soil resuspension, where air with resuspended soil from several and sometimes distant locations becomes mixed, the influence of these two unique samples on the average concentration of DU in air is not significant, because of the considerable dilution with air coming from other areas. The situation is different in the case of soil ingestion, as it cannot be excluded that an adult may work or a child play at these precise contaminated spots (see Section 6.2.2).

The sample in which the highest DU concentration was measured ('Nasir-soil-02-09') was used for the calculation of the inhalation dose. The time spent outdoors in a year by hypothetical exposed individuals at this location was assumed to be 3650 h. This occupancy corresponds to adults and children spending about 10 h each day of the year out of doors.

By using the previously reported values of the inhalation rates for adults and children (Table 7), the inhalation doses shown in Table 11 were calculated.

The estimated annual inhalation dose due to DU in this area to both adults and children is about 1 µSv. This is a small radiation dose, about 0.6% of the world average annual dose due to natural radiation (~2.4 mSv/a). In fact, the doses received by any persons living in this vicinity are likely to be much smaller than the estimates in Table 11, because the time that any persons are exposed in a year is likely to be much less than that assumed here and also because of the conservative nature of the dust loading model employed (see Section 4.1).

6.2.2. Doses due to the ingestion of soil

The radiation dose that a person could receive via this pathway by spending 10 d in a year at the most contaminated spot identified in this area can be calculated using the uranium isotope concentrations measured in the sample 'Nasir-soil-scraps'. This sample was collected in the proximity of a tank hit by DU ammunition. The dose estimate based on this measurement is conservative because the measurement is higher than the average levels in soil at An Nasiriyah and, furthermore, it is unlikely that an individual would spend 10 d in a year at exactly the spot where the sample was taken. It is, therefore, a very conservative assumed exposure scenario.

The results of the calculations are shown in Table 12.

6.2.3. Doses due to the ingestion of vegetables and drinking water

6.2.3.1. Vegetables

No vegetation samples were collected.

6.2.3.2. Water

At this location, three water samples were collected from surface water puddles. Although all three samples were found to contain some DU, in two of them, cross-contamination was suspected by the analysts of the Spiez Laboratory. For the purpose of the dose calculation, however, all samples were included. The estimates of radiation doses due to the ingestion of water were made using the sample ‘Nasir-water-01-02’, in which the highest uranium concentration and the highest percentage of DU (12%) were measured (Table 13). This is a conservative calculation because of the suspected cross-contamination and because, in reality, the puddle water is not used for drinking purposes.

Although this is a very conservative calculation, the estimates of dose are low. In fact, the total uranium concentration in the water sample is about five times lower than the WHO guideline value for drinking water of 15 μg/L [22].

6.2.4. Doses due to the ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls)

Forty-four smear samples were collected in this area. In some of them, there was evidence of cross-contamination that probably occurred during the packaging of the samples. One smear sample (‘smear-bombarded tank (outlet)’) was taken at the point/hole at which a DU penetrator exited the wall of the tank. In this sample, the highest DU percentage (99.1%) was measured. The dose estimates based on this sample are reported in Table 14.

The estimated doses are low but, in view of the conservative assumptions made for ingestion from surfaces (see Section 4.6), and taking account of the extreme nature of the sample chosen, they are undoubtedly overestimates.

TABLE 12. AN NASIRIYAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INGESTION OF SOIL *(99.4% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in soil sample ‘Nasir-soil-scraps’	3224	0.0351	6.44	0.0248	3250	
Annual dose (μSv) to adults	0.9	0.002	0.012	0.14	~ 1	~ 1
Annual dose (μSv) to children (10 years old)	2.7	0.006	0.037	0.43	~ 3	~ 3

TABLE 13. AN NASIRIYAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INGESTION OF WATER *(12% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/L) in water sample ‘Nasir-water-01-02’	3.32×10^{-3}	7.1×10^{-6}	2.16×10^{-5}	2.02×10^{-7}	3.35×10^{-3}	
Annual dose (μSv) to adults	1.81	0.78	0.08	2.28	~ 5	~ 1
Annual dose (μSv) to children (10 years old)	2.73	1.19	0.12	3.45	~ 8	~ 2

TABLE 14. AN NASIRIYAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO INGESTION FROM CONTAMINATED SURFACES *(99.1% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Amount in mg present in sample ‘smear-bombarded tank (outlet)’	9.35×10^{-2}	1.12×10^{-4}	1.88×10^{-4}	6.1×10^{-7}	9.29×10^{-2}	
Annual dose (μSv) to adults	5.10	0.012	0.07	0.69	~ 6	~ 6
Annual dose (μSv) to children (10 years old)	7.66	0.019	0.11	1.04	~ 9	~ 9

TABLE 15. AL BASRAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INHALATION OF RESUSPENDED SOIL *(4.2% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in soil sample ‘BASRA-113-soil’	2.60	3.5×10^{-5}	0.0128	1.01×10^{-4}	2.61	
Annual dose (μSv) to adults	13	0.035	0.42	11	~ 24	~ 6
Annual dose (μSv) to children (10 years old)	12	0.035	0.42	10	~ 23	~ 6

6.3. AL BASRAH

6.3.1. Doses due to the inhalation of soil resuspended by wind or human activities

The soil in Al Basrah was sampled in four different AOIs (AOI-1, AOI-2, AOI-3 and AOI-4). A total of 65 soil samples were collected. DU was detected in 26 samples. In AOI-2, no DU was measured. Small amounts of DU were measured in some soil samples taken from AOI-3 and AOI-4. The highest DU concentrations were measured in the soil from AOI-1, where 21 soil samples were collected. Seventeen samples out of 21 were found to contain DU. The highest DU concentrations were found in the four soil samples collected near a tank hit by DU munitions (‘BASRA-115-soil’, ‘BASRA-115-soil a’, ‘BASRA-115-soil b’, ‘BASRA-115-soil c’). However, similarly to the case of An Nasiriyah and for the same reasons given earlier, these samples are not representative and were not used for the calculation.

The inhalation radiation doses were calculated utilizing the concentrations measured in sample ‘BASRA-113-soil’ where the DU percentage was 42.7%. The time spent at the site by hypothetical individuals was assumed to be the same as for An Nasiriyah. Estimated doses from inhalation of resuspended soil are shown in Table 15.

The estimated annual inhalation radiation doses to adults and 10 year old children in Table 16 are very similar to those evaluated for An Nasiriyah.

As an extreme case, the possible inhalation of resuspended contaminated soil that may occur when an abandoned DU contaminated tank is moved from one location to another has been evaluated. The exposed person was assumed not to be wearing a protective mask. Assuming that such an operation would last for 4 h, and that all the dust is generated from the location of the sample (sample ‘BASRA-115-soil c’) where the highest uranium concentration (1901 mg/kg) and DU percentage (10%) were measured, the estimated dose would be about 10 μSv. However, the dust inhaled is most likely to be derived from soils having a uranium concentration that is close to the average of the four samples (‘BASRA-115-soil’, ‘BASRA-115-soil a’, ‘BASRA-115-soil b’, ‘BASRA-115-soil c’), namely, about 700 mg/kg. This concentration corresponds to an inhalation dose of about 3 μSv.

6.3.2. Doses due to the ingestion of soil

Radiation doses due to the ingestion of soil were calculated for an adult working or a child playing near the abandoned tank hit by DU munitions, directly on the spot where the most contaminated soil was measured (sample

TABLE 16. AL BASRAH: ESTIMATED COMMITTED EFFECTIVE DOSES FROM THE INGESTION OF SOIL *(100% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in soil sample 'BASRA-115-soil c'	1901	5.69×10^{-2}	3.12	1.03×10^{-2}	1904	
Annual dose (μSv) to adults	0.52	0.0031	0.0057	0.058	~ 0.6	~ 0.6
Annual dose (μSv) to children (10 years old)	1.6	0.0096	0.017	0.18	~ 2	~ 2

TABLE 17. AL BASRAH: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO INGESTION FROM CONTAMINATED SURFACES *(100% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Amount in mg present in smear sample 'BASRA-115-A-smear-S'	8.50×10^{-2}	2.4×10^{-6}	1.39×10^{-4}	4.80×10^{-7}	8.50×10^{-2}	
Annual dose (μSv) to adults	4.7	0.026	0.051	0.54	~ 5	~ 5
Annual dose (μSv) to children (10 years old)	7.0	0.040	0.078	0.82	~ 8	~ 8

'BASRA-115-soil c'). The radiation doses are given in Table 16. The calculation indicates that even with these pessimistic assumptions, the radiation doses due to ingestion are very low.

6.3.3. Doses due to the ingestion of vegetables and drinking water

6.3.3.1. Vegetables

No vegetation samples were collected.

6.3.3.2. Water

At this location, four water samples were collected. In only two of the samples was DU detected, namely, in 'BASRA-108-water' (from a puddle) with total uranium equal to 1.1 μg/L, and 'BASRA-116-water' (drinking water) with total uranium equal to 0.9 μg/L. For these two samples, the analysing laboratory reported that the presence of DU was probably due to cross-contamination of the samples. However, even if these samples are included, the concentration of all uranium isotopes in all samples is low in comparison to the sample 'Nasir-water-01-02', previously discussed (Table 13). The conclusion can, therefore, be reached that the annual radiation doses from all uranium present will be extremely low.

6.3.4. Doses due to the ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls)

Thirty-four smear samples were collected at this location. In some of them, there was evidence of cross-contamination that probably occurred during the packaging of the samples. The radiation doses from ingestion of DU contaminated dust were calculated using concentrations measured in smear sample 'BASRA-115-A-smear-S', which had the highest DU percentage (~100%) and the highest total U mass. The estimated radiation doses are reported in Table 17.

The estimated doses are low, nevertheless, in view of the conservative assumptions made for ingestion from surfaces (see Section 4.7), and taking account of the extreme nature of the sample chosen, they are undoubtedly overestimates.

6.4. AZ ZUBAYR

6.4.1. Doses due to the inhalation of soil resuspended by wind or human activities

Twenty-two soil samples were collected at this location. DU was measured in nine of them. The most contaminated soil was found at a scrapyard where tanks hit by DU shells and parts of tanks were stored (‘ZUBA-105’). Soil concentrations of up to 590 mg/kg were measured at some points. The median soil concentration at this scrapyard (seven samples, all containing DU) was used to calculate doses due to the inhalation of resuspended soil.

The time spent in a year by hypothetical adults and children at the scrapyard was assumed to be 2000 h. This occupancy corresponds to an adult working at the site for about 6 h each day for the whole year, or working 40 h/week for about 12 months of each year, and corresponds to a child playing in the DU contaminated area for about 6 h each day for one year. Inhalation rates for adults and children used in the calculation are reported in Table 4. Annual inhalation rates used in the assessment are reported in Table 18. Estimated annual doses due to the inhalation of resuspended DU contaminated soil are reported in Table 19.

The estimated radiation doses due to the inhalation of resuspended material at this location are higher than the doses estimated at other locations but, nevertheless, small in comparison with the global natural radiation background (2.4 mSv/a) and in comparison with internationally recommended dose limits for members of the public (1 mSv/a). As previously stated, the assumptions made with respect to occupancy and the modelling of resuspension are such that the doses via this pathway are likely to be significantly overestimated.

6.4.2. Doses due to the ingestion of DU contaminated soil

The radiation doses due to the ingestion of soil at Az Zubayr calculated using the median concentration of the seven samples measured (‘ZUBA-105-soil- (2nd mission)’) are reported in Table 20.

TABLE 18. AZ ZUBAYR: ASSUMED ANNUAL INHALATION RATE AT THE SCRAPYARD

Age group	Annual inhalation rate (m^3/a)
Adults	1680
Children (10 years old)	1280

TABLE 19. AZ ZUBAYR: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INHALATION OF RESUSPENDED SOIL AT THE SCRAPYARD *(94% DU)*

U isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in median ‘ZUBA-105-soil’ samples (‘ZUBA-105-soil-F (2nd Mission)’)	27	5.6×10^{-4}	5.9×10^{-2}	2.9×10^{-4}	27.1	
Annual dose (μSv) to adults	72	0.32	1.06	16.8	~ 90	~ 72
Annual dose (μSv) to children (10 years old)	68	0.30	1.06	16.4	~ 86	~ 70

TABLE 20. AZ ZUBAYR: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO THE INGESTION OF SOIL *(95.4% DU)*

U Isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Concentration (mg/kg) in median ‘ZUBA-105-soil’ samples	27	5.6×10^{-4}	5.9×10^{-2}	2.9×10^{-4}	27.1	
Annual dose (μSv) to adults	0.27	0.0011	0.0040	0.060	~ 0.33	~ 0.3
Annual dose (μSv) to children (10 years old)	0.81	0.0034	0.012	0.18	~ 1	~ 1

6.4.3. Doses due to the ingestion of vegetation and drinking water

6.4.3.1. Vegetation

Fifteen vegetation samples were collected. DU was not detected in any of them.

6.4.3.2. Water

One water sample was collected and no DU was detected in it.

6.4.4. Doses due to the ingestion of DU contaminated dust from flat surfaces (metal, concrete, walls)

Twenty-nine smear samples were collected at this location. In some of them, there was evidence of cross-contamination that probably occurred during the packaging of the samples. One smear sample, 'ZUBA-105-D1-smear Surface Tank (2nd Mission)', was taken from the surface of a tank hit by DU ammunition. In this sample, the highest total uranium concentration and one of the highest DU percentages (>99%) were measured. The radiation doses were calculated using this sample and are reported in Table 21. Although slightly higher than doses estimated at other locations, the values are still low in comparison to natural radiation background.

TABLE 21. AZ ZUBAYR: ESTIMATED COMMITTED EFFECTIVE DOSES DUE TO INGESTION FROM CONTAMINATED SURFACES *(100% DU)*

U Isotope	^{238}U	^{236}U	^{235}U	^{234}U	Total	Dose attributed to DU
Amount in mg present in sample 'ZUBA-105-D1-smear Surface Tank (2nd Mission)'	0.154	7×10^{-7}	3.11×10^{-4}	1.04×10^{-6}	0.154	
Annual dose (μSv) to adults	8.4	0.0077	0.11	1.2	~ 10	~ 10
Annual dose (μSv) to children (10 years old)	13	0.012	0.17	1.8	~ 15	~ 15

7. SUMMARY OF FINDINGS AND CONCLUSIONS

7.1. ESTIMATES OF RADIATION DOSES INSIDE ABANDONED MILITARY VEHICLES HIT BY DU MUNITIONS

The impact of DU munition on an object generates a DU dust cloud, even if the DU penetrator traverses it and does not remain in the object. The impact causes localized ground contamination around the object and surface contamination on the object itself. In general, the surface contamination is not substantial from a radiological perspective, but some precautionary measures are needed when the objects are touched, handled or manipulated by persons.

As explained in Section 4.2, the doses accumulated by individuals who enter vehicles which have been hit by DU ammunition (generally tanks or armed personnel carriers) due to the inhalation of resuspended dust containing residual DU are likely to be higher than those received out of doors due to the inhalation of resuspended contaminated soil. This is due to the relatively higher concentrations of DU that can be present in the dust inside vehicles and because the dust can remain in place longer periods, since there is no mechanism to disperse it. If it is assumed that a person could spend 10 h inside such a vehicle (adults dismantling it or children playing) and the air concentration of DU is maintained at its maximum estimated value, the committed effective doses via inhalation could be of the order of 1 mSv. These doses are higher than most of those evaluated for persons exposed as a result of the contamination found on the ground at various sites and comparable with the global natural radiation background (2.4 mSv/a) and the internationally recommended dose limits for members of the public (1 mSv/a).

7.2. SITE SPECIFIC FINDINGS

7.2.1. As Samawah

At this location, no DU residues were detected in soil. Two destroyed tanks were found at this location. It was concluded from sampling that one of them was not hit by DU munitions, but it is not known whether any other tank was destroyed by DU munitions as no samples were taken.

7.2.2. An Nasiriyah

DU residues were detected in soil at this location. However, the DU concentrations in soil are low. Upper estimates of the annual doses to adults and children due to the possible inhalation of DU present in the soil are about 1 μSv; doses via ingestion pathways are of the same order. DU was also detected in the scrapyard at this location where local people have been active in steel recycling. Smear tests taken from the surfaces of battle tanks and other military equipment showed evidence of the presence of DU contamination — confirming that the surfaces of tanks hit by DU ammunition become contaminated. The maximum estimated annual radiation dose due to the possible ingestion of DU from contaminated surfaces is about 9 μSv.

7.2.3. Al Basrah

At this location, DU residues were detected in soil. However, the concentrations were low and the maximum estimated annual doses as a result of the possible inhalation of DU present in soil were about 6 μSv; estimated doses due to the ingestion of vegetables, water and soil are less than this. DU was also detected on walls and surfaces of tanks in the area. Maximum possible doses due to the ingestion of DU removed from contaminated walls and surfaces of tanks are about 8 μSv.

7.2.4. Az Zubayr

At this location, DU was detected in the soil samples collected at a scrapyard where tanks hit by DU shells and parts of tanks were stored. Most of the smear tests taken from the battle tanks or other military equipment clearly indicated the presence of DU, and soil spots contaminated with DU were identified with DU concentrations of up to 590 mg/kg. The maximum estimated annual radiation dose due to the inhalation of resuspended soil is about 70 μSv. The radiation doses due to other possible exposure pathways, i.e. the ingestion of DU from surfaces and soil, are significantly lower than this.

7.3. OVERALL FINDINGS

(1) On the basis of the measurements carried out on the samples collected in this study, and the estimations using the assumptions and parameters of conservative models, the radiation doses from DU do not pose a radiological hazard to the population at the four studied locations in southern Iraq. The estimated annual radiation doses that could arise from exposure to DU residues in the environment are low, always less than 100 μSv in a year and only to a few, if any, individuals, and therefore of little radiological concern. For perspective, the estimated radiation doses are less than those received on average by individuals in the world from natural sources of radiation in the environment (2.4 mSv/a) and below internationally recommended dose limits for members of the public (1 mSv/a). A further perpective on the radiation doses reported here is provided in Appendix V which contains information on radiation doses received by people from different types of voluntary and involuntary exposures.

(2) The estimated radiation doses are far below the action level of 10 mSv/a set out in the Basic Safety Standards [1] as a criterion to establish whether remedial actions are necessary. Therefore, on the basis of this assessment, no remediation measures (involving soil removal, covering, etc.) are necessary at any of the sites investigated.

(3) The results and conclusions given previously were based on site specific information, such as the measurements made at the specific location, the nature of the local terrain and the use to which the area is put (agricultural, urban), and cannot be directly extrapolated to other locations in Iraq where DU ammunition was used. However, it is likely that the general picture is similar at other locations in Iraq where DU was used in the 2003 conflict. The conclusions reached in the studies of the radiological situation in Kuwait [2] and in the Balkans [10] were similar to those of this report, and support the conclusion that the radiological impact of the firing of DU munitions is also likely to be generally low in other parts of Iraq.

(4) The doses that could be accumulated by individuals who enter abandoned vehicles which have been hit by DU ammunition may be higher than those from DU in the environment due to the inhalation of residual dust containing DU inside the vehicles. It should be recognized that such vehicles may present an inhalation hazard and members of the public should be prevented from entering them.

(5) Although very few DU penetrators or DU penetrator fragments were identified during the sampling campaign, it cannot be excluded that they might be found and collected by members of the public in areas where DU munitions were used. Individuals who handle DU penetrators or fragments could be exposed to external radiation. Although the radiation dose would become significant only if the person exposed were to be in direct contact with DU munitions or fragments for a considerable period of time, the handling of DU penetrators or fragments should be kept to a minimum, and protective gloves should be worn when DU munitions are being handled. Used DU munitions or fragments should be considered and managed as LLRW.

(6) If military vehicles which have been hit by DU munitions are reprocessed for scrap, exposure may occur during the various scrap metal handling and treatment processes. For this reason, metal from vehicles hit by DU munitions should not be used as scrap metal unless specially equipped melting facilities are available. Rather, the vehicles should be directly disposed of (i.e. without decontamination) as LLRW.

Appendix I

DESCRIPTION OF THE FOUR LOCATIONS INVESTIGATED AND OF THE MAJOR BATTLES THAT TOOK PLACE THERE

The information in this appendix was taken from documentation provided to the IAEA by UNEP.

I.1. AS SAMAWAH

As Samawah has a population of approximately 180 000 inhabitants and is located about 250 km south of Baghdad along the main road that links the port of Umm Qasr in the south to Baghdad. The town is split at its northern end by the Euphrates River. Several bridges link both sides of the town together. One main bridge connecting both sides of the town's main road was subject to heavy fighting in 2003 between Iraqi forces and the Coalition Forces. The major fighting is thought to have taken place on both the south and north sides of the bridge. A cement factory is located to the south-east of the town and was believed to have been used as a strategic location for protection of the main bridge by Iraqi tanks. Tanks were placed south and south-east of the factory in order to provide protection to the main bridge located about 1.5 km away (the approximate firing range of a T-72 tank). The main road continues southwards from the main bridge and curves eastwards for 3–4 km from the main bridge. It is believed that a number of Iraqi tanks were placed along both sides of the road to give protection to the main bridge and town. The sites described comprise the main areas of the current study. Iraqi T-72 tanks are thought to have been placed at and around each of these sites. Although the number of tanks is not known, estimates (based on reports and on common conflict strategies) indicate that about 50 Iraqi tanks were used during the As Samawah battle. Several A-10 Thunderbolt II ('Warthog') aircraft attacks are believed to have targeted these sites between 29 March and 2 April 2003. The exact number of attacks is unknown, but reports mention six A-10 'Warthog' attacks and 305 tank rounds. It is known that, in one A-10 attack, up to 2000 DU penetrators can be dropped on the target and its surroundings. The directions of flight of the A-10 planes are unknown.

Four AOIs were investigated within As Samawah, including the area surrounding the main bridge, the main road (upper section), the cement factory and the main road (lower section). Additional investigations were conducted in areas where DU contamination was suspected based on field observations. These areas included vacant land on the outskirts of As Samawah, the train station in the Al-Khafora region, a scrapyard near the cement factory, and areas in which piles of waste and debris were observed. Intact and bombed tanks were observed at several of these locations. Smear and soil samples were collected from the tanks and the immediate areas. A total of 202 samples was collected in the five AOIs (including the additional investigation points), with the following breakdown: 71 soil samples, 10 water samples, 106 smear samples and 15 vegetation samples.

I.1.1. As Samawah — AOI-1

AOI-1 is within an urban area, and the predominant land uses are commercial and residential (Table 22). The ground surface cover consists of paved roads and bridges, bare sandy soil and grassy vegetated areas. The Euphrates River is the main body of surface water in this area, and flows from west to east. AOI-1 was subdivided into 13 sampling areas. In each area, soil, water, surface and vegetation samples were collected. A total of 56 samples (14 soil samples, 5 water samples, 30 smear samples and 7 vegetation samples) were collected. No DU fragments were found. DU was measured in 12 of the smear samples, including those taken from wall and horizontal surfaces. However, the mass spectrometric analysis of the packages of samples indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. The results of the DU sampling programme indicate that DU munitions were used in this AOI. The range of the ambient dose rate (1 m above ground) was 0.08–0.16 μSv/h. No DU residues (penetrators, fragments) were found.

TABLE 22. AS SAMAWAH — AOI-1

City/town	As Samawah
Area of interest	AOI-1
Description	Area surrounding the main bridge
UTM coordinates (centroid)	527990 E 3464442 N
Area size	850 m × 700 m
Investigation dates	5–6 February 2006, 7–8 May 2006
Infrastructure	Two bridges across the Euphrates River, located approximately 530 m apart, linking both sides of the main north–south road, bordered by several buildings
Conflict dates	March–April 2003
Conflict description	Heavy fighting occurred on both the north and south sides of the bridge, including multiple A-10 attacks
Samples	SAMA 101–SAMA 113

I.1.2. As Samawah — AOI-2

TABLE 23. AS SAMAWAH — AOI-2

City/town	As Samawah
Area of interest	AOI-2
Description	The main road (upper section)
UTM coordinates (centroid)	527453 E 3463193 N
Area size	1700 m × 1200 m
Investigation dates	6–7 February 2006, 9 May 2006
Infrastructure	The main north–south road, bordered by buildings to the west and predominantly open space to the east
Conflict dates	March–April 2003
Conflict description	It is believed that Iraqi tanks were positioned along both sides of the road to give protection to the main bridge and the town
Samples	SAMA 201–SAMA 210

Tank positions along the road were subject to A-10 aircraft attacks. AOI-2 is within an urban area, consisting predominantly of commercial and residential properties (Table 23). The ground surface cover consists of paved roads, bare sandy soil and grassy vegetated areas. Traffic along the main road is typically heavy. AOI-2 was subdivided into ten sampling areas. In each area, soil, water, surface and vegetation samples were taken. A total of 39 samples (12 soil samples, 5 water samples, 20 smear samples and 2 vegetation samples) were collected. No DU fragments were found. DU was detected in six of the smear samples, including the ones taken from wall and horizontal surfaces. However, the mass spectrometric analysis of the sample packages indicated a certain degree of cross-contamination of the samples during the fieldwork. The results of the DU sampling programme indicate that DU munitions may have been used in AOI-2. The range of the ambient dose rate (1 m above ground) was 0.06–0.15 μSv/h. No DU residues (penetrators, fragments) were found.

I.1.3. As Samawah — AOI-3

TABLE 24. AS SAMAWAH — AOI-3

City/town	As Samawah
Area of interest	AOI-3
Description	Cement factory
UTM coordinates (centroid)	5286230 E 3462766 N
Area size	2000 m × 1500 m
Investigation dates	5–7 February 2006, 7–8 May 2006
Infrastructure	A cement factory consisting of multiple buildings and roadways
Conflict dates	March–April 2003
Conflict description	It is believed that the cement factory was used as a strategic location by the Iraqi forces for the protection of the main bridge; tanks were placed on the south and south-eastern sides of the factory
Samples	SAMA 301–SAMA 311

Iraqi tanks were placed on the southern and south-eastern sides of the factory and the area was subject to attacks involving the use of DU munitions. AOI-3 is within an abandoned industrial area, consisting of multiple buildings (Table 24). The ground surface cover consists of paved roadways and bare sandy soil. Only very sparse vegetation is present and no surface water was observed. The cement factory is no longer operational and is enclosed by fences. AOI-3 was subdivided into 11 sampling areas. In each area, soil, water, surface and vegetation samples were taken. A total of 38 samples (14 soil samples, 20 smear samples and 4 vegetation samples) were collected. No DU fragments were found. DU was detected in the two smear samples taken from wall and horizontal surfaces approximately 16 m apart. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. The results of the DU sampling programme indicate that DU munitions were used in this AOI. The range of the ambient dose rate (1 m above ground) was 0.03–0.18 μSv/h. No DU residues (penetrators, fragments) were found.

I.1.4. As Samawah — AOI-4

TABLE 25. AS SAMAWAH — AOI- 4

City/town	As Samawah
Area of interest	AOI-4
Description	The main road (lower section)
UTM coordinates (centroid)	5288355 E 3461856 N
Area size	3000 m × 1000 m
Investigation dates	7–12 February 2006, 10 May 2006
Infrastructure	The east–west curve of the main road, sparsely bordered by buildings to the north and south
Conflict dates	March–April 2003
Conflict description	It is believed that Iraqi tanks were positioned along both sides of the road to give protection to the town
Samples	SAMA 401–SAMA 411

The main road in As Samawah curves towards the east for approximately 3 km at the southern edge of the city. Tanks were positioned along both sides of the road to give protection to the town and the main bridge. The area was the site of an intense battle involving the use of DU munitions. AOI-4 consists of predominantly vacant land to the north and south of the main road (Table 25). Sparse residential and commercial buildings are present in the area, and the ground surface cover is primarily bare soil and grassy vegetation. Surface water was not observed in the area. Traffic along this section of the main road is typically heavy. AOI-4 was subdivided into 11 sampling areas. In each area, soil, water, surface and vegetation samples were taken. A total of 32 samples (11 soil samples, 19 smear samples and 2 vegetation samples) were collected. No DU fragments were found. DU was detected in the smear samples taken from wall and horizontal surfaces. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. The results indicate that DU munitions were used in this AOI. The range of the ambient dose rate (1 m above ground) was 0.10–0.18 μSv/h. No DU residues (penetrators, fragments) were found.

I.1.5. As Samawah — Additional investigation points

Additional investigations were conducted in areas where DU contamination was suspected based on field observations (Table 26). These areas included vacant land on the outskirts of As Samawah, the train station in the Al-Khafora region, a scrapyard near the cement factory, and areas in which piles of waste and debris were observed. Intact and bombed tanks were observed at several of these locations. Smear samples were taken from tank surfaces and soil samples were collected in the immediate areas. Railway staff reported that the bombed tanks and cannons present on railway wagons were being transported by railway between several stations, including the Al-Khafora and Al-Khader stations. However, neither their origins nor final destinations were known. A total of 37 samples (20 soil samples and 17 smear samples) were collected at these additional investigation points. DU was detected in all of the smear samples taken from the artillery cannons and the tank surfaces. The range of the ambient dose rate (1 m above ground) was 0.03–0.10 μSv/h. No DU residues (penetrators, fragments) were found.

TABLE 26. AS SAMAWAH — ADDITIONAL INVESTIGATION POINTS

City/town	As Samawah
Area of interest	Additional points
Description	Various areas
UTM coordinates (centroid)	See summary of results See summary of results
Area size	n/a
Investigation dates	7–12 May 2006
Infrastructure	Investigated areas included vacant land, a train station, a scrapyard and areas of waste piles
Conflict dates	March–April 2003
Conflict description	Conflict may have occurred at the various investigated areas
Samples	SAMA-Intact tank-smear-03-S, SAMA-cannon 1-smear-a-S — SAMA-cannon 2-smear-d-S, SAMAWA-sample-a-smear-T, SAMAWA-sample-b-smear-T, SAMAWA-sample-c-smear-T

I.2. AN NASIRIYAH

An Nasiriyah is located on the Euphrates River, approximately 360 km south-east of Baghdad. The city has an estimated population of 560 000. An Nasiriyah is an important crossing point of the Euphrates and a major railroad junction for the area. The predominant industries in the city include date cultivation, aluminium fabrication and shipbuilding. During March and April 2003, An Nasiriyah was the site of intense conflict as Coalition Forces attempted to take control of the city. Confrontations included tank battles and aircraft attacks, including the use of DU munitions. The number of DU rounds used in this area remains unknown. The DU investigations were conducted within the city centre and the surrounding areas, and included samples from bombed tanks and the surrounding soil. A total of 14 AOIs were investigated. A total of 153 samples were collected in 13 AOIs (two could not be sampled) and in the additional investigation points.

I.2.1. An Nasiriyah — AOI-1

TABLE 27. AN NASIRIYAH — AOI-1

City/town	An Nasiriyah
Area of interest	AOI-1
Description	South-east
UTM coordinates (centroid)	621900 E 3412500 N
Area size	1.8 km × 2.4 km
Investigation date	24 July 2006
Infrastructure	Open land south of main road; it includes earth berms for tank defence
Conflict dates	March–April 2003
Conflict description	Tanks were positioned in this area to defend the main road; conflict is believed to have occurred throughout the area
Samples	NASIR 101–NASIR 108

AOI-1 is located south of the city centre, along the main road (Table 27). It is an open, vacant area and includes abandoned agricultural lands. The ground surface cover consists of the main paved road and bare sandy soil. AOI-1 was subdivided into 8 sampling areas. Soil samples were collected from each sampling area. One surface water sample was also collected. A total of 7 samples (6 soil samples and 1 water sample) were collected. No DU fragments were found. DU was detected in the surface water sample collected from a puddle in AOI-1. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the water sample may be the result of cross-contamination. Based on the results of the sampling in AOI-1, the use of DU munitions in this area cannot be confirmed. The range of the ambient dose rate (1 m above ground) was 0.09–0.19 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.2. An Nasiriyah — AOI-2

TABLE 28. AN NASIRIYAH — AOI-2

City/town	An Nasiriyah
Area of interest	AOI-2
Description	South of main road
UTM coordinates (centroid)	614175 E 3413800 N
Area size	1.8 km × 2.4 km
Investigation date	23 July 2006
Infrastructure	Open land, including an abandoned railway and earth berms for tank defence
Conflict dates	March–April 2003
Conflict description	Tanks were positioned in this area to defend the main road; conflict is believed to have occurred throughout the area
Samples	NASIR 201–NASIR 210

AOI-2 is located south of the city centre, south of the main road (Table 28). An abandoned railway is located within this area. AOI-2 is an open, vacant area and includes abandoned agricultural lands. The ground surface cover primarily consists of bare sandy soil. AOI-2 was subdivided into ten sampling areas. Soil samples were collected from each sampling area. A total of ten soil samples were collected. No DU fragments were found. DU was detected in three of the soil samples taken from AOI-2. The range of the ambient dose rate (1 m above ground) was 0.03–0.20 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.3. An Nasiriyah — AOI-3

AOI-3 consists of an open area located to the south of An Nasiriyah (Table 29). AOI-3 was subdivided into ten sampling areas. Soil samples were collected from each sampling area. Water and smear samples were collected at selected locations. A total of 12 samples (10 soil samples, 1 surface water sample and 1 smear sample) was collected. No DU fragments were found. DU was detected in one of the soil samples from AOI-3. DU was also detected in a surface water sample collected from a puddle. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU contamination measured in the water sample may be a result of cross-contamination. DU was detected in the smear sample from AOI-3. The results of the sampling programme indicate that activities during the conflict involving the use of DU ammunition were conducted in this area. The range of the ambient dose rate (1 m above ground) was 0.09–0.25 μSv/h. No DU residues (penetrators, fragments) were found.

TABLE 29. AN NASIRIYAH — AOI-3

City/town	An Nasiriyah
Area of interest	AOI-3
Description	Army camp/warehouse
UTM coordinates (centroid)	613900 E 3427500 N
Area size	1.8 km × 2.4 km
Investigation date	25 July 2006
Infrastructure	Open land, includes a former camp and warehouse of the Iraqi Army
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 301–NASIR 310

I.2.4. An Nasiriyah — AOI-4

AOI-4 consists of an open area located to the south of An Nasiriyah and includes a former munitions storehouse, and was subdivided into ten sampling areas (Table 30). Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 12 samples (10 soil samples and 2 smear samples) was collected. No DU fragments were found. DU was detected in one of the ten soil samples from AOI-4. DU was detected in one of the two smear samples taken from walls of the former munitions storehouse facility. The results indicate that DU munitions were used in this area. The range of the ambient dose rate

(1 m above ground) was 0.10–0.19 μSv/h. No DU residues (penetrators, fragments) were found.

TABLE 30. AN NASIRIYAH — AOI-4

City/town	An Nasiriyah
Area of interest	AOI-4
Description	Munitions storehouse
UTM coordinates (centroid)	611500 E 3427500 N
Area size	1.8 km × 2.4 km
Investigation date	25 July 2006
Infrastructure	Open land; it includes a former munitions storehouse
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 401–NASIR 410

I.2.5. An Nasiriyah — AOI-5 and AOI-6

Investigations were planned for two AOIs located to the south of An Nasiriyah, but no samples were taken for security reasons.

I.2.6. An Nasiriyah — AOI-7

AOI-7 primarily consists of an open area located to the south of An Nasiriyah (Table 31). The area includes a former munitions storehouse facility, with associated roads and buildings. AOI-7 was subdivided into ten sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 12 samples (10 soil samples and 2 smear samples) was collected. No DU fragments were found. DU was detected in three of the ten soil samples and in both the smear samples. The results indicate that DU munitions were used in this area. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the smear samples had occurred during the fieldwork. Therefore, the DU contamination measured in the smear samples may be the result of cross-contamination. The range of the ambient dose rate (1 m above ground) was 0.12–0.38 μSv/h. No DU residues (penetrators, fragments) were found.

TABLE 31. AN NASIRIYAH — AOI-7

City/town	An Nasiriyah
Area of interest	AOI-7
Description	Munitions storehouse
UTM coordinates (centroid)	610400 E 3430000 N
Area size	1.8 km × 2.4 km
Investigation date	25 July 2006
Infrastructure	Open land; it includes a former munitions storehouse and road
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 701–NASIR 710

I.2.7. An Nasiriyah — AOI-8

TABLE 32. AN NASIRIYAH — AOI-8

City/town	An Nasiriyah
Area of interest	AOI-8
Description	South-west of city
UTM coordinates (centroid)	600250 E 3429100 N
Area size	1.8 km × 2.4 km
Investigation date	24 July 2006
Infrastructure	Open land, near a former Coalition military camp, east of the main road
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 801–NASIR 810

AOI-8 consists of an open area located to the south-west of An Nasiriyah (Table 32). The area is situated near a former Coalition military camp, and the main road is located at the western edge of AOI-8. AOI-8 was subdivided into ten sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 14 samples (10 soil samples and 4 smear samples) was collected in this AOI. DU was detected in one of the ten soil samples. DU was also detected in one of the four smear samples. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU contamination measured in the smear samples may be a result of cross-contamination. The results of the samples collected indicate that some activity involving DU ammunition had taken place in this area. The range of the ambient dose rate (1 m above ground) was 0.10–0.22 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.8. An Nasiriyah — AOI-9

TABLE 33. AN NASIRIYAH — AOI-9

City/town	An Nasiriyah
Area of interest	AOI-9
Description	South-west of city
UTM coordinates (centroid)	600700 E 3434150 N
Area size	1.8 km × 2.4 km
Investigation date	26 July 2006
Infrastructure	Open land, near former Coalition military camp, east of the main road
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 901–NASIR 909

AOI-9 consists of an open area located to the south-west of An Nasiriyah (Table 33). The area is located near a former Coalition military camp. AOI-9 was subdivided into eight sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 10 samples (8 soil samples and 2 smear samples) was collected. No DU fragments were found. None of the soil samples contained DU. DU was detected in one of the two smear samples. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU contamination measured in the smear samples may be a result of cross-contamination. The results do not provide a clear indication that DU munitions were used in this area. The range of the ambient dose rate (1 m above ground) was 0.12–0.19 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.9. An Nasiriyah — AOI-10

TABLE 34. AN NASIRIYAH — AOI-10

City/town	An Nasiriyah
Area of interest	AOI-10
Description	West of city, south of Euphrates River
UTM coordinates (centroid)	604700 E 3438800 N
Area size	1.8 km × 2.4 km
Investigation date	26 July 2006
Infrastructure	Open land south of the Euphrates River; it includes various roadways
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 1001–NASIR 1007

AOI-10 consists of an open area located to the west of An Nasiriyah, south of the Euphrates River (Table 34). AOI-10 was subdivided into seven sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 9 samples (7 soil samples and 2 smear samples) was collected in this AOI. No DU fragments were found. None of the soil samples contained DU. There was no DU present in the analysed smear samples. The results indicate that no DU ammunition was used in this area. The range of the ambient dose rate (1 m above ground) was 0.09–0.20 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.10. An Nasiriyah — AOI-11

TABLE 35. AN NASIRIYAH — AOI-11

City/town	An Nasiriyah
Area of interest	AOI-11
Description	North of city
UTM coordinates (centroid)	619700 E 3439700 N
Area size	1.8 km × 2.4 km
Investigation date	24 July 2006
Infrastructure	Northern edge of urban area includes residential, commercial and industrial properties, as well as roads and waterways
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area, and primarily in the vicinity of the bridge across the waterway
Samples	NASIR 1101–NASIR 1109

AOI-11 is located at the northern edge of the urban area of An Nasiriyah (Table 35). The DU investigation focused on the areas surrounding the main north–south road and the bridge across the waterway. Samples were also collected from an open area located to the north-east of the bridge. AOI-11 was subdivided into nine sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 14 samples (9 soil samples and 5 smear samples) were collected in this AOI. No DU fragments were found. DU was detected in one of the nine soil samples. DU was detected in three of the five smear samples, including wall and horizontal surface samples. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the smear samples may be the result of cross-contamination. The results indicate that DU ammunition was used in this area. The range of the ambient dose rate (1 m above ground) was 0.10–0.38 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.11. An Nasiriyah — AOI-12

TABLE 36. AN NASIRIYAH — AOI-12

City/town	An Nasiriyah
Area of interest	AOI-12
Description	City centre
UTM coordinates (centroid)	619400 E 3435450 N
Area size	1.8 km × 2.1 km
Investigation date	25 July 2006
Infrastructure	Urban area, includes residential, commercial and industrial properties, as well as roadways; the Euphrates River flows from west to east and three bridges crossing the river are located within AOI-12
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area, and primarily along the main roads and in the vicinity of the bridges across the Euphrates River
Samples	NASIR 1201–NASIR 1216

AOI-12 is located within the urban area of An Nasiriyah (Table 36). The DU investigation focused on the areas surrounding the main roadways and the bridges across the Euphrates River. Also investigated was a former Iraqi military camp located to the south of the river. AOI-12 was subdivided into 16 sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. A total of 26 samples (13 soil samples and 13 smear samples) was collected. No DU fragments were found. None of the soil samples contained DU. DU was detected in eight of the 13 smear samples. These samples were collected from areas near the main roads, near bombarded houses and bridges. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the smear samples may be the result of cross-contamination. The range of the ambient dose rate (1 m above ground) was 0.10–0.22 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.12. An Nasiriyah — AOI-13

TABLE 37. AN NASIRIYAH — AOI-13

City/town	An Nasiriyah
Area of interest	AOI-13
Description	South of city
UTM coordinates (centroid)	620850 E 3430900 N
Area size	1.8 km × 2.4 km
Investigation date	26 July 2006
Infrastructure	Area south of the city, primarily industrial properties and open land
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	NASIR 1301–NASIR 1306

AOI-13 is located to the south of An Nasiriyah, in a primarily industrial area with open land and bare, sandy soil (Table 37). A main road runs north–south through AOI-3. The remains of a bombed tank were also identified in the area. The DU investigation focused on the areas surrounding the main road and on the bombed tank. AOI-13 was subdivided into six sampling areas. Soil samples were collected from each sampling area. Smear samples were collected at selected locations. None of the soil samples was found to contain DU. DU was detected in three of the five smear samples collected, including both wall and horizontal surface samples. These samples were collected from areas near the main road, and in open areas. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the smear samples may be the result of cross-contamination. The range of the ambient dose rate (1 m above ground) was 0.01–0.08 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.13. An Nasiriyah — AOI-14

TABLE 38. AN NASIRIYAH — AOI-14

City/town	An Nasiriyah
Area of interest	AOI-14
Description	North-east of city
UTM coordinates (centroid)	622500 E 3439300 N
Area size	1.8 km × 1.8 km
Investigation date	23 July 2006
Infrastructure	North-east edge of the city; it includes a main north–south road and a bridge across the waterway; primarily open land, forested areas and wetlands
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred primarily along the main roadway
Samples	NASIR 1401–NASIR 1406

AOI-14 is located to the north-east of An Nasiriyah, along a main north–south road with a bridge across the waterway (Table 38). The area is primarily open land and wetlands, although the south-west corner of AOI-14 includes residential areas. The DU investigation focused on the areas surrounding the main road and bridge. AOI-14 was subdivided into 6 sampling areas. Soil samples were collected from each sampling area. Surface water and smear samples were collected at selected locations. A total of 9 samples (5 soil samples, 1 surface water sample and 3 smear samples) was collected in this AOI. No DU fragments were found. None of the soil samples was found to contain DU. DU was detected in the surface water sample. DU was detected in all three smear samples collected, including both wall and horizontal surface samples. These samples were collected from surfaces on and near the bridge. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the smear samples may be the result of cross-contamination. Nevertheless, the puddle water analysed indicates that some DU ammunition was used in this area. The range of the ambient dose rate (1 m above ground) was 0.11–0.22 μSv/h. No DU residues (penetrators, fragments) were found.

I.2.14. An Nasiriyah — Additional investigation points

TABLE 39. AN NASIRIYAH — ADDITIONAL INVESTIGATION POINTS

City/town	An Nasiriyah
Area of interest	Additional points
Description	City area
UTM coordinates of bombed tank	620617 E 3431554 N
UTM coordinates of scrapyard	619503 E 3429394 N
Investigation date	26 July 2006
Infrastructure	One bombed tank located in the northern part of the city and one scrapyard located south of the city
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred at the location of the bombed tank, but not in the area of the scrapyard
Samples	Nasir-soil-scraps, Nasir-soil-bombarded tank, smear-bombarded tank (entry), smear-bombarded tank (outlet), smear-scraps A–smear-scraps C

A total of 7 samples (2 soil samples and 5 smear samples) was collected at the additional investigation points (Table 39). DU was detected in all the soil and smear samples collected. DU was measured on most of the surfaces of the tanks or the military equipment in the scrapyard where local people are conducting steel recycling. In addition, residual PCBs and hydraulic oils are present at this site. The range of the ambient dose rate (1 m above ground) was 0.11–0.22 μSv/h. DU residues were found on and near the investigated military equipment.

I.3. AL BASRAH

Al Basrah, located on the west bank of Shatt Al-Arab waterway, is the second largest city in Iraq, with an estimated population of 2.6 million. The city is situated approximately 55 km from the Persian Gulf, 550 km south-east of Baghdad. Al Basrah is the main port in Iraq, and is the terminal point for oil pipelines. Intense conflict occurred in and around Al Basrah in 2003 as Coalition Forces advanced into the city. Multiple tank battles and aircraft attacks were reported in the area, including the use of DU munitions. The DU investigations focused on areas south of the city centre and the city's southern suburbs. A total of four AOIs were investigated. A total of 103 samples were collected in the four AOIs, with the following breakdown: 65 soil samples, 4 water samples and 34 smear samples.

I.3.1. Al Basrah — AOI-1

TABLE 40. AL BASRAH — AOI-1

City/town	Al Basrah
Area of interest	AOI-1
Description	North-west quadrant
UTM coordinates (centroid)	767050 E 3374750 N
Area size	4.2 km × 2.7 km
Investigation dates	21–22 June 2006
Infrastructure	Urban area including the main south-west–north-east road; it includes industrial, commercial and residential areas
Conflict dates	March–April 2003
Conflict description	Heavy fighting primarily occurred along the main road, but included locations throughout the area
Samples	BASRA 101–BASRA 118

AOI-1 is located south of the city centre (Table 40). Between 25 March and 6 April 2003, the area was the location of an intense battle involving tanks and air strikes. DU munitions were reportedly used during the conflict, but the number of rounds is unknown. AOI-1 is within an urban area and the predominant land uses are industrial, commercial and residential. The ground surface cover consists of paved roads, bare sandy soil and grassy vegetated areas. AOI-1 was subdivided into 18 sampling areas. Soil samples were collected from each sampling area. Water and smear samples were collected at selected locations. A total of 39 samples (21 soil samples, 2 water samples and 16 smear samples) were collected. DU was detected in all 16 of the smear samples collected, including wall and horizontal surface samples. The results of the smear samples confirm the use of DU munitions in this AOI. The range of the ambient dose rate (1 m above ground) was 0.06–0.25 μSv/h. No DU residues (penetrators, fragments) were found.

I.3.2. Al Basrah — AOI-2

TABLE 41. AL BASRAH — AOI-2

City/town	Al Basrah
Area of interest	AOI-2
Description	North-east quadrant
UTM coordinates (centroid)	771150 E 3374750 N
Area size	4.2 km × 2.7 km
Investigation dates	22–23 June 2006
Infrastructure	Urban area including the main east–west road; it includes industrial, commercial and residential areas
Conflict dates	March–April 2003
Conflict description	Heavy fighting primarily occurred along the main road
Samples	BASRA 201–BASRA 211

This is an urban area located south of the city centre. Conflicts primarily occurred along the main east–west road. DU munitions were reportedly used during the battle, but the number of rounds is unknown. The land is for industrial, commercial and residential uses. The ground surface cover consists of paved roads, bare sandy soil and grassy vegetated areas. The area was subdivided into 11 sampling areas, based on the available conflict information and inferred areas of interest. Soil samples were collected from each sampling area, and water and smear samples were collected at selected locations. A total of 17 samples (11 soil samples, 1 water sample and 5 smear samples) were collected. DU was identified in all the smear samples, including the ones collected on wall and horizontal surfaces. This indicated that a certain number of DU munitions were used in the area. However, the mass spectrometric analysis of the sample packages indicated that a certain cross-contamination of filter material occurred during the fieldwork. The range of the ambient dose rate (1 m above ground) was 0.10–0.25 μSv/h. No DU residues (penetrators, fragments) were found.

I.3.3. Al Basrah — AOI-3

TABLE 42. AL BASRAH — AOI-3

City/town	Al Basrah
Area of interest	AOI-3
Description	South-east quadrant
UTM coordinates (centroid)	771150 E 3372150 N
Area size	4.2 km × 2.7 km
Investigation dates	23–24 June 2006
Infrastructure	Industrial, commercial and residential properties on the western side of the area, vacant land on the eastern side of the area
Conflict dates	March–April 2003
Conflict description	It is believed that conflict occurred throughout the area
Samples	BASRA 301–BASRA 314

AOI-3 includes the edge of the urban area in Al Basrah (Table 42). Industrial, commercial and residential neighbourhoods are located at the western side. The area was subdivided into 14 sampling areas. Soil samples were collected from each sampling area. Water and smear samples were collected at selected locations. A total of 17 samples were collected (14 soil samples, 1 water sample and 2 smear samples). DU was detected in both of the smear samples collected from AOI-3. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU contamination measured in the smear samples may be a result of cross-contamination. The results of the measurements indicate that DU munitions may have been used in this AOI. The range of the ambient dose rate (1 m above ground) was 0.09–0.226 µSv/h. No DU residues (penetrators, fragments) were found.

I.3.4. Al Basrah — AOI-4

TABLE 43. AL BASRAH — AOI-4

City/town	Al Basrah
Area of interest	AOI-4
Description	South-west quadrant
UTM coordinates (centroid)	767050 E 3372150 N
Area size	4.2 km × 2.7 km
Investigation dates	24–25 June 2006
Infrastructure	Urban area, including the main south-west–north-east road; it includes industrial, commercial and residential areas
Conflict dates	March–April 2003
Conflict description	Heavy fighting primarily occurred along the main road, but included locations throughout the area
Samples	BASRA 401–BASRA 419

The area is located to the south-west of the city centre (Table 43). AOI-4 is within an urban area, and the predominant land uses are industrial, commercial and residential. The ground surface cover consists of paved roads, bare sandy soil and grassy vegetated areas. The area was subdivided into 19 sampling areas and a total of 30 samples was collected, comprising 19 soil samples, one from each sampling area, and 11 smear samples from selected locations. DU was detected in four of the 19 soil samples. DU was also identified in all the smear samples taken from walls and horizontal surfaces and tank surfaces. However, the mass spectrometric analysis of the sample packages indicated that a certain degree of cross-contamination of the samples had occurred during the fieldwork. Therefore, the DU measured in the smear samples may be a result of cross-contamination. The results of the DU sampling programme indicate that DU munitions have been used in this area. The range of the ambient dose rate (1 m above ground) was 0.09–0.31 µSv/h. No DU residues (penetrators, fragments) were found.

I.4. AZ ZUBAYR

Az Zubayr, with an approximate population of 185 000, is located in south-eastern Iraq, to the south-east of Lake al-Hammar, at the terminus of a railway line to Baghdad. It has long been an important centre of trade with Saudi Arabia and Kuwait, and is approximately 20 km south of the major city of Al Basrah. A former munitions storage facility is also located in Az Zubayr. Az Zubayr was the site of intense conflict in April 2003 as Coalition Forces moved towards Al Basrah. DU munitions were reportedly used during A-10 aircraft attacks throughout the city. Several bombed tanks and tank parts were identified during the field investigations, and soil and surface smear samples were taken from the tanks and surrounding areas. For the purposes of this investigation, the city was considered to be a single AOI. A total of 62 samples was collected in this AOI, with the following breakdown: 22 soil samples, 1 water sample, 29 smear samples and 10 vegetation samples.

I.4.1. Az Zubayr — AOI-1

TABLE 44. AZ ZUBAYR — AOI-1

City/town	Az Zubayr
Area of interest	AOI-1
Description	Locations throughout the city
UTM coordinates (centroid)	4771263 E 3038117 N
Area size	5000 m × 6000 m
Investigation dates	6–9 February 2006, 26 June 2006
Infrastructure	Industrial, commercial and residential areas, including roads, buildings and open areas; several tank parts investigated during 2nd Mission
Conflict dates	March–April 2003
Conflict description	Coalition Forces performed precision strikes at various strategic locations in the city
Samples	ZUBA 101–ZUBA 113, Zubayr 01-02, Zubayr 01-03, Zubayr 01-05 A –Zubayr 01-05 H, Zubayr 01-11

This AOI is within an urban area that includes industrial, commercial and residential land uses. The ground surface cover consists of paved roads, bare sandy soil and grassy areas. Intact and bombed tanks were observed at several locations. Samples of soil were collected from the tanks and the immediate areas. The area was subdivided into 13 sampling areas. In each area, soil, water, surface samples and vegetation were taken. A total of 62 samples (22 soil samples, 1 water sample, 29 smear samples and 10 vegetation samples) was collected. DU was measured in nine of the soil samples, six of which were collected from a military scrapyard area, where bombed tanks and tank parts were being stored (ZUBA-105) and steel recycling operations were being conducted. The other samples were collected from areas identified on the basis of the United Kingdom Ministry of Defence DU shooting coordinates. DU was measured in 27 of the 29 smear samples taken, including those taken from vertical and horizontal surfaces, and tank surfaces. The results confirmed that DU munitions had been used in Az Zubayr. The ambient dose rate (1 m above ground) was about 0.10 μSv/h. DU residues (penetrators, fragments) were found near or on military equipment hit by DU munitions.

Appendix II

IDENTIFICATION OF THE SAMPLING LOCATIONS AND SAMPLING METHODOLOGY

The information reported in this appendix was taken from documentation provided to the IAEA by UNEP.

II.1. IDENTIFICATION OF SAMPLING LOCATIONS

The identification of the sampling locations was performed by UNEP using the following sources of information and criteria:

(1) The exact coordinates of the DU targets fired upon by United Kingdom tanks during the 2003 conflict in Iraq as provided by the Ministry of Defence of the United Kingdom to UNEP on 24 June 2003. These consisted of a list of 51 coordinates and an associated map with Challenger 2 tank DU target points. The amount of DU fired by the United Kingdom during the conflict was around 1.9 t. Information on amounts of DU used by the United Kingdom forces during the conflict in 1990–1991 was also included in the 24 June 2003 correspondence. In that conflict, less than 1 t of DU tank ammunition was used. No data were given on the coordinates of firing points or target sites in that conflict.

(2) Maps illustrating the areas affected by DU in Iraq in general, and specifically in Al Basrah, provided to UNEP by the Iraqi RPC.

(3) Other sources of information such as obtained from extensive Internet searches, media coverage, specialized reports, and proceedings of international seminars and conferences, and details provided by the Coalition Forces.

(4) Expertise in DU investigations gained from previous assessments.

Having identified the tentative locations, UNEP procured high resolution satellite images of these areas on dates both before and after the conflict. Based on this work, a series of maps containing suggested sampling areas was then produced. Typical DU targets included the following:

- Where Iraqi tanks were placed/hidden;
- Where signs of intense fighting were apparent;
- Bridges and locations of military strategic importance, for example, where important damage could be detected.

By means of this process, UNEP was able to define precise sampling areas and sampling points at which DU contamination was thought to be present. The maps with the suggested sampling areas and the additional information were then provided to the staff of the Iraqi RPC to guide them in performing ground verification in the various areas and in the collection of environmental samples.

In order to identify DU contaminated areas and surfaces, and to locate any existing penetrators and/or fragments, the Iraqi RPC sampling staff used field radiological measurements. Global position coordinates were determined using Garmin GPS-12 model type.

The identification of spots contaminated by DU is a complex task. Even when coordinates are known, it is difficult to identify the presence of radiation, even if the observations are performed within a few metres of the source. Moreover, the sources may have been moved in the intervening period (i.e. between the conflict and the time of the survey). Finally, due to the nature of the terrain, sources could have been buried under the ground surface. In this case, radiation signals would no longer be detectable on the surface.

II.2. SAMPLING METHODOLOGY

II.2.1. Soil samples

The following procedure was followed for the collection of soil samples:

- Soil samples ranging from 0 cm to 5 cm depth were collected using a manual corer.

- Each soil sample consisted of at least seven soil cores collected from an area of approximately 2 m × 2 m.
- The soil cores were combined in a double plastic bag and the bags were labelled with the sample code. A sampling form was completed for each sample.
- The typical mass of each composite soil sample was approximately 1 kg. From this total, approximately 250 g of soil was submitted to the Spiez Laboratory.

II.2.2. Vegetation samples

Vegetation sampling focused on grass, vegetables and dates. The collected samples were transported to the RPC laboratory and then shipped to the Spiez Laboratory.

II.2.3. Water samples

In order to verify the presence of DU in drinking water, water samples from private wells and taps were collected, where possible. One litre of water was sampled at each location using a polyethylene bottle. Samples were preserved immediately after sampling according to standard methods. Bottles were labelled, stored and then transported to the Iraqi RPC laboratory, before being shipped to the Spiez Laboratory.

II.2.4. Smear samples

Smear samples on smooth surfaces were collected using dry smear sampling kits from an approximate area ranging from 100 cm^2 to 2500 cm^2. The smear sample was folded and placed in a plastic bag, coded and the corresponding sampling form was filled in. Field blank samples were also collected for quality assurance/quality control purposes. These samples were transported in the field, exposed to atmospheric conditions and subjected to the standard sample handling procedures, but were not used to collect a smear.

The number of AOIs identified at each location and the total number of samples collected varied, according to the region:

- As Samawah: Five AOIs. A total of 202 samples was collected in the AOIs (including the additional investigation points), with the following breakdown: 71 soil samples, 10 water samples, 106 smear samples and 15 vegetation samples.
- An Nasiriyah: 15 AOIs. A total of 153 samples was collected in 13 AOIs (two could not be sampled) and in the additional investigation points.
- Al Basrah: Four AOIs. A total of 103 samples was collected in the AOIs, with the following breakdown: 65 soil samples, 4 water samples and 34 smear samples.
- Az Zubayr: One AOI. A total of 62 samples was collected in this AOI, with the following breakdown: 22 soil samples, 1 water sample, 29 smear samples and 10 vegetation samples.

Appendix III

LABORATORY ANALYSIS AND ANALYTICAL RESULTS

The information reported in this appendix was taken from documentation provided to IAEA by UNEP.

This appendix provides the results of the analyses of the environmental samples collected at the four selected areas in southern Iraq.

The analyses were performed by the Spiez Laboratory. This is a governmental institute of the Swiss Ministry of Defence, Civil Protection and Sports, under the authority of Civil Protection. The Laboratory is focused mainly on nuclear, biological and chemical (NBC) defence related questions. In this field, it has become a reference laboratory for various international organizations. The various departments of the Spiez Laboratory are all accredited in accordance with ISO/IEC 17025. Accredited procedures (ISO/IEC 17025) in Spiez Laboratory's STS 028 Testing Laboratory were implemented to prepare and measure the samples.

Samples of the various media (soil, water, smear samples and vegetation) were prepared for analysis following standard procedures specific to that sample type. Soil samples were dried and homogenized prior to preparation for analysis. Water samples were filtered and acidified with HNO_3. Vegetation samples were dried and separated from the soil and leaves prior to analysis. The smear sample filter papers were leached in HNO_3 and exposed to an ultrasonic bath prior to leachate filtration.

All samples were analysed with a double focusing sector field inductively coupled plasma mass spectrometer (ICP-MS). The ^{238}U concentration in each sample was measured quantitatively with external calibration. The uranium isotopes ^{236}U, ^{235}U and ^{234}U were also measured. The uranium contribution of the chemical reagents was determined by the analysis of blank samples. In the case of the soil, vegetation and smear samples, nitric acid was used as a blank. Distilled water was analysed as a blank for the water samples. The uranium contribution was found to be low enough to be neglected for all blank samples.

The percentage of DU present was calculated from the ^{235}U/^{238}U isotope ratio as follows:

$$DU[\%] = 100 \cdot \frac{R_{U-nat} - R_m}{R_{U-nat} - R_{DU}}$$
$$= 100 \cdot \frac{0.00725 - R_m}{0.00525}$$

R_{U-nat} Isotope ratio ^{235}U/^{238}U of natural U (= 0.00725)

R_{DU} Isotope ratio ^{235}U/^{238}U of depleted U (= 0.002)

R_m Measured isotope ratio ^{235}U/^{238}U of the sample

It should be noted, however, that there is inherent uncertainty in the measurement of uranium isotopes, which corresponds to combined laboratory procedural errors. The detection limit of the percentage of DU of the total uranium was calculated from three times the uncertainty of the isotope ratio ^{235}U/^{238}U.

Small amounts of DU were detected in several of the field blank samples, ranging from 0.2 ng to 10 ng DU per filter. These results highlight the difficulty in obtaining truly representative samples, and in avoiding cross-contamination during the handling of equipment and other samples in the field. Therefore, the results of the sampling programme, particularly those samples in which very low levels of DU were detected, are subject to additional uncertainties related to the field blank results.

The tables given in this appendix, that is, Table 45 Soil Samples, Table 46 Water Samples and Table 47 Vegetation Samples, give the sample codes and the concentrations of ^{238}U, ^{235}U, ^{234}U, ^{236}U, the isotopic mass ratio ^{235}U/^{238}U, the total uranium concentration, the percentage of DU and the total DU concentration in each sample. In Table 48 Surface Samples (Smears), the total masses of ^{238}U, ^{235}U, ^{234}U and ^{236}U detected in the smear sample are reported.

TABLE 45. SOIL SAMPLES

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(μg/g)	± 1σ (μg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(μg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
As Samawah																
SAMA-101-soil-A	1.24	0.08	8.8	0.8	68	13	<	3	0.00723	0.00003	1.25	< DL	—	1.9	< DL	0.024
SAMA-102-soil-A	1.06	0.06	7.6	0.6	60	10	<	7	0.00724	0.00005	1.07	< DL	—	3.1	< DL	0.033
SAMA-103-soil-A	1.58	0.10	11.3	0.9	83	10	<	4	0.00724	0.00003	1.59	< DL	—	1.8	< DL	0.028
SAMA-104-soil-A	1.35	0.08	9.6	0.6	73	11	<	4	0.00721	0.00006	1.36	< DL	—	3.4	< DL	0.047
SAMA-106-soil-A	1.30	0.08	9.3	0.6	70	5	<	2	0.00724	0.00005	1.31	< DL	—	2.9	< DL	0.038
SAMA-107-soil-A	1.46	0.09	10.5	0.6	83	8	<	2	0.00729	0.00002	1.47	< DL	—	1.4	< DL	0.021
SAMA-111-soil-A	1.35	0.08	9.7	0.6	84	7	<	4	0.00728	0.00008	1.36	< DL	—	4.6	< DL	0.062
SAMA-112-soil-A	1.68	0.10	12.0	0.7	98	9	<	5	0.00727	0.00002	1.69	< DL	—	1.2	< DL	0.020
SAMA-202-soil-A	1.01	0.06	7.3	0.5	55	4	<	2	0.00725	0.00003	1.02	< DL	—	2.0	< DL	0.020
SAMA-204-soil-A	1.82	0.11	13.0	0.8	103	10	<	9	0.00726	0.00001	1.84	< DL	—	0.8	< DL	0.015
SAMA-205-soil	1.83	0.11	13.1	0.8	116	24	<	10	0.00725	0.00002	1.84	< DL	—	0.9	< DL	0.017
SAMA-207-soil-A	1.09	0.07	7.9	0.5	68	12	<	22	0.00731	0.00002	1.10	< DL	—	1.0	< DL	0.011
SAMA-208-soil-A	1.51	0.09	10.8	0.7	83	7	<	8	0.00726	0.00003	1.52	< DL	—	1.8	< DL	0.028
SAMA-209-soil-A	1.00	0.06	7.2	0.4	57	5	<	10	0.00728	0.00005	1.01	< DL	—	2.7	< DL	0.028
SAMA-210-soil-A	1.70	0.10	12.0	0.7	98	9	<	7	0.00719	0.00004	1.71	< DL	—	2.0	< DL	0.034
SAMA-301-soil-A	1.50	0.09	10.7	0.7	83	8	<	7	0.00723	0.00004	1.51	< DL	—	2.3	< DL	0.034
SAMA-302-soil-A	1.28	0.08	9.2	0.6	73	7	<	3	0.00727	0.00019	1.29	< DL	—	10.8	< DL	0.140
SAMA-303-soil-A	2.19	0.14	15.5	1.0	134	10	<	4	0.00716	0.00006	2.21	< DL	—	3.3	< DL	0.074

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
SAMA-304-soil-A	1.99	0.12	14.2	0.9	114	10	<	4	0.00721	0.00004	2.01	< DL	—	2.3	< DL	0.046
SAMA-305-soil-A	1.55	0.10	11.1	0.7	88	8	<	9	0.00726	0.00002	1.56	< DL	—	1.1	< DL	0.017
SAMA-306-soil-A	1.50	0.09	10.7	0.7	81	8	<	8	0.00729	0.00003	1.51	< DL	—	1.6	< DL	0.025
SAMA-307-soil-A	1.14	0.07	8.1	0.5	51	13	<	21	0.00727	0.00006	1.14	< DL	—	3.4	< DL	0.039
SAMA-308-soil-A	1.49	0.09	10.7	0.7	88	10	<	7	0.00726	0.00002	1.50	< DL	—	1.1	< DL	0.016
SAMA-309-soil-A	1.23	0.08	8.8	0.6	72	8	<	5	0.00725	0.00002	1.24	< DL	—	1.4	< DL	0.017
SAMA-311-soil-A	1.95	0.12	14.0	0.9	109	11	<	5	0.00730	0.00002	1.96	< DL	—	1.2	< DL	0.024
SAMA-401-soil-A	1.53	0.09	11.0	0.7	88	9	<	3	0.00724	0.00006	1.54	< DL	—	3.3	< DL	0.051
SAMA-403-soil-A	1.74	0.11	12.5	0.8	91	10	<	13	0.00723	0.00006	1.76	< DL	—	3.2	< DL	0.056
SAMA-405-soil-A	1.20	0.07	8.6	0.6	72	7	<	9	0.00723	0.00004	1.21	< DL	—	2.2	< DL	0.026
SAMA-405-soil-B	1.67	0.10	11.9	0.8	88	9	<	16	0.00720	0.00003	1.68	< DL	—	1.6	< DL	0.027
SAMA-406-soil-A	2.15	0.13	15.5	1.0	124	14	<	5	0.00725	0.00007	2.17	< DL	—	4.2	< DL	0.091
SAMA-407-soil-C	1.87	0.11	13.4	0.8	115	10	<	5	0.00724	0.00006	1.88	< DL	—	3.5	< DL	0.065
SAMA-408-soil-A	2.06	0.13	14.8	1.1	125	16	<	12	0.00728	0.00004	2.08	< DL	—	2.2	< DL	0.046
SAMA-411-soil-A	1.40	0.09	10.1	0.9	80	11	<	6	0.00728	0.00005	1.41	< DL	—	2.8	< DL	0.039
As Samawah (2nd Mission)																
SAMA-102-soil-A (2nd Mission)	0.96	0.03	6.8	0.3	46	9	<	7	0.00737	0.00010	0.96	< DL	—	5.5	< DL	0.053
SAMA-103-soil-A (2nd Mission)	1.45	0.04	10.1	0.4	69	13	<	4	0.00714	0.00009	1.46	< DL	—	5.3	< DL	0.077
SAMA-104-soil-A (2nd Mission)	1.55	0.04	11.0	0.5	83	16	<	3	0.00730	0.00009	1.56	< DL	—	5.3	< DL	0.083

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
SAMA-104-soil-B (2nd Mission)	1.46	0.04	10.3	0.4	76	13	<	3	0.00728	0.00010	1.47	< DL	—	5.6	< DL	0.082
SAMA-106-soil-A (2nd Mission)	1.35	0.04	9.5	0.4	65	12	<	3	0.00727	0.00009	1.36	< DL	—	5.1	< DL	0.070
SAMA-112-soil-A (2nd Mission)	1.51	0.05	10.7	0.5	77	14	<	3	0.00727	0.00009	1.52	< DL	—	5.4	< DL	0.082
SAMA-208-soil-A (2nd Mission)	1.37	0.04	9.6	0.4	77	17	<	14	0.00725	0.00010	1.38	< DL	—	5.9	< DL	0.082
SAMA-208-soil-B (2nd Mission)	1.04	0.03	7.3	0.3	56	14	<	13	0.00726	0.00009	1.05	< DL	—	5.0	< DL	0.053
SAMA-209-soil-A (2nd Mission)	1.30	0.04	9.1	0.4	66	13	<	5	0.00720	0.00009	1.31	< DL	—	5.1	< DL	0.067
SAMA-210-soil-A (2nd Mission)	1.97	0.06	13.8	0.6	117	21	<	10	0.00723	0.00009	1.98	< DL	—	5.2	< DL	0.103
SAMA-210-soil-B (2nd Mission)	1.48	0.04	10.4	0.4	83	17	<	8	0.00722	0.00009	1.49	< DL	—	5.1	< DL	0.076
SAMA-301-soil-A (2nd Mission)	1.35	0.04	9.4	0.4	68	16	<	13	0.00716	0.00010	1.36	< DL	—	5.8	< DL	0.079
SAMA-307-soil-A (2nd Mission)	1.08	0.03	7.5	0.3	64	18	<	22	0.00718	0.00011	1.09	< DL	—	6.1	< DL	0.067
SAMA-309-soil-A (2nd Mission)	1.44	0.05	10.1	0.4	81	17	<	7	0.00721	0.00010	1.45	< DL	—	5.7	< DL	0.083
SAMA-311-soil-A (2nd Mission)	1.71	0.05	12.0	0.5	87	16	<	6	0.00719	0.00009	1.73	< DL	—	5.0	< DL	0.086
SAMA-410-soil-A (2nd Mission)	1.31	0.04	9.2	0.4	74	20	<	19	0.00719	0.00009	1.32	< DL	—	5.3	< DL	0.070
SAMA-410-soil-B (2nd Mission)	1.45	0.04	10.0	0.4	79	15	<	8	0.00713	0.00011	1.46	< DL	—	6.4	< DL	0.093
SAMA-411-soil-A (2nd Mission)	1.81	0.05	12.7	0.5	97	18	<	7	0.00720	0.00010	1.82	< DL	—	5.4	< DL	0.099
SAMA-intact tak-soil-01 (2nd Mission)	1.14	0.03	8.1	0.3	50	19	<	27	0.00729	0.00009	1.15	< DL	—	5.1	< DL	0.058
SAMA-intact tak-soil-04 (2nd Mission)	1.35	0.04	9.6	0.4	67	13	<	7	0.00734	0.00010	1.36	< DL	—	5.5	< DL	0.074
SAMA-intact tak-soil-07 (2nd Mission)	1.54	0.04	10.9	0.4	84	17	<	5	0.00731	0.00010	1.55	< DL	—	6.0	< DL	0.093
SAMA-intact tak-soil-08 (2nd Mission)	1.35	0.04	9.6	0.8	70	16	<	7	0.00734	0.00010	1.36	< DL	—	5.8	< DL	0.079

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
SAMA-intact tak-soil-09 (2nd Mission)	1.66	0.04	11.8	0.5	82	15	<	6	0.00732	0.00010	1.67	< DL	—	5.4	< DL	0.091
SAMA-bombarded tank-soil-10 (2nd Mission)	2.21	0.06	15.7	0.7	118	23	<	16	0.00732	0.00010	2.23	< DL	—	5.6	< DL	0.125
SAMA-bombarded tank-soil-11 (2nd Mission)	2.04	0.06	14.5	0.7	120	22	<	9	0.00730	0.00010	2.05	< DL	—	5.6	< DL	0.114
SAMA-bombarded tank-soil-12 (2nd Mission)	1.61	0.05	11.5	0.5	77	17	<	17	0.00734	0.00009	1.62	< DL	—	5.2	< DL	0.085
SAMA-bombarded tank-soil-15 (2nd Mission)	1.93	0.05	13.6	0.6	96	18	<	5	0.00727	0.00009	1.94	< DL	—	5.3	< DL	0.103
SAMA-bombarded tank-soil-16 (2nd Mission)	1.48	0.04	10.4	0.4	75	14	<	6	0.00726	0.00009	1.49	< DL	—	5.1	< DL	0.076
SAMA-bombarded tank-soil-17 (2nd Mission)	1.60	0.05	11.3	0.5	77	17	<	13	0.00729	0.00009	1.61	< DL	—	5.2	< DL	0.084
SAMA-bombarded tank-soil-18 (2nd Mission)	1.84	0.05	13.1	0.5	84	16	<	3	0.00730	0.00010	1.86	< DL	—	5.9	< DL	0.109
SAMA-bombarded tank-soil-19 (2nd Mission)	1.35	0.04	9.6	0.4	65	14	<	4	0.00733	0.00009	1.36	< DL	—	5.3	< DL	0.072
SAMA-bombarded tank-soil-20 (2nd Mission)	1.12	0.03	7.9	0.3	46	15	<	20	0.00728	0.00010	1.13	< DL	—	5.7	< DL	0.064
SAMA-bombarded tank-soil-21 (2nd Mission)	1.89	0.05	13.4	0.5	90	20	<	11	0.00732	0.00010	1.90	< DL	—	5.5	< DL	0.105
SAMA-bombarded tank-soil-22 (2nd Mission)	1.49	0.04	10.6	0.4	76	15	<	7	0.00728	0.00009	1.50	< DL	—	5.3	< DL	0.079
SAMA-bombarded tank-soil-23 (2nd Mission)	1.49	0.04	10.6	0.4	74	15	<	12	0.00732	0.00010	1.50	< DL	—	5.5	< DL	0.083
SAMA-bombarded tank-soil-24 (2nd Mission)	1.60	0.04	11.2	0.5	73	15	<	13	0.00723	0.00009	1.61	< DL	—	5.1	< DL	0.082
SAMA-cannon 1-soil (2nd Mission)	1.22	0.03	8.4	0.3	65	12	<	3	0.00716	0.00009	1.22	< DL	—	5.2	< DL	0.063
SAMA-farm-soil (2nd Mission)	1.46	0.04	10.2	0.4	66	15	<	8	0.00726	0.00012	1.47	< DL	—	6.6	< DL	0.097
Az Zubayr																
ZUBA-102-soil-A	1.10	0.07	7.8	0.5	64	6	<	16	0.00725	0.00005	1.11	< DL	—	2.7	< DL	0.030
ZUBA-103-soil-A	1.21	0.07	7.8	0.5	60	8	<	5	0.00658	0.00003	1.21	13.0	0.6	1.8	0.15	0.022

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(μg/g)	± 1σ (μg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(μg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
ZUBA-104-soil-A	1.00	0.06	7.1	0.4	62	6	<	3	0.00723	0.00006	1.01	< DL	—	3.3	< DL	0.033
ZUBA-105-soil-A	1.04	0.06	7.4	0.5	65	8	<	4	0.00723	0.00005	1.04	< DL	—	2.7	< DL	0.028
ZUBA-106-soil-A	1.48	0.09	10.6	0.7	84	8	<	3	0.00722	0.00003	1.49	< DL	—	1.9	< DL	0.028
ZUBA-107-soil-A	0.71	0.04	5.1	0.3	42	6	<	5	0.00725	0.00003	0.71	< DL	—	1.7	< DL	0.012
ZUBA-108-soil-A	0.99	0.06	7.0	0.4	57	5	<	10	0.00720	0.00006	0.99	< DL	—	3.4	< DL	0.034
ZUBA-109-soil-A	0.65	0.04	4.6	0.3	37	3	<	6	0.00719	0.00005	0.65	< DL	—	2.7	< DL	0.017
ZUBA-110-soil-A	2.77	0.17	19.8	1.2	182	18	<	5	0.00724	0.00002	2.79	< DL	—	1.3	< DL	0.035
ZUBA-111-soil-A	3.46	0.21	24.7	1.5	222	18	<	6	0.00723	0.00004	3.49	< DL	—	2.1	< DL	0.073
ZUBA-112-soil-A	0.72	0.04	5.0	0.3	40	4	3	2	0.00714	0.00003	0.72	2.1	0.5	1.6	0.01	0.012
ZUBA-113-soil-A	1.03	0.06	7.3	0.4	63	6	<	10	0.00723	0.00004	1.03	< DL	—	2.1	< DL	0.021
Az Zubayr (2nd Mission)																
ZUBA-102-soil (2nd Mission)	0.87	0.02	6.2	0.2	53	5	<	3	0.00725	0.00005	0.88	< DL	—	2.8	< DL	0.024
ZUBA-103-soil (2nd Mission)	1.03	0.03	6.7	0.2	52	3	3	1	0.00663	0.00003	1.04	12.0	0.5	1.6	0.12	0.016
ZUBA-105-soil-A (2nd Mission)	0.95	0.02	6.8	0.2	58	4	<	2	0.00725	0.00005	0.95	< DL	—	2.9	< DL	0.028
ZUBA-105-soil-B (2nd Mission)	3.00	0.08	10.8	0.3	65	5	16	3	0.00367	0.00002	3.01	68.2	0.3	1.0	2.05	0.029
ZUBA-105-soil-C (2nd Mission)	591.00	15.00	1182.0	31.0	5778	2995	8372	425	0.00204	0.00003	592.20	99.3	0.1	0.2	588.00	0.992
ZUBA-105-soil-D (2nd Mission)	52.70	1.30	111.0	3.0	401	49	220	32	0.00215	0.00002	52.77	97.2	0.5	1.4	51.28	0.737
ZUBA-105-soil-F (2nd Mission)	27.00	0.80	59.0	2.0	291	14	562	57	0.00224	0.00003	27.10	95.4	0.5	1.5	25.85	0.395
ZUBA-105-soil-G (2nd Mission)	5.80	0.10	16.6	0.4	99	15	114	10	0.00293	0.00001	5.78	82.3	0.1	0.4	4.75	0.023

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
ZUBA-105-soil-H (2nd Mission)	62.10	1.70	129.0	4.0	506	20	414	30	0.00212	0.00001	62.20	97.7	0.2	0.5	60.79	0.283
ZUBA-111-soil (2nd Mission)	2.69	0.07	19.2	0.6	168	13	<	3	0.00726	0.00005	2.71	< DL	—	2.9	< DL	0.079
Al Basrah																
BASRA-101-soil	5.30	0.20	19.5	0.8	145	19	94	10	0.00378	0.00002	5.29	66.2	0.4	1.2	3.50	0.064
BASRA-102-soil	14.80	0.60	35.7	1.5	198	31	361	37	0.00245	0.00003	14.86	91.4	0.5	1.5	13.58	0.217
BASRA-103-soil	1.72	0.07	10.1	0.4	82	12	16	6	0.00601	0.00004	1.73	23.7	0.7	2.0	0.41	0.035
BASRA-104-soil	1.87	0.07	12.3	0.5	88	10	6	2	0.00673	0.00005	1.88	10.0	0.9	2.7	0.19	0.051
BASRA-105-soil	1.63	0.06	11.2	0.5	100	12	<	14	0.00699	0.00004	1.64	5.0	0.7	2.2	0.08	0.036
BASRA-106-soil	1.88	0.07	13.2	0.8	130	21	<	18	0.00716	0.00004	1.90	< DL	—	2.2	< DL	0.042
BASRA-107-soil	1.50	0.06	10.6	0.5	94	9	<	15	0.00719	0.00004	1.51	< DL	—	2.3	< DL	0.035
BASRA-108-soil	1.23	0.05	7.9	0.3	69	11	<	15	0.00653	0.00004	1.23	13.7	0.8	2.3	0.17	0.029
BASRA-109-soil	1.16	0.05	8.1	0.3	67	8	<	12	0.00714	0.00006	1.17	< DL	—	3.2	< DL	0.037
BASRA-110-soil	1.36	0.05	9.6	0.4	83	13	<	18	0.00716	0.00005	1.37	< DL	—	2.9	< DL	0.040
BASRA-111-soil	1.91	0.07	9.9	0.4	79	9	31	4	0.00527	0.00004	1.92	37.7	0.8	2.5	0.72	0.048
BASRA-112-soil	1.42	0.06	8.6	0.3	76	7	27	5	0.00618	0.00005	1.43	20.4	0.9	2.6	0.29	0.037
BASRA-113-soil	2.60	0.10	12.8	0.5	101	10	35	3	0.00501	0.00002	2.61	42.7	0.4	1.1	1.12	0.027
BASRA-114-soil	0.77	0.03	5.0	0.4	39	4	3	1	0.00670	0.00003	0.77	10.5	0.6	1.9	0.08	0.015
BASRA-115-soil	3.50	0.14	12.0	0.5	86	15	75	11	0.00350	0.00001	3.51	71.5	0.2	0.7	2.51	0.026
BASRA-115-soil a	744.00	28.00	1220.0	49.0	4079	598	22225	2211	0.00167	0.00001	745.40	106.3	0.3	0.8	792.00	6.167

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
BASRA-115-soil b	80.80	3.10	138.0	6.0	470	50	2369	214	0.00174	0.00001	80.89	104.9	0.1	0.4	84.84	0.309
BASRA-115-soil c	1901.00	73.00	3122.0	127.0	10273	1043	56931	5192	0.00167	0.00001	1905.00	106.2	0.1	0.4	2023.00	7.449
BASRA-116-soil	1.52	0.06	8.6	0.4	76	11	20	6	0.00577	0.00002	1.53	28.1	0.3	0.9	0.43	0.014
BASRA-117-soil	1.19	0.05	8.0	0.3	65	6	4	1	0.00682	0.00005	1.20	8.3	0.9	2.7	0.10	0.032
BASRA-118-soil	1.39	0.06	8.9	0.4	69	7	6	1	0.00656	0.00002	1.40	13.1	0.5	1.4	0.18	0.019
BASRA-201-soil	1.63	0.07	11.6	0.5	108	14	<	12	0.00727	0.00004	1.64	< DL	—	2.6	< DL	0.042
BASRA-202-soil	1.22	0.05	8.7	0.4	79	10	<	11	0.00729	0.00003	1.23	< DL	—	1.7	< DL	0.021
BASRA-203-soil	1.13	0.04	8.0	0.3	63	8	<	9	0.00725	0.00002	1.14	< DL	—	1.1	< DL	0.012
BASRA-204-soil	1.19	0.05	8.3	0.3	68	12	<	16	0.00725	0.00003	1.18	< DL	—	1.6	< DL	0.019
BASRA-205-soil	1.52	0.06	10.8	0.4	81	13	<	17	0.00728	0.00003	1.53	< DL	—	1.9	< DL	0.029
BASRA-206-soil	1.10	0.04	7.9	0.3	67	12	<	14	0.00730	0.00003	1.11	< DL	—	2.0	< DL	0.022
BASRA-207-soil	1.23	0.05	8.7	0.4	77	8	<	8	0.00724	0.00007	1.24	< DL	—	3.8	< DL	0.047
BASRA-208-soil	0.71	0.03	5.0	0.2	54	15	<	23	0.00729	0.00004	0.71	< DL	—	2.0	< DL	0.014
BASRA-209-soil	1.45	0.06	10.3	0.5	93	12	<	12	0.00730	0.00004	1.46	< DL	—	2.1	< DL	0.031
BASRA-210-soil	1.38	0.05	9.8	0.4	83	15	<	19	0.00727	0.00003	1.39	< DL	—	1.9	< DL	0.026
BASRA-211-soil	1.15	0.05	8.2	0.4	73	10	<	11	0.00724	0.00006	1.16	< DL	—	3.4	< DL	0.040
BASRA-301-soil	1.86	0.07	12.8	0.5	115	14	<	12	0.00705	0.00004	1.87	3.8	0.8	2.3	0.07	0.042
BASRA-302-soil	1.32	0.05	8.5	0.4	80	13	<	17	0.00663	0.00004	1.32	11.8	0.8	2.5	0.16	0.033
BASRA-303-soil	1.26	0.05	8.8	0.4	81	12	<	14	0.00716	0.00005	1.27	< DL	—	2.6	< DL	0.033

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
BASRA-304-soil	2.38	0.09	16.3	0.7	145	15	<	10	0.00702	0.00002	2.40	4.4	0.4	1.3	0.11	0.032
BASRA-305-soil	1.57	0.09	10.8	0.6	93	10	9	3	0.00706	0.00006	1.58	3.6	1.2	3.6	0.06	0.057
BASRA-306-soil	1.56	0.06	11.0	0.5	92	9	<	16	0.00725	0.00003	1.57	< DL	—	1.6	< DL	0.025
BASRA-307-soil	1.79	0.07	12.6	0.6	115	11	<	7	0.00722	0.00006	1.80	< DL	—	3.2	< DL	0.058
BASRA-308-soil	1.68	0.07	12.0	0.5	111	11	<	8	0.00729	0.00002	1.69	< DL	—	1.4	< DL	0.023
BASRA-309-soil	1.63	0.06	11.4	0.5	104	12	<	11	0.00716	0.00002	1.64	1.7	0.3	1.0	0.03	0.017
BASRA-310-soil	1.87	0.07	13.3	0.5	123	14	<	12	0.00725	0.00004	1.89	< DL	—	2.5	< DL	0.048
BASRA-311-soil	1.37	0.05	9.6	0.4	86	12	<	14	0.00719	0.00005	1.38	< DL	—	3.1	< DL	0.043
BASRA-312-soil	1.67	0.08	11.9	0.6	106	13	<	17	0.00729	0.00005	1.68	< DL	—	3.1	< DL	0.052
BASRA-313 soil	1.64	0.06	11.6	0.5	102	12	<	10	0.00724	0.00001	1.65	< DL	—	0.5	< DL	0.009
BASRA-314-soil	1.75	0.07	12.3	0.5	104	12	<	9	0.00723	0.00001	1.76	< DL	—	0.7	< DL	0.013
BASRA-401-soil	1.73	0.07	12.2	0.5	108	12	<	10	0.00722	0.00003	1.75	< DL	—	2.0	< DL	0.035
BASRA-402-soil	1.57	0.06	10.8	0.5	92	10	<	11	0.00703	0.00004	1.58	4.1	0.7	2.2	0.07	0.035
BASRA-403-soil	1.28	0.05	8.9	0.4	69	8	<	12	0.00714	0.00004	1.29	< DL	—	2.5	< DL	0.033
BASRA-404-soil	1.38	0.05	9.8	0.4	82	13	<	18	0.00722	0.00005	1.39	< DL	—	3.0	< DL	0.042
BASRA-405-soil	1.87	0.07	13.1	0.5	114	11	<	14	0.00718	0.00004	1.88	< DL	—	2.2	< DL	0.041
BASRA-406-soil	2.26	0.09	15.7	0.6	145	11	<	10	0.00712	0.00003	2.27	2.4	0.6	1.9	0.06	0.044
BASRA-407-soil	1.13	0.04	8.0	0.3	72	9	<	11	0.00720	0.00007	1.14	< DL	—	3.9	< DL	0.045
BASRA-408-soil	1.71	0.07	11.9	0.5	106	12	<	15	0.00709	0.00009	1.73	< DL	—	5.2	< DL	0.089

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
BASRA-409-soil	0.97	0.04	6.9	0.3	61	6	<	19	0.00719	0.00004	0.98	< DL	—	2.1	< DL	0.020
BASRA-410-soil	1.86	0.07	12.4	0.5	100	9	20	4	0.00681	0.00003	1.87	8.4	0.6	1.9	0.16	0.035
BASRA-411-soil	1.13	0.05	7.8	0.3	67	8	<	11	0.00710	0.00007	1.14	< DL	—	3.8	< DL	0.044
BASRA-412-soil	1.37	0.05	9.4	0.4	74	11	<	15	0.00702	0.00005	1.38	4.4	1.0	2.9	0.06	0.039
BASRA-413-soil	1.59	0.06	11.2	0.5	90	9	<	16	0.00721	0.00004	1.60	< DL	—	2.1	< DL	0.034
BASRA-414-soil	2.90	0.11	20.5	0.8	188	17	<	29	0.00722	0.00004	2.92	< DL	—	2.0	< DL	0.059
BASRA-415-soil	1.76	0.07	12.4	0.5	109	8	<	17.6	0.00720	0.00005	1.77	< DL	—	2.8	< DL	0.050
BASRA-416-soil	1.61	0.06	11.4	0.5	95	8	<	16	0.00721	0.00005	1.62	< DL	—	3.0	< DL	0.049
BASRA-417-soil	1.64	0.07	11.6	0.5	106	9	<	16	0.00720	0.00005	1.65	< DL	—	3.0	< DL	0.049
BASRA-418-soil	1.35	0.05	9.5	0.4	75	6	<	27	0.00717	0.00003	1.36	< DL	—	1.9	< DL	0.026
BASRA-419-soil	1.59	0.06	11.2	0.5	89	8	<	16	0.00723	0.00005	1.60	< DL	—	2.8	< DL	0.044
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Nasir-soil-01-02	1.77	0.08	12.5	0.7	106	12	<	9	0.00730	0.00003	1.78	< DL	—	1.9	< DL	0.033
Nasir-soil-01-04	1.66	0.08	11.8	0.6	90	8	<	5	0.00729	0.00003	1.67	< DL	—	1.5	< DL	0.024
Nasir-soil-01-05	1.30	0.06	9.2	0.5	67	8	<	5	0.00729	0.00001	1.31	< DL	—	0.8	< DL	0.011
Nasir-soil-01-06	1.44	0.07	10.2	0.5	80	9	<	5	0.00729	0.00002	1.45	< DL	—	1.2	< DL	0.017
Nasir-soil-01-07	1.28	0.06	9.1	0.5	68	11	<	15	0.00728	0.00002	1.29	< DL	—	1.1	< DL	0.014
Nasir-soil-01-08	1.51	0.07	10.7	0.6	83	8	<	5	0.00726	0.00003	1.52	< DL	—	1.6	< DL	0.024
Nasir-soil-02-01	1.69	0.08	11.9	0.6	92	10	<	5	0.00726	0.00003	1.70	< DL	—	2.0	< DL	0.034

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-02-02	1.70	0.08	12.0	0.7	94	9	<	6	0.00729	0.00002	1.71	< DL	—	1.0	< DL	0.018
Nasir-soil-02-03	1.56	0.07	11.0	0.6	90	10	<	8	0.00725	0.00002	1.57	< DL	—	1.0	< DL	0.015
Nasir-soil-02-04	1.36	0.07	9.5	0.5	75	7	<	4	0.00724	0.00002	1.37	< DL	—	1.2	< DL	0.017
Nasir-soil-02-05	2.01	0.09	11.8	0.6	90	8	7	2	0.00602	0.00001	2.02	23.4	0.2	0.7	0.47	0.015
Nasir-soil-02-06	1.97	0.09	12.9	0.7	103	12	<	3	0.00674	0.00004	1.99	9.6	0.8	2.4	0.19	0.047
Nasir-soil-02-07	1.95	0.09	13.7	0.7	112	10	<	4	0.00725	0.00004	1.96	< DL	—	2.3	< DL	0.045
Nasir-soil-02-08	1.67	0.08	11.7	0.6	97	10	<	9	0.00724	0.00003	1.68	< DL	—	1.7	< DL	0.028
Nasir-soil-02-09	2.10	0.10	13.8	0.7	111	12	3	2	0.00679	0.00003	2.11	8.7	0.5	1.5	0.18	0.032
Nasir-soil-02-10	1.90	0.09	13.0	0.7	104	8	<	6	0.00711	0.00005	1.91	< DL	—	2.9	< DL	0.055
Nasir-soil-03-01	1.79	0.09	13.0	0.6	108	11	<	4	0.00725	0.00002	1.80	< DL	—	1.2	< DL	0.021
Nasir-soil-03-02	2.26	0.11	16.0	0.8	140	11	<	8	0.00724	0.00003	2.28	< DL	—	1.5	< DL	0.034
Nasir-soil-03-03	1.66	0.08	11.8	0.6	96	10	<	7	0.00727	0.00003	1.68	< DL	—	1.5	< DL	0.025
Nasir-soil-03-04	2.32	0.11	16.4	0.9	148	15	<	5	0.00726	0.00004	2.33	< DL	—	2.2	< DL	0.051
Nasir-soil-03-05	3.04	0.14	21.5	1.1	196	14	<	9	0.00726	0.00003	3.06	< DL	—	1.6	< DL	0.048
Nasir-soil-03-06	1.77	0.08	12.4	0.6	103	11	<	8	0.00719	0.00002	1.78	< DL	—	1.3	< DL	0.024
Nasir-soil-03-07	2.00	0.09	14.1	0.7	119	9	<	7	0.00723	0.00002	2.02	< DL	—	1.3	< DL	0.027
Nasir-soil-03-08	1.51	0.07	10.5	0.5	91	11	<	18	0.00715	0.00003	1.52	2.0	0.5	1.5	0.03	0.023
Nasir-soil-03-09	2.04	0.10	14.4	0.7	132	15	<	7	0.00725	0.00004	2.06	< DL	—	2.1	< DL	0.043
Nasir-soil-03-10	2.07	0.10	14.5	0.7	125	9	<	14	0.00720	0.00008	2.08	< DL	—	4.6	< DL	0.096

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-04-01	2.08	0.10	14.3	0.7	112	9	<	12	0.00703	0.00002	2.10	4.3	0.4	1.1	0.09	0.022
Nasir-soil-04-02	1.83	0.09	12.9	0.7	103	8	<	18	0.00722	0.00003	1.84	< DL	—	1.7	< DL	0.031
Nasir-soil-04-03	1.70	0.08	12.0	0.6	97	11	<	17	0.00725	0.00003	1.71	< DL	—	1.5	< DL	0.025
Nasir-soil-04-04	1.29	0.06	9.1	0.5	79	9	<	19	0.00722	0.00004	1.30	< DL	—	2.0	< DL	0.026
Nasir-soil-04-05	2.01	0.10	14.3	0.7	118	10	<	18	0.00727	0.00002	2.03	< DL	—	1.1	< DL	0.022
Nasir-soil-04-06	1.72	0.08	12.2	0.6	100	7	<	3	0.00728	0.00003	1.73	< DL	—	1.9	< DL	0.033
Nasir-soil-04-07	1.68	0.08	12.0	0.7	104	10	<	4	0.00727	0.00008	1.70	< DL	—	4.4	< DL	0.075
Nasir-soil-04-08	1.66	0.08	11.8	0.8	98	8	<	8	0.00726	0.00003	1.67	< DL	—	1.7	< DL	0.029
Nasir-soil-04-09	1.49	0.07	10.6	0.5	89	7	<	6	0.00727	0.00003	1.50	< DL	—	1.5	< DL	0.022
Nasir-soil-04-10	1.75	0.08	12.4	0.6	106	6	<	3	0.00724	0.00007	1.77	< DL	—	4.0	< DL	0.070
Nasir-soil-07-01	1.99	0.09	13.2	0.7	114	7	<	4	0.00679	0.00004	2.00	8.7	0.8	2.4	0.17	0.049
Nasir-soil-07-02	1.63	0.08	11.6	0.6	97	7	<	3	0.00725	0.00004	1.64	< DL	—	2.1	< DL	0.034
Nasir-soil-07-03	1.71	0.08	12.1	0.6	100	7	<	5	0.00723	0.00003	1.72	< DL	—	1.6	< DL	0.027
Nasir-soil-07-04	1.98	0.10	14.0	0.7	114	10	<	4	0.00720	0.00006	2.00	< DL	—	3.3	< DL	0.065
Nasir-soil-07-05	1.82	0.09	12.9	0.6	112	9	<	12	0.00723	0.00004	1.84	< DL	—	2.3	< DL	0.043
Nasir-soil-07-06	1.56	0.07	10.9	0.5	90	7	<	3	0.00719	0.00002	1.57	< DL	—	1.4	< DL	0.022
Nasir-soil-07-07	2.08	0.10	14.4	0.7	121	11	<	4	0.00710	0.00003	2.09	2.9	0.6	1.9	0.06	0.040
Nasir-soil-07-08	2.00	0.10	13.8	0.7	117	8	<	3	0.00708	0.00004	2.01	3.3	0.8	2.4	0.07	0.048
Nasir-soil-07-09	1.78	0.08	12.6	0.6	107	7	<	9	0.00725	0.00003	1.79	< DL	—	1.5	< DL	0.027

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-07-10	1.50	0.07	10.6	0.5	88	6	<	6	0.00722	0.00003	1.51	< DL	—	1.7	< DL	0.025
Nasir-soil-08-01	1.48	0.07	10.4	0.5	86	9	<	16	0.00720	0.00005	1.49	< DL	—	3.1	< DL	0.046
Nasir-soil-08-02	1.00	0.05	6.9	0.4	56	8	<	18	0.00710	0.00008	1.01	< DL	—	4.6	< DL	0.046
Nasir-soil-08-03	1.24	0.06	8.6	0.4	73	9	<	22	0.00712	0.00004	1.24	2.5	0.8	2.3	0.03	0.029
Nasir-soil-08-04	1.29	0.06	9.1	0.5	68	12	<	24	0.00720	0.00004	1.30	< DL	—	2.4	< DL	0.032
Nasir-soil-08-05	1.20	0.06	8.4	0.4	61	10	<	20	0.00719	0.00008	1.20	< DL	—	4.7	< DL	0.056
Nasir-soil-08-06	1.19	0.06	8.4	0.4	64	9	<	14	0.00722	0.00005	1.20	< DL	—	3.1	< DL	0.037
Nasir-soil-08-07	1.45	0.07	10.3	0.5	83	9	<	10	0.00724	0.00005	1.46	< DL	—	2.6	< DL	0.038
Nasir-soil-08-08	1.44	0.07	10.2	0.5	82	9	<	8	0.00724	0.00004	1.45	< DL	—	2.4	< DL	0.035
Nasir-soil-08-09	1.57	0.07	11.2	0.5	89	9	<	11	0.00727	0.00004	1.58	< DL	—	2.3	< DL	0.036
Nasir-soil-08-10	0.65	0.03	4.7	0.2	34	4	<	1	0.00727	0.00005	0.66	< DL	—	2.8	< DL	0.019
Nasir-soil-09-02	1.77	0.08	12.6	0.6	105	11	<	2	0.00723	0.00004	1.78	< DL	—	2.5	< DL	0.045
Nasir-soil-09-03	2.58	0.12	18.4	0.9	176	18	<	5	0.00727	0.00005	2.60	< DL	—	2.8	< DL	0.072
Nasir-soil-09-04	2.12	0.10	15.1	0.7	131	14	<	3	0.00724	0.00005	2.14	< DL	—	2.6	< DL	0.055
Nasir-soil-09-05	2.05	0.10	14.5	0.7	126	14	<	2	0.00724	0.00004	2.06	< DL	—	2.4	< DL	0.049
Nasir-soil-09-06	2.02	0.09	14.3	0.7	123	13	<	4	0.00724	0.00004	2.03	< DL	—	2.4	< DL	0.050
Nasir-soil-09-07	1.78	0.08	12.6	0.6	104	12	<	10	0.00723	0.00004	1.79	< DL	—	2.3	< DL	0.041
Nasir-soil-09-08	1.54	0.07	10.9	0.5	93	10	<	4	0.00724	0.00005	1.55	< DL	—	2.6	< DL	0.041
Nasir-soil-09-09	1.02	0.05	7.2	0.4	59	6	<	6	0.00724	0.00005	1.03	< DL	—	2.6	< DL	0.027

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-10-01	1.41	0.07	10.0	0.5	77	10	<	21	0.00725	0.00003	1.42	< DL	—	1.8	< DL	0.026
Nasir-soil-10-02	1.69	0.08	12.0	0.6	100	7	<	5	0.00728	0.00003	1.70	< DL	—	2.0	< DL	0.034
Nasir-soil-10-03	1.75	0.08	12.4	0.6	101	7	<	3	0.00726	0.00004	1.76	< DL	—	2.2	< DL	0.039
Nasir-soil-10-04	2.27	0.11	16.1	0.8	134	10	<	3	0.00725	0.00002	2.29	< DL	—	1.1	< DL	0.024
Nasir-soil-10-05	1.38	0.07	9.9	0.5	83	8	<	14	0.00729	0.00005	1.39	< DL	—	2.9	< DL	0.040
Nasir-soil-10-06	1.75	0.08	12.4	0.6	111	10	<	18	0.00727	0.00005	1.76	< DL	—	2.6	< DL	0.045
Nasir-soil-10-07	2.09	0.10	14.9	0.7	133	11	<	19	0.00729	0.00002	2.11	< DL	—	1.1	< DL	0.023
Nasir-soil-11-01	1.35	0.07	9.6	0.5	75	6	<	4	0.00726	0.00002	1.36	< DL	—	1.2	< DL	0.016
Nasir-soil-11-02	1.51	0.07	10.7	0.5	85	6	<	3	0.00724	0.00004	1.53	< DL	—	2.4	< DL	0.037
Nasir-soil-11-03	1.45	0.07	10.3	0.5	84	6	<	3	0.00725	0.00004	1.46	< DL	—	2.3	< DL	0.033
Nasir-soil-11-04	1.72	0.08	9.9	0.5	73	5	13	1	0.00589	0.00003	1.73	25.8	0.6	1.8	0.45	0.031
Nasir-soil-11-05	1.37	0.07	9.7	0.5	73	7	<	12	0.00725	0.00003	1.38	< DL	—	1.7	< DL	0.023
Nasir-soil-11-06	1.36	0.06	9.6	0.5	75	8	<	9	0.00723	0.00004	1.37	< DL	—	2.2	< DL	0.030
Nasir-soil-11-07	1.16	0.06	8.2	0.4	70	5	<	6	0.00724	0.00004	1.17	< DL	—	2.1	< DL	0.024
Nasir-soil-11-08	1.55	0.07	10.9	0.5	86	8	<	3	0.00722	0.00002	1.56	< DL	—	1.2	< DL	0.018
Nasir-soil-11-09	1.28	0.06	9.1	0.4	74	6	<	3	0.00722	0.00003	1.29	< DL	—	1.5	< DL	0.020
Nasir-soil-12-01	1.24	0.06	8.8	0.4	69	6	<	6	0.00722	0.00006	1.25	< DL	—	3.2	< DL	0.040
Nasir-soil-12-02	1.19	0.06	8.4	0.4	64	8	<	11	0.00723	0.00005	1.20	< DL	—	2.8	< DL	0.034
Nasir-soil-12-03	1.24	0.06	8.8	0.4	68	10	<	14	0.00723	0.00006	1.25	< DL	—	3.2	< DL	0.040

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-12-04	1.65	0.08	11.8	0.6	93	9	<	3	0.00725	0.00005	1.66	< DL	—	2.9	< DL	0.049
Nasir-soil-12-05	1.34	0.06	9.5	0.5	77	7	<	6	0.00723	0.00006	1.34	< DL	—	3.2	< DL	0.043
Nasir-soil-12-07	1.63	0.08	11.5	0.6	86	10	<	3	0.00718	0.00003	1.64	< DL	—	1.4	< DL	0.023
Nasir-soil-12-09	0.84	0.04	6.0	0.3	48	5	<	3	0.00724	0.00005	0.85	< DL	—	2.6	< DL	0.022
Nasir-soil-12-10	1.38	0.07	9.8	0.5	79	7	<	3	0.00724	0.00005	1.38	< DL	—	2.8	< DL	0.039
Nasir-soil-12-12	1.43	0.07	10.1	0.5	84	7	<	4	0.00723	0.00002	1.44	< DL	—	1.3	< DL	0.018
Nasir-soil-12-13	2.13	0.10	15.1	0.7	128	10	<	9	0.00722	0.00007	2.14	< DL	—	3.8	< DL	0.081
Nasir-soil-12-14	1.38	0.07	9.8	0.5	77	7	<	9	0.00722	0.00007	1.39	< DL	—	4.0	< DL	0.056
Nasir-soil-12-15	0.91	0.04	6.4	0.3	56	5	<	5	0.00720	0.00003	0.92	< DL	—	1.7	< DL	0.016
Nasir-soil-12-16	1.43	0.07	10.1	0.5	81	7	<	3	0.00720	0.00010	1.44	< DL	—	5.7	< DL	0.083
Nasir-soil-13-01	2.02	0.10	14.4	0.7	128	12	<	20	0.00723	0.00003	2.04	< DL	—	1.9	< DL	0.038
Nasir-soil-13-02	2.01	0.10	14.1	0.7	115	8	<	52	0.00716	0.00004	2.02	< DL	—	2.0	< DL	0.041
Nasir-soil-13-03	2.00	0.09	14.2	0.7	123	8	<	6	0.00725	0.00004	2.01	< DL	—	2.0	< DL	0.040
Nasir-soil-13-04	1.44	0.07	10.3	0.5	88	9	<	9	0.00729	0.00004	1.45	< DL	—	2.1	< DL	0.031
Nasir-soil-13-05	2.09	0.10	14.8	0.8	128	7	<	10	0.00724	0.00006	2.10	< DL	—	3.4	< DL	0.072
Nasir-soil-13-06	1.43	0.07	10.1	0.5	87	10	<	7	0.00722	0.00004	1.44	< DL	—	2.1	< DL	0.030
Nasir-soil-14-01	1.36	0.06	9.6	0.5	77	6	<	11	0.00726	0.00005	1.37	< DL	—	3.1	< DL	0.043
Nasir-soil-14-03	1.68	0.08	11.9	0.6	99	10	<	20	0.00725	0.00004	1.69	< DL	—	2.2	< DL	0.038
Nasir-soil-14-04	1.73	0.08	12.2	0.6	95	6	<	10	0.00722	0.00007	1.74	< DL	—	3.7	< DL	0.065

TABLE 45. SOIL SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of total U		DL (DU)	Total DU in sample	DL
	(µg/g)	± 1σ (µg/g)	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(pg/g)	± 1σ (pg/g)	At ratio	± 1σ at ratio	(µg/g)	Percentage (mass%)	± 1σ (mass%)	(mass%)	(mg/kg)	(mg/kg)
Nasir-soil-14-05	1.60	0.08	11.2	0.6	91	5	<	8	0.00719	0.00007	1.61	< DL	—	3.9	< DL	0.063
Nasir-soil-14-06	1.12	0.06	7.9	0.4	65	5	<	9	0.00725	0.00003	1.13	< DL	—	1.8	< DL	0.020
Nasir-soil-scraps	3244.00	154.00	6442.0	324.0	24858	3054	35359	4457	0.00203	0.00001	3251.00	99.4	0.2	0.5	3231.00	16.946
Nasir-soil-bombarded tank	49.70	2.30	107.0	5.3	410	51	575	66	0.00221	0.00002	49.77	96.0	0.4	1.2	47.76	0.613

TABLE 46. WATER SAMPLES

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of Total U		DL (DU)	Total DU in Sample	DL
	(ng/ml)	± 1σ (ng/ml)	(pg/ml)	± 1σ (pg/ml)	(fg/ml)	± 1σ (fg/ml)	(fg/ml)	± 1σ (fg/ml)	at ratio	± 1σ at ratio	(ng/ml)	percentage (mass%)	± 1σ (mass%)	(mass%)	(µg/l)	(µg/l)
As Samawah																
SAMA-102-T	1.91	0.09	13.7	0.6	120	13	<	2.6	0.00728	0.00005	1.92	< DL	—	2.6	< DL	0.050
SAMA-102-S	1.89	0.09	13.5	0.6	120	13	<	2.7	0.00728	0.00005	1.91	< DL	—	2.6	< DL	0.050
SAMA-108-T	2.89	0.13	20.7	1.0	187	22	<	4.0	0.00727	0.00006	2.91	< DL	—	3.3	< DL	0.090
SAMA-108-S	2.85	0.13	20.3	1.0	187	21	<	4.0	0.00726	0.00007	2.87	< DL	—	4.2	< DL	0.120
SAMA-110-T	2.05	0.09	14.5	0.7	129	14	<	2.7	0.00722	0.00004	2.06	< DL	—	2.4	< DL	0.050
SAMA-201	2.06	0.09	14.7	0.7	128	15	<	2.8	0.00726	0.00004	2.08	< DL	—	2.5	< DL	0.050
SAMA-204	1.91	0.09	13.6	0.6	117	13	<	2.8	0.00724	0.00005	1.92	< DL	—	2.9	< DL	0.060
SAMA-207	1.91	0.09	13.5	0.6	122	13	<	2.8	0.00722	0.00004	1.92	< DL	—	2.4	< DL	0.050
SAMA-208	1.91	0.09	13.6	0.6	121	14	<	2.8	0.00723	0.00007	1.92	< DL	—	3.8	< DL	0.070
SAMA-209	1.83	0.08	13.0	0.6	115	14	<	2.8	0.00725	0.00005	1.84	< DL	—	2.9	< DL	0.050
Az Zubayr																
ZUBA-101	126.00	5.70	897.0	42.0	7742	928	<	162.0	0.00723	0.00004	127.20	< DL	—	2.3	< DL	2.910
Al Basrah																
BASRA-108-water	1.10	0.04	7.4	0.3	75	4	2.4	0.8	0.00688	0.00003	1.10	7.0	0.6	1.7	0.08	0.020
BASRA-116-water	0.90	0.04	5.6	0.3	51	3	3.7	0.3	0.00629	0.00006	0.90	18.3	1.2	3.5	0.17	0.030
BASRA-201-water	0.96	0.04	6.8	0.3	69	3	<	0.7	0.00722	0.00006	0.97	< DL	—	3.7	< DL	0.040
BASRA-304-water	0.52	0.02	3.8	0.2	37	4	<	0.4	0.00724	0.00006	0.53	< DL	—	3.7	< DL	0.020

TABLE 46. WATER SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		$^{235}U/^{238}U$		Total U	DU of Total U		DL (DU)	Total DU in Sample	DL
	(ng/ml)	± 1σ (ng/ml)	(pg/ml)	± 1σ (pg/ml)	(fg/ml)	± 1σ (fg/ml)	(fg/ml)	± 1σ (fg/ml)	at ratio	± 1σ at ratio	(ng/ml)	percentage (mass%)	± 1σ (mass%)	(mass%)	(μg/l)	(μg/l)
An Nasiriyah																
Nasir-water-01-02	3.32	0.09	21.6	0.7	202	14	7.1	1.8	0.00662	0.00005	3.34	12.0	0.9	2.6	0.40	0.090
Nasir-water-03-10	3.13	0.09	21.2	0.7	188	14	3.8	1.4	0.00690	0.00004	3.15	6.6	0.8	2.4	0.21	0.070
Nasir-water-14-01	1.20	0.03	8.3	0.3	85	5	<	1.5	0.00707	0.00004	1.21	3.4	0.7	2.2	0.04	0.030

TABLE 47. VEGETATION SAMPLES

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		DL (DU)	Total DU in Sample	DL
	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(fg/g)	± 1σ (fg/g)	(fg/g)	± 1σ (fg/g)	(ng/g)	at ratio	± 1σ at ratio	percentage (mass%)	± 1σ (mass%)	(mass%)	(μg/kg)	(μg/kg)
As Samawah																
SAMA-102-vegetation-A	56.00	5.70	401.0	41.0	3363	400	<	45.0	57.000	0.00718	0.00005	< DL	—	2.9	< DL	1.600
SAMA-103-vegetation-A	72.00	7.30	473.0	49.0	4007	502	163	45.0	72.247	0.00670	0.00006	10.5	1.2	3.5	7.59	2.500
SAMA-103-vegetation-B	62.00	6.30	420.0	48.0	3458	433	99	30.0	62.000	0.00691	0.00005	6.5	1.0	2.9	4.07	1.800
SAMA-104-vegetation-A	9.00	0.90	63.0	8.0	527	72	<	8.0	9.070	0.00711	0.00005	< DL	—	3.1	< DL	0.300
SAMA-111-vegetation-B	18.00	1.80	125.0	13.0	1012	127	<	144.0	18.000	0.00703	0.00006	4.3	1.2	3.5	0.77	0.600
SAMA-112-vegetation-A	6.30	0.60	45.0	5.0	370	44	<	13.0	6.320	0.00725	0.00004	< DL	—	2.1	< DL	0.100
SAMA-112-vegetation-B	12.00	1.20	85.0	9.0	779	88	<	36.0	12.000	0.00724	0.00009	< DL	—	5.2	< DL	0.600
SAMA-202-vegetation	39.00	3.90	280.0	29.0	2744	400	<	3715.0	39.000	0.00723	0.00009	< DL	—	5.1	< DL	2.000
SAMA-210-vegetation	85.00	8.60	609.0	62.0	5345	625	<	62.0	86.000	0.00724	0.00005	< DL	—	2.8	< DL	2.400
SAMA-301-vegetation-A	366.00	37.00	2647.0	269.0	24057	3679	<	257.0	369.000	0.00730	0.00005	< DL	—	2.9	< DL	10.900
SAMA-301-vegetation-B	273.00	27.60	1973.0	201.0	18619	2156	<	546.0	275.000	0.00730	0.00007	< DL	—	4.1	< DL	11.200
SAMA-311-vegetation-A	117.00	11.80	842.0	87.0	7076	864	<	84.0	118.000	0.00727	0.00008	< DL	—	4.5	< DL	5.300
SAMA-311-vegetation-B	100.00	10.10	724.0	74.0	5904	686	<	72.0	101.000	0.00728	0.00005	< DL	—	2.8	< DL	2.800
SAMA-411-vegetation-A	21.00	2.10	147.0	16.0	1263	171	<	237.0	21.000	0.00719	0.00004	< DL	—	2.1	< DL	0.400
SAMA-411-vegetation-B	207.00	20.90	1469.0	173.0	13027	1717	<	157.0	208.000	0.00722	0.00008	< DL	—	4.8	< DL	10.100
Az Zubayr																
ZUBA-101-vegetation	7.90	0.80	56.0	6.0	494	60	<	7.0	7.910	0.00723	0.00009	< DL	—	5.0	< DL	0.400
ZUBA-104-vegetation-A	161.00	16.20	1138.0	122.0	9811	1419	<	121.0	162.0	0.00720	0.00004	< DL	—	2.2	< DL	3.600

TABLE 47. VEGETATION SAMPLES (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		DL (DU)	Total DU in Sample	DL
	(ng/g)	± 1σ (ng/g)	(pg/g)	± 1σ (pg/g)	(fg/g)	± 1σ (fg/g)	(fg/g)	± 1σ (fg/g)	(ng/g)	at ratio	± 1σ at ratio	percentage (mass%)	± 1σ (mass%)	(mass%)	(μg/kg)	(μg/kg)
ZUBA-104-vegetation-B	405.00	40.90	2883.0	363.0	24815	3573	<	327.0	408.000	0.00723	0.00007	< DL	—	4.1	< DL	16.900
ZUBA-106-vegetation-A	407.00	41.20	2906.0	302.0	25327	3361	<	291.0	410.000	0.00726	0.00004	< DL	—	2.3	< DL	9.600
ZUBA-106-vegetation-B	48.00	4.80	336.0	39.0	2889	441	<	40.0	48.000	0.00716	0.00005	< DL	—	2.8	< DL	1.400
ZUBA-106-vegetation-C	1.40	0.14	10.1	1.5	88	16	<	1.6	1.430	0.00723	0.00005	< DL	—	2.9	< DL	0.000
ZUBA-107-vegetation-B	6.50	0.70	46.0	5.2	415	55	<	6.0	6.500	0.00723	0.00004	< DL	—	2.3	< DL	0.200
ZUBA-108-vegetation-A	0.44	0.05	3.2	0.3	27	4	<	2.0	0.440	0.00737	0.00006	< DL	—	3.7	< DL	0.000
ZUBA-108-vegetation-B	0.60	0.06	4.3	0.4	39	5	<	1.0	0.600	0.00737	0.00005	< DL	—	3.1	< DL	0.000
ZUBA-108-vegetation-C	5.00	0.50	36.0	3.7	302	44	<	7.0	5.020	0.00725	0.00004	< DL	—	2.3	< DL	0.100

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
As Samawah (1st Mission)														
SAMA-101-smear-W	5.85	0.20	41.0	2.0	358	59	<	59.0	5.890	0.00710	0.00003	2.8	0.6	1.7
SAMA-101-smear-S	7.54	0.50	52.0	4.0	446	46	<	41.0	7.590	0.00704	0.00004	4.0	0.7	2.2
SAMA-105-smear-W	7.83	0.30	55.0	3.0	474	36	<	24.0	7.890	0.00706	0.00004	3.7	0.7	2.1
SAMA-105-smear-S	6.10	0.50	40.0	3.0	343	33	25	4.0	6.140	0.00663	0.00003	11.8	0.6	1.7
SAMA-106-smear-W	3.47	0.20	23.0	1.0	178	19	<	22.0	3.490	0.00683	0.00006	7.9	1.2	3.5
SAMA-106-smear-S	6.49	0.30	45.0	2.0	408	40	<	18.0	6.540	0.00706	0.00003	3.5	0.5	1.6
SAMA-107-smear-W	3.71	0.20	27.0	1.0	222	15	<	5.0	3.740	0.00724	0.00003	< DL	—	1.9
SAMA-107-smear-S	22.01	0.80	156.0	6.0	1277	127	<	440.0	22.170	0.00719	0.00003	< DL	—	2.0
SAMA-108-smear-W	15.95	0.50	115.0	4.0	928	197	<	158.0	16.070	0.00729	0.00004	< DL	—	2.0
SAMA-108-smear-S	6.37	0.20	45.0	2.0	401	18	<	8.0	6.420	0.00712	0.00007	< DL	—	4.0
SAMA-109-smear-W	6.95	0.30	49.0	2.0	416	35	<	21.0	7.000	0.00715	0.00002	1.8	0.4	1.3
SAMA-109-smear-S	7.35	0.30	50.0	2.0	443	31	23	10.0	7.400	0.00690	0.00005	6.7	0.9	2.7
SAMA-110-smear-W	7.73	0.40	55.0	4.0	456	48	<	9.0	7.790	0.00718	0.00007	< DL	—	3.9
SAMA-110-smear-S	7.16	0.30	51.0	2.0	470	74	<	20.0	7.210	0.00721	0.00003	< DL	—	1.6
SAMA-113-smear-W	12.86	0.40	90.0	5.0	769	62	<	13.0	12.950	0.00706	0.00004	3.5	0.7	2.1
SAMA-113-smear-S	7.24	0.30	51.0	2.0	474	38	<	8.0	7.290	0.00718	0.00004	< DL	—	2.0
SAMA-201-smear-W	4.22	0.20	30.0	2.0	240	18	<	19.0	4.250	0.00717	0.00005	< DL	—	2.9
SAMA-201-smear-S	7.50	0.30	54.0	3.0	459	34	<	8.0	7.550	0.00725	0.00005	< DL	—	2.9
SAMA-202-smear-W	8.75	0.40	62.0	3.0	490	30	<	9.0	8.810	0.00714	0.00003	2.2	0.5	1.6

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
SAMA-203-smear-W	9.82	0.50	69.0	4.0	657	152	<	1669.0	9.890	0.00713	0.00020	< DL	—	11.2
SAMA-203-smear-S	10.60	0.40	75.0	3.0	713	106	<	233.0	10.680	0.00173	0.00013	< DL	—	7.7
SAMA-204-smear-W	6.49	0.30	46.0	2.0	406	82	<	22.0	6.540	0.00714	0.00006	< DL	—	3.5
SAMA-205-smear-W	5.48	0.30	38.0	2.0	363	51	<	7.0	5.520	0.00710	0.00004	2.9	0.8	2.5
SAMA-205-smear-S	4.68	0.20	33.0	2.0	309	52	<	47.0	4.710	0.00712	0.00010	< DL	—	5.6
SAMA-206-smear-W	2.74	0.20	19.0	1.0	150	14	<	10.0	2.760	0.00706	0.00003	3.5	0.6	1.9
SAMA-206-smear-S	4.36	0.30	31.0	2.0	284	22	<	16.0	4.390	0.00724	0.00007	< DL	—	3.8
SAMA-207-smear-W	3.47	0.20	25.0	1.0	220	21	<	5.0	3.490	0.00717	0.00004	< DL	—	2.3
SAMA-207-smear-S	20.39	0.60	145.0	9.0	1351	119	<	408.0	20.540	0.00722	0.00008	< DL	—	4.8
SAMA-209-smear-W	6.27	0.20	44.0	2.0	381	31	<	31.0	6.310	0.00710	0.00004	2.8	0.8	2.4
SAMA-209-smear-S	4.93	0.30	34.0	2.0	304	47	<	21.0	4.960	0.00693	0.00003	6.1	0.6	1.8
SAMA-301-smear-W	18.70	0.60	133.0	6.0	1228	98	<	215.0	18.830	0.00721	0.00006	< DL	—	3.3
SAMA-301-smear-S	17.41	0.60	125.0	5.0	1025	66	<	50.0	17.540	0.00724	0.00003	< DL	—	2.0
SAMA-302-smear-W	12.13	0.40	87.0	4.0	756	153	<	243.0	12.220	0.00722	0.00012	< DL	—	6.7
SAMA-302-smear-S	14.51	0.50	105.0	4.0	906	77	<	177.0	14.620	0.00729	0.00007	< DL	—	4.2
SAMA-305-smear-W	6.42	0.20	46.0	2.0	415	48	<	25.0	6.470	0.00722	0.00009	< DL	—	5.0
SAMA-305-smear-S	5.52	0.30	39.0	2.0	388	28	<	6.0	5.560	0.00718	0.00007	< DL	—	3.8
SAMA-306-smear-W-A	7.77	0.30	55.0	2.0	466	25	<	8.0	7.830	0.00714	0.00003	2.1	0.6	1.9
SAMA-306-smear-W-B	7.69	0.30	54.0	3.0	432	41	<	9.0	7.740	0.00708	0.00003	3.2	0.6	1.8
SAMA-310-smear-W-A	19.50	0.70	141.0	8.0	1206	131	<	390.0	19.640	0.00731	0.00016	< DL	—	9.0

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
SAMA-310-smear-W-B	49.42	1.50	354.0	35.0	2914	375	<	54.0	49.780	0.00726	0.00005	< DL	—	2.8
SAMA-310-smear-S-A	13.55	0.40	97.0	4.0	826	78	<	271.0	13.650	0.00727	0.00011	< DL	—	6.4
SAMA-310-smear-S-B	84.59	2.60	606.0	26.0	4862	217	<	70.0	85.200	0.00724	0.00005	< DL	—	3.0
SAMA-401-smear-W-A	17.51	0.60	126.0	5.0	975	67	<	175.0	17.640	0.00728	0.00007	< DL	—	4.1
SAMA-401-smear-W-B	10.65	0.60	76.0	5.0	736	100	<	224.0	10.730	0.00719	0.00012	< DL	—	7.0
SAMA-402-smear-W	18.47	0.60	131.0	5.0	1308	213	<	369.0	18.600	0.00720	0.00004	< DL	—	2.3
SAMA-402-smear-S	5.80	0.20	41.0	2.0	373	19	<	58.0	5.840	0.00716	0.00003	< DL	—	1.8
SAMA-403-smear-W	25.43	0.80	182.0	8.0	1614	158	<	763.0	25.610	0.00726	0.00011	< DL	—	6.2
SAMA-403-smear-S	15.93	0.50	113.0	4.0	962	153	<	150.0	16.040	0.00719	0.00009	< DL	—	5.3
SAMA-404-smear-W-A	6.71	0.30	48.0	2.0	365	26	<	32.0	6.760	0.00726	0.00004	< DL	—	2.0
SAMA-404-smear-W-B	34.63	1.00	248.0	10.0	1997	132	<	37.0	34.880	0.00725	0.00005	< DL	—	2.6
SAMA-404-smear-S	15.78	0.60	113.0	5.0	867	119	<	158.0	15.890	0.00728	0.00002	< DL	—	1.2
SAMA-409-smear-W-A	29.47	0.90	184.0	8.0	1552	134	503	155.0	29.660	0.00631	0.00012	18.0	2.3	7.0
SAMA-409-smear-W-B	9.96	0.40	71.0	4.0	660	101	<	299.0	10.030	0.00720	0.00015	< DL	—	8.3
SAMA-409-smear-S-A	10.68	0.40	76.0	4.0	647	42	<	21.0	10.750	0.00724	0.00003	< DL	—	1.5
SAMA-409-smear-S-B	4.21	0.20	30.0	2.0	256	32	<	6.0	4.240	0.00714	0.00004	< DL	—	2.2
SAMA-410-smear-S	24.84	0.90	177.0	8.0	1509	160	<	497.0	25.020	0.00721	0.00005	< DL	—	2.7
SAMA-410-smear-T	4.04	0.20	26.0	1.0	210	21	<	14.0	4.070	0.00651	0.00005	14.0	0.9	2.8

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
As Samawah (2nd Mission)														
SAMA-102-smear-W (2nd Mission)	7.13	0.30	51.0	2.0	388	28	<	13.0	7.180	0.00722	0.00003	< DL	—	2.0
SAMA-102-smear-S (2nd Mission)	5.62	0.30	40.0	2.0	326	32	<	12.0	5.660	0.00722	0.00005	< DL	—	3.1
SAMA-103-smear-W (2nd Mission)	11.19	0.40	78.0	3.0	688	50	<	20.0	11.270	0.00709	0.00004	3.1	0.7	2.2
SAMA-103-smear-S (2nd Mission)	5.33	0.30	35.0	2.0	303	24	26	6.0	5.360	0.00667	0.00006	11.1	1.1	3.2
SAMA-104-smear-W (2nd Mission)	6.87	0.30	49.0	2.0	403	43	<	34.0	6.920	0.00722	0.00004	< DL	—	2.5
SAMA-104-smear-S (2nd Mission)	11.28	0.50	80.0	4.0	751	103	<	56.0	11.360	0.00720	0.00005	< DL	—	2.9
SAMA-105-smear-W (2nd Mission)	8.82	0.30	62.0	3.0	541	31	<	35.0	8.880	0.00718	0.00002	1.3	0.4	1.1
SAMA-105-smear-S (2nd Mission)	8.87	0.50	63.0	4.0	526	37	<	14.0	8.940	0.00718	0.00009	< DL	—	5.1
SAMA-106-smear-W (2nd Mission)	16.62	0.70	119.0	5.0	970	75	<	21.0	16.740	0.00725	0.00004	< DL	—	2.0
SAMA-106-smear-S (2nd Mission)	14.91	0.60	105.0	5.0	869	70	<	21.0	15.020	0.00718	0.00006	< DL	—	3.3
SAMA-112-smear-W (2nd Mission)	8.14	0.40	58.0	3.0	502	88	<	33.0	8.200	0.00721	0.00003	< DL	—	1.9
SAMA-112-smear-S (2nd Mission)	10.73	0.50	77.0	5.0	659	47	<	54.0	10.800	0.00727	0.00005	< DL	—	2.8
SAMA-113-smear-W (2nd Mission)	20.20	0.70	143.0	6.0	1189	75	<	21.0	20.340	0.00719	0.00004	< DL	—	2.2
SAMA-113-smear-S (2nd Mission)	12.63	0.50	89.0	4.0	783	89	<	63.0	12.720	0.00717	0.00006	< DL	—	3.2
SAMA-208-smear-W (2nd Mission)	17.46	0.70	125.0	5.0	1109	73	<	20.0	17.590	0.00727	0.00004	< DL	—	2.1
SAMA-208-smear-S (2nd Mission)	19.07	0.60	137.0	6.0	1197	78	<	22.0	19.210	0.00728	0.00005	< DL	—	2.8
SAMA-209-smear-W (2nd Mission)	14.90	0.60	105.0	7.0	912	72	<	22.0	15.010	0.00716	0.00008	< DL	—	4.4
SAMA-209-smear-S (2nd Mission)	6.35	0.30	43.0	2.0	381	39	<	32.0	6.390	0.00697	0.00003	5.3	0.5	1.4
SAMA-210-smear-W (2nd Mission)	5.53	0.20	39.0	2.0	355	20	<	39.0	5.570	0.00727	0.00004	< DL	—	2.4

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
SAMA-210-smear-S (2nd Mission)	8.47	0.30	60.0	2.0	477	58	<	42.0	8.530	0.00719	0.00003	< DL	—	1.5
SAMA-301-smear-W (2nd Mission)	12.12	0.40	87.0	3.0	736	73	<	36.0	12.210	0.00727	0.00004	< DL	—	2.2
SAMA-301-smear-S (2nd Mission)	30.36	1.00	215.0	12.0	1829	150	<	29.0	30.580	0.00722	0.00002	< DL	—	1.4
SAMA-307-smear-W (2nd Mission)	14.75	0.50	106.0	4.0	979	64	<	44.0	14.850	0.00729	0.00006	< DL	—	3.2
SAMA-307-smear-S (2nd Mission)	9.27	0.40	65.0	3.0	534	33	<	13.0	9.330	0.00717	0.00003	< DL	—	1.5
SAMA-309-smear-W (2nd Mission)	11.47	0.40	82.0	3.0	702	60	<	46.0	11.550	0.00729	0.00004	< DL	—	2.5
SAMA-309-smear-S (2nd Mission)	20.45	0.80	147.0	6.0	1287	94	<	25.0	20.600	0.00730	0.00007	< DL	—	4.0
SAMA-311-smear-W (2nd Mission)	5.95	0.30	42.0	2.0	345	24	<	36.0	5.990	0.00720	0.00005	< DL	—	3.0
SAMA-311-smear-S (2nd Mission)	19.14	0.70	136.0	13.0	1163	146	<	24.0	19.280	0.00722	0.00005	< DL	—	3.1
SAMA-410-smear-W (2nd Mission)	21.44	0.70	153.0	6.0	1314	109	<	43.0	21.590	0.00723	0.00004	< DL	—	2.4
SAMA-410-smear-S (2nd Mission)	5.74	0.30	40.0	2.0	336	32	<	29.0	5.780	0.00718	0.00007	< DL	—	4.1
SAMA-411-smear-W (2nd Mission)	50.27	1.80	359.0	15.0	3104	194	<	151.0	50.630	0.00727	0.00003	< DL	—	1.5
SAMA-411-smear-S (2nd Mission)	8.04	0.40	57.0	3.0	508	35	<	13.0	8.100	0.00722	0.00003	< DL	—	1.7
SAMA-intact tank-smear-02-S (2nd Mission)	13.17	0.50	94.0	4.0	841	59	<	20.0	13.260	0.00722	0.00008	< DL	—	4.5
SAMA-intact tank-smear-03-S (2nd Mission)	7.15	0.30	49.0	2.0	417	22	27	6.0	7.200	0.00698	0.00006	5.2	1.2	3.7
SAMA-intact tank-smear-05-S (2nd Mission)	10.28	0.40	73.0	4.0	634	49	<	31.0	10.350	0.00720	0.00002	< DL	—	1.2
SAMA-intact tank-smear-05-W (2nd Mission)	11.05	0.40	77.0	4.0	651	44	<	19.0	11.130	0.00712	0.00004	< DL	—	2.6
SAMA-smear-14-W (2nd Mission)	9.33	0.30	66.0	3.0	551	29	<	13.0	9.400	0.00721	0.00011	< DL	—	6.4
SAMA-smear-14-S (2nd Mission)	17.39	0.70	123.0	7.0	1067	77	<	35.0	17.520	0.00719	0.00007	< DL	—	4.0
SAMA-bombarded tank-smear-19-S (2nd Mission)	14.97	0.60	106.0	5.0	927	76	<	45.0	15.080	0.00722	0.00005	< DL	—	2.7

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
SAMA-cannon 1-smear-a-S (2nd Mission)	203.03	6.80	420.0	31.0	1676	195	5352	399.0	203.500	0.00211	0.00001	98.0	0.1	0.4
SAMA-cannon 1-smear-b-S (2nd Mission)	50622.00	1673.30	98842.0	4022.0	333221	30789	1165791	73675.0	50721.000	0.00199	0.00001	100.2	0.2	0.7
SAMA-cannon 1-smear-c-S (2nd Mission)	59.29	2.10	141.0	6.0	680	74	1454	123.0	59.430	0.00242	0.00001	92.0	0.2	0.6
SAMA-cannon 2-smear-a-S (2nd Mission)	244.68	8.30	514.0	22.0	2263	149	6686	602.0	245.200	0.00214	0.00002	97.4	0.5	1.4
SAMA-cannon 2-smear-b-S (2nd Mission)	43.87	2.30	111.0	6.0	578	52	948	74.0	43.980	0.00259	0.00001	88.8	0.3	0.8
SAMA-cannon 2-smear-c-S (2nd Mission)	71.84	2.70	167.0	12.0	748	70	1585	243.0	72.010	0.00237	0.00001	93.0	0.3	0.8
SAMA-cannon 2-smear-d-S (2nd Mission)	3017.36	101.50	5890.0	299.0	21575	1320	68259	3260.0	3023.300	0.00199	0.00002	100.2	0.3	0.9
SAMA-sample-a-smear-T (2nd Mission)	3970.60	132.00	7854.0	295.0	30505	3365	93873	4385.0	3978.500	0.00202	0.00002	99.7	0.4	1.2
SAMA-sample-b-smear-T (2nd Mission)	4726.70	159.20	9332.0	454.0	32560	1692	115071	8603.0	4736.100	0.00201	0.00001	99.8	0.3	0.8
SAMA-sample-c-smear-T (2nd Mission)	976.45	33.50	1949.0	87.0	6874	773	22405	1750.0	978.400	0.00203	0.00001	99.4	0.2	0.6
Az Zubayr (1st Mission)														
ZUBA-101-smear-A (ZUBA-101-smear-W-A)	2.05	0.20	14.0	1.0	192	49	<	17.0	2.060	0.00710	0.00004	2.9	0.8	2.3
ZUBA-101-smear-B (ZUBA-101-smear-W-B)	2.77	0.30	20.0	2.0	173	28	<	43.0	2.790	0.00712	0.00005	< DL	—	2.7
ZUBA-101-smear-C (ZUBA-101-smear-S-A)	2.66	0.20	19.0	2.0	168	18	<	5.0	2.680	0.00711	0.00004	2.6	0.8	2.3
ZUBA-101-smear-D (ZUBA-101-smear-S-B)	1.59	0.10	11.0	1.0	132	70	<	16.0	1.600	0.00718	0.00005	< DL	—	3.0
ZUBA-103-smear-S	2.84	0.20	20.0	2.0	267	45	<	5.0	2.860	0.00698	0.00003	5.2	0.6	1.8
ZUBA-105-smear-S	2.09	0.20	14.0	1.0	143	19	<	11.0	2.100	0.00675	0.00003	9.5	0.6	1.8
ZUBA-112-smear-A	18.66	1.30	118.0	9.0	970	80	100	48.0	18.780	0.00642	0.00003	15.8	0.6	1.7
ZUBA-112-smear-B	2.76	0.20	19.0	2.0	163	20	<	72.0	2.780	0.00697	0.00002	5.4	0.4	1.3
ZUBA-113-smear-W	2.74	0.20	19.0	2.0	168	35	<	18.0	2.760	0.00687	0.00007	7.2	1.4	4.1

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	^{235}U/^{238}U		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
Filter blank package I	1.15	0.10	6.0	0.6	55	10	<	15.0	1.150	0.00538	0.00009	35.6	1.6	4.9
Filter blank package I	2.98	0.20	8.0	0.7	52	11	74	20.0	2.990	0.00275	0.00001	85.7	0.2	0.6
Filter blank package I	0.91	0.00	6.0	0.3	46	29	6	10.0	0.920	0.00695	0.00013	< DL	—	7.6
Filter blank package I	0.72	0.00	4.0	0.2	21	5	13	3.0	0.720	0.00528	0.00009	37.6	1.6	4.9
Blank package 1; Ø 15 cm	0.46	0.04	3.1	0.3	29	16	<	5.0	0.460	0.00690	0.00005	6.7	0.9	2.8
Blank package 1; Ø 15 cm	2.78	0.10	9.2	0.4	63	9	32	8.0	2.790	0.00337	0.00005	73.8	0.9	2.7
Az Zubayr (2nd Mission)														
ZUBA-102-smear Surface (2nd Mission)	10.06	0.40	63.0	3.0	545	56	39	9.0	10.120	0.00629	0.00009	18.2	1.8	5.4
ZUBA-102-smear Wall (2nd Mission)	62.20	2.00	156.0	5.0	871	129	1634	136.0	62.350	0.00254	0.00002	89.7	0.4	1.2
ZUBA-103-smear Surface (2nd Mission)	93.06	2.90	302.0	17.0	1880	146	678	96.0	93.360	0.00329	0.00001	75.5	0.1	0.4
ZUBA-105-A-smear Surface (2nd Mission)	81.90	2.70	287.0	23.0	1835	228	534	68.0	82.190	0.00355	0.00001	70.6	0.2	0.7
ZUBA-105-A2-smear Surface Tank (2nd Mission)	55.64	1.90	268.0	10.0	2264	168	210	41.0	55.910	0.00489	0.00005	45.0	0.9	2.8
ZUBA-105-B1-smear Surface Tank (2nd Mission)	2052.68	64.00	4184.0	134.0	13983	2127	15533	1841.0	2057.000	0.00206	0.00002	98.8	0.4	1.2
ZUBA-105-B2-smear Surface Tank (2nd Mission)	8783.47	270.00	17903.0	619.0	64080	8932	69989	11251.0	8801.000	0.00206	0.00001	98.8	0.3	0.8
ZUBA-105-C1-smear Surface Tank (2nd Mission)	62112.94	1954.00	124523.0	4151.0	444702	35955	506261	73737.0	62238.000	0.00203	0.00002	99.4	0.4	1.2
ZUBA-105-C2-smear Surface Tank (2nd Mission)	137.38	4.40	321.0	11.0	1366	73	1075	102.0	137.700	0.00236	0.00001	93.1	0.2	0.6
ZUBA-105-D1-smear Surface Tank (2nd Mission)	153961.50	4732.00	310612.0	9974.0	1042394	198586	754455	163284.0	154273.000	0.00204	0.00001	99.2	0.2	0.5
ZUBA-105-D2-smear Surface Tank (2nd Mission)	5051.77	157.00	10136.0	354.0	34412	4459	25904	2129.0	5062.000	0.00203	0.00001	99.4	0.3	0.8
ZUBA-105-E1-smear Surface Tank (2nd Mission)	228.80	7.10	479.0	16.0	1802	123	1652	165.0	229.300	0.00212	0.00001	97.8	0.3	0.8
ZUBA-105-E2-smear Surface Tank (2nd Mission)	616.48	19.00	1290.0	41.0	4578	625	4657	366.0	617.800	0.00212	0.00002	97.8	0.4	1.1

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
ZUBA-105-F1-smear Surface Tank (2nd Mission)	12691.99	392.00	25591.0	852.0	80871	6424	278387	39301.0	12718.000	0.00204	0.00002	99.2	0.4	1.3
ZUBA-105-F2-smear Surface Tank (2nd Mission)	19235.50	590.00	38750.0	1272.0	146406	21429	433724	31462.0	19274.000	0.00204	0.00001	99.3	0.2	0.6
ZUBA-105-G1-smear Surface Tank (2nd Mission)	161.83	5.10	374.0	13.0	1639	123	2015	176.0	162.200	0.00234	0.00001	93.5	0.1	0.4
ZUBA-105-G2-smear Surface Tank (2nd Mission)	149.44	4.90	403.0	17.0	2001	252	1834	118.0	149.800	0.00273	0.00001	86.1	0.1	0.4
ZUBA-105-H1-smear Surface Tank (2nd Mission)	57680.96	1791.00	116061.0	4044.0	412236	56187	232187	33360.0	57797.000	0.00204	0.00001	99.3	0.2	0.5
ZUBA-105-H2-smear Surface Tank (2nd Mission)	805.86	24.80	1704.0	63.0	6013	435	5607	1060.0	807.600	0.00214	0.00002	97.3	0.4	1.1
ZUBA-111-A1-smear Surface Tank (2nd Mission)	81.91	2.60	337.0	11.0	2468	133	423	73.0	82.250	0.00416	0.00001	58.9	0.2	0.7
Al Basrah														
Basra-109-smear-W	16.85	0.60	89.0	3.0	720	72	192	22.0	16.940	0.00538	0.00002	35.7	0.3	1.0
Basra-109-smear-S	18.13	0.60	118.0	4.0	1035	87	79	12.0	18.250	0.00659	0.00003	12.5	0.7	2.0
Basra-111-smear-W	54.84	1.80	167.0	6.0	1046	107	1165	92.0	55.010	0.00309	0.00002	79.3	0.4	1.2
Basra-111-smear-S	69.76	2.20	215.0	7.0	1427	99	1520	63.0	69.980	0.00311	0.00004	78.8	0.8	2.3
Basra-112-smear-W	65.96	2.10	160.0	7.0	944	51	1702	106.0	66.120	0.00245	0.00001	91.5	0.2	0.6
Basra-112-smear-S	67.96	2.10	191.0	6.0	1228	127	1622	80.0	68.150	0.00284	0.00002	83.9	0.3	1.0
Basra-113-smear-W	73.54	2.30	268.0	10.0	1792	113	1513	139.0	73.810	0.00368	0.00002	68.0	0.3	1.0
Basra-113-smear-S	61.48	2.00	160.0	6.0	948	78	1559	117.0	61.640	0.00264	0.00001	87.8	0.2	0.5
Basra-114-smear-W	151.76	4.80	397.0	14.0	2384	173	3714	232.0	152.200	0.00264	0.00002	87.7	0.3	0.9
Basra-114-smear-S	133.53	4.20	255.0	10.0	1099	101	3727	412.0	133.800	0.00193	0.00001	101.3	0.2	0.6
Basra-115-A-smear-S	84969.90	2596.00	139411.0	4475.0	480306	100366	2395464	152812.0	85110.000	0.00166	0.00001	106.5	0.1	0.3
Basra-115-B-smear-S	6930.20	212.00	11573.0	364.0	39257	5845	200532	8324.0	6942.000	0.00169	0.00001	105.9	0.1	0.3

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
Basra-115-C-smear-S	2679.60	83.00	4571.0	154.0	16860	1529	77963	6974.0	2684.000	0.00173	0.00001	105.2	0.2	0.6
Basra-115-D-smear-S	13508.20	417.00	22320.0	1184.0	77537	6531	397230	20766.0	13531.000	0.00167	0.00001	106.2	0.2	0.6
Basra-118-smear-W	8.66	0.40	36.0	2.0	259	38	138	27.0	8.700	0.00423	0.00002	57.6	0.4	1.2
Basra-118-smear-S	18.55	0.80	109.0	5.0	895	98	171	27.0	18.660	0.00599	0.00003	24.1	0.6	1.7
Basra-204-smear-S	18.32	0.70	105.0	4.0	887	66	158	15.0	18.430	0.00583	0.00002	27.0	0.5	1.4
Basra-207-smear-S	11.26	0.40	60.0	2.0	499	52	124	14.0	11.320	0.00543	0.00003	34.6	0.6	1.9
Basra-207-smear-W	16.95	0.60	95.0	4.0	792	101	162	20.0	17.050	0.00567	0.00003	30.1	0.5	1.6
Basra-211-smear-S	48.70	1.60	260.0	9.0	2340	203	447	49.0	48.960	0.00542	0.00003	34.9	0.6	1.9
Basra-211-smear-W	19.21	0.60	78.0	3.0	601	48	340	31.0	19.290	0.00410	0.00002	60.0	0.4	1.2
Basra-305-smear-S	21.02	0.70	105.0	5.0	920	88	271	44.0	21.130	0.00507	0.00005	41.4	1.0	3.1
Basra-306-smear-S	18.01	0.60	80.0	3.0	623	61	280	36.0	18.090	0.00449	0.00002	52.6	0.4	1.2
Basra-403-smear-S	36.08	1.40	206.0	9.0	1719	186	349	51.0	36.290	0.00578	0.00002	28.0	0.4	1.1
Basra-404-smear-S	45.14	1.40	244.0	8.0	1954	148	440	48.0	45.390	0.00549	0.00003	33.6	0.6	1.9
Basra-405-smear-S	33.32	1.20	85.0	4.0	531	42	903	81.0	33.410	0.00260	0.00001	88.5	0.2	0.7
Basra-410-smear-W	107.46	3.40	346.0	13.0	2226	103	1531	103.0	107.800	0.00326	0.00001	76.0	0.2	0.5
Basra-410-smear-S	158.91	5.40	447.0	16.0	2637	164	1740	170.0	159.400	0.00284	0.00001	83.9	0.3	0.8
Basra-411-A-smear-Tank	177.52	5.60	433.0	17.0	2066	142	1914	130.0	178.000	0.00247	0.00003	91.1	0.5	1.5
Basra-411-B-smear-Tank	389.40	12.00	794.0	25.0	2653	403	2947	349.0	390.200	0.00206	0.00002	98.8	0.4	1.2
Basra-412-smear-W	32.12	1.00	119.0	4.0	916	87	655	49.0	32.240	0.00377	0.00003	66.3	0.6	1.8
Basra-412-smear-S	48.93	1.60	167.0	6.0	1188	125	987	85.0	49.100	0.00345	0.00002	72.3	0.4	1.2

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
Basra-413-smear-S	79.55	2.50	274.0	25.0	1906	378	1471	138.0	79.830	0.00348	0.00005	71.8	0.9	2.6
Basra-416-smear-S	52.54	1.80	141.0	6.0	907	119	1248	100.0	52.680	0.00272	0.00004	86.4	0.7	2.1
An Nasiriyah														
Nasir-smear-03-10 surface	10.29	0.40	63.0	3.0	577	51	28	12.0	10.360	0.00624	0.00002	19.1	0.4	1.1
Nasir-smear-04-03 wall (A)	32.60	1.10	231.0	8.0	1961	147	<	30.0	32.830	0.00720	0.00003	< DL	—	1.9
Nasir-smear-04-03 wall (B)	11.66	0.40	82.0	3.0	692	55	<	16.0	11.740	0.00714	0.00002	2.0	0.3	0.9
Nasir-smear-07-07 surface	38.71	1.30	266.0	9.0	2552	204	<	36.0	38.980	0.00701	0.00005	4.6	0.9	2.8
Nasir-smear-07-08 surface	22.79	0.80	138.0	6.0	1218	103	58	20.0	22.930	0.00615	0.00002	20.9	0.4	1.3
Nasir-smear-08-04 surface	4.48	0.20	31.0	2.0	278	26	<	7.0	4.510	0.00710	0.00006	< DL	—	3.3
Nasir-smear-08-04 wall	4.08	0.20	29.0	1.0	254	30	<	6.0	4.110	0.00718	0.00006	< DL	—	3.3
Nasir-smear-08-06 surface	3.44	0.10	24.0	1.0	217	25	<	6.0	3.460	0.00702	0.00005	4.3	1.0	3.1
Nasir-smear-08-09 surface	6.46	0.20	46.0	2.0	401	38	<	14.0	6.500	0.00719	0.00006	< DL	—	3.4
Nasir-smear-09-07 surface	11.14	0.40	79.0	3.0	739	58	<	15.0	11.220	0.00724	0.00002	< DL	—	1.2
Nasir-smear-09-09 surface	6.64	0.00	44.0	2.0	383	51	<	14.0	6.680	0.00679	0.00005	8.8	1.0	2.9
Nasir-smear-10-03 from tree	5.24	0.00	37.0	1.0	338	33	11	7.0	5.280	0.00729	0.00004	< DL	—	2.0
Nasir-smear-10-03 from palm	5.55	0.00	40.0	2.0	354	29	<	6.0	5.590	0.00726	0.00003	< DL	—	1.8
Nasir-smear-11-08 wall	10.05	0.00	70.0	3.0	611	56	<	15.0	10.120	0.00713	0.00002	2.3	0.3	0.9
Nasir-smear-11-09 surface	6.24	0.20	43.0	2.0	351	30	<	14.0	6.290	0.00695	0.00004	5.7	0.8	2.3
Nasir-smear-11-09 wall	15.62	0.50	110.0	4.0	930	76	<	18.0	15.730	0.00718	0.00003	< DL	—	1.9
Nasir-smear-11-02 surface	21.78	0.80	154.0	6.0	1360	115	<	23.0	21.940	0.00721	0.00003	< DL	—	1.9

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
Nasir-smear-11-02 wall	9.09	0.30	63.0	2.0	520	43	<	15.0	9.150	0.00706	0.00002	3.6	0.3	0.9
Nasir-smear-12-01 surface	13.26	0.50	93.0	3.0	795	70	<	17.0	13.350	0.00715	0.00002	2.0	0.4	1.2
Nasir-smear-12-02 surface	26.17	0.90	185.0	7.0	1632	152	<	25.0	26.360	0.00721	0.00003	< DL	—	1.5
Nasir-smear-12-03 surface	22.13	0.80	156.0	6.0	1368	109	<	22.0	22.280	0.00720	0.00002	< DL	—	1.3
Nasir-smear-12-04 surface	7.77	0.30	54.0	2.0	461	39	<	14.0	7.830	0.00705	0.00002	3.8	0.4	1.3
Nasir-smear-12-05	11.11	0.40	76.0	3.0	637	67	<	16.0	11.190	0.00698	0.00003	5.2	0.6	1.8
Nasir-smear-12-06	5.69	0.20	39.0	2.0	342	36	16	10.0	5.730	0.00700	0.00002	4.8	0.5	1.4
Nasir-smear-12-07	59.49	2.00	424.0	16.0	3596	285	<	61.0	59.920	0.00726	0.00002	< DL	—	1.1
Nasir-smear-12-08 surface	6.77	0.30	46.0	2.0	407	35	<	14.0	6.820	0.00698	0.00004	5.2	0.7	2.1
Nasir-smear-12-09 surface	21.88	0.80	155.0	6.0	1359	106	<	22.0	22.040	0.00723	0.00003	< DL	—	1.6
Nasir-smear-12-10 surface	33.71	1.20	239.0	10.0	2086	174	<	34.0	33.950	0.00723	0.00005	< DL	—	2.7
Nasir-smear-12-11 surface	14.18	0.50	99.0	4.0	894	74	30	7.0	14.280	0.00711	0.00003	2.6	0.6	1.7
Nasir-smear-12-12 surface	6.04	0.00	42.0	1.0	377	32	8	16.0	6.080	0.00704	0.00005	4.0	1.0	2.9
Nasir-smear-12-15 surface	9.92	0.40	70.0	3.0	598	51	<	15.0	9.990	0.00717	0.00003	1.6	0.5	1.5
Nasir-smear-13-03 tank	32.77	1.10	231.0	8.0	1974	158	<	32.0	33.000	0.00719	0.00002	< DL	—	1.3
Nasir-smear-13-05 surface	5.93	0.20	41.0	2.0	375	31	<	6.0	5.970	0.00713	0.00006	< DL	—	3.5
Nasir-smear-13-05 wall	5.19	0.20	31.0	1.0	241	21	15	3.0	5.220	0.00605	0.00003	22.8	0.6	1.9
Nasir-smear-13-06 surface	15.17	0.50	97.0	4.0	807	76	20	6.0	15.270	0.00649	0.00005	14.4	1.0	2.9
Nasir-smear-13-06 wall	14.20	0.50	81.0	3.0	671	62	70	18.0	14.290	0.00583	0.00002	27.0	0.4	1.1
Nasir-smear-14-01 wall	5.59	0.20	20.0	1.0	134	18	47	15.0	5.610	0.00363	0.00003	69.0	0.5	1.4

TABLE 48. SURFACE SAMPLES (SMEARS) (*: MASS%) (cont.)

Sample	^{238}U		^{235}U		^{234}U		^{236}U		Total U	$^{235}U/^{238}U$		DU of Total U		
	(ng)	± 1σ (ng)	(pg)	± 1σ (pg)	(fg)	± 1σ (fg)	(fg)	± 1σ (fg)	(ng)	at ratio	± 1σ at ratio	mass%	± 1σ*	DL (mass %)
Nasir-smear-14-02 surface	4.02	0.10	23.0	1.0	180	21	21	4.0	4.040	0.00575	0.00006	28.6	1.2	3.7
Nasir-smear-14-03 surface	6.21	0.20	35.0	1.0	291	37	28	8.0	6.240	0.00568	0.00004	29.9	0.7	2.2
Smear-bombarded tank (entry)	445.10	15.00	973.0	36.0	3650	371	5187	466.0	446.100	0.00223	0.00002	95.7	0.3	1.0
Smear-bombarded tank (outlet)	93504.30	3186.00	188145.0	6953.0	610201	48124	1125148	118998.0	93693.000	0.00205	0.00001	99.1	0.1	0.3
Smear-scraps A	3819.80	129.00	7674.0	365.0	27258	3472	39410	4042.0	3828.000	0.00205	0.00001	99.1	0.1	0.3
Smear-scraps B	2565.30	85.60	5135.0	178.0	17822	1892	21199	3246.0	2570.000	0.00204	0.00001	99.3	0.3	0.8
Smear-scraps C	871.10	29.00	1806.0	66.0	7103	693	8630	832.0	872.900	0.00211	0.00001	97.9	0.2	0.5
Filter blank package II	2.30	0.10	4.0	0.3	17	2	58	5.0	2.300	0.00286	0.00003	83.6	0.5	1.6
Filter blank package II	1.18	0.10	3.0	0.3	23	3	11	7.0	1.190	0.00254	0.00004	89.7	0.8	2.3
Filter blank package II	9.83	0.30	19.0	0.7	71	7	250	14.0	9.850	0.00198	0.00001	100.5	0.3	0.8
Filter blank package II	1.11	0.00	3.0	0.2	21	2	11	6.0	1.120	0.00295	0.00007	81.9	1.3	4.0
Blank package 2; Ø 12.5 cm	0.43	0.02	2.0	0.2	17	6	5	6.0	0.430	0.00470	0.00018	48.5	3.5	10.5
Blank package 2; Ø 12.5 cm	1.57	0.10	4.5	0.2	35	15	20	6.0	1.580	0.00289	0.00005	83.0	0.9	2.6

Appendix IV

HABIT DATA UTILIZED FOR RADIATION DOSE ASSESSMENTS

Summary of the non-radiological and habit data utilized for radiation dose assessments

Inhalation of DU contaminated resuspended soil outdoors

Dust loading factor = 1.6×10^{-5} kg/m^3
Inhalation rate of children (10 years old) = 0.64 m^3/h
Inhalation rate of adults = 0.84 m^3/h
Time spent outdoors by adults and children = 10 h × 365 d = 3650 h/a
Time spent in the Az Zubayr scrapyard by working adults = 2000 h/a
Time spent in the Az Zubayr scrapyard by children = 2000 h/a

Inhalation of DU dust inside military vehicles (tanks) hit by DU munitions

Concentration of the DU dust inside the tank = 1 mg/m^3
Time spent inside military vehicles hit by DU munitions = 10 h/a

Ingestion of DU from soil outdoors

Soil ingestion rate of adults = 0.0183 kg/a
Soil ingestion rate of children = 0.0365 kg/a

Ingestion of DU from vegetation and drinking water

Ingestion of the collected (unknown) vegetation = 300 kg/a
Ingestion of drinking water = 2.7 L/d = 1000 L/a

Ingestion of DU from contaminated flat surfaces (metal, concrete, walls)

Ingestion 100 times/a of the total DU present in the smear test with the highest DU amount

Appendix V

EXAMPLES OF RADIATION DOSES RECEIVED BY PEOPLE FROM DIFFERENT TYPES OF VOLUNTARY AND INVOLUNTARY EXPOSURES

TABLE 49. EXAMPLES OF RADIATION DOSES RECEIVED BY PEOPLE FROM DIFFERENT TYPES OF VOLUNTARY AND INVOLUNTARY EXPOSURES

Type of exposure	**Yearly dose**
Natural average world background [5]	2400 μSv/a
Cosmic rays [26]	310 μSv/a
Naturally occurring radioactive elements in the human body [26]	390 μSv/a
Additional annual dose received by people living in a room with granite floor tiles [24]	up to 1000 μSv/a
Average annual effective dose in different occupations	**Yearly dose**
Civil aircrew [25]	3000 μSv/a
Coal miners [25]	700 μSv/a
Radiotherapy [25]	600 μSv/a
Radiology [25]	500 μSv/a
Dentistry [25]	60 μSv/a
Watching TV regularly (2–3 h/d) [27]	10 μSv/a
Type of exposure (one exposure)	**Dose**
One computed tomography scan to body [25]	1100 μSv
One mammogram [26]	100 μSv
One dental X ray [25]	80 μSv
One chest X ray [25]	100 μSv
One crossing of the USA by jet aircraft [26]	50 μSv

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During the conflict in Iraq in 2003, depleted uranium munitions were employed by the Coalition Forces. As a result, residues of depleted uranium contaminated both localized areas of land and vehicles. The possible health effects of such residues on the Iraqi population living in the vicinity of the affected areas raised concerns. In 2004, the Iraqi Minister of Environment made a formal request of the United Nations Environment Programme for a comprehensive field assessment. In early 2005, a meeting involving UNEP, the World Health Organization and the IAEA took place to discuss, plan and coordinate work on the assessment of depleted uranium residues in southern Iraq. In 2006, during a follow-up meeting that included UNEP, the IAEA and the Radiation Protection Centre of the Iraqi Ministry of Environment, the IAEA was invited to undertake a radiological assessment of the data collected by the Radiation Protection Centre. This report describes the methods, assumptions and parameters used by the IAEA in the assessment of the post-conflict radiological conditions of specified locations for local populations and in the environment. The report uses the results provided by UNEP from the 2006–2007 sampling campaigns, and presents these results, findings and conclusions.

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