GROUP OF GOVERNMENTAL EXPERTS OF THE STATES PARTIES TO THE CONVENTION ON PROHIBITIONS OR RESTRICTIONS ON THE USE OF CERTAIN CONVENTIONAL WEAPONS WHICH MAY BE DEEMED TO BE EXCESSIVELY INJURIOUS OR TO HAVE INDISCRIMINATE EFFECTS

CCW/GGE/XIII/WG.1/WP.7
23 February 2006

Original: ENGLISH

Thirteenth Session
Geneva, 6-10 March 2006
Item 7 of the Agenda
Explosive Remnants of War

Working Group on Explosive Remnants of War

Assessment of the relative risk of categories of explosive ordnance becoming Explosive Remnants of War: Methodology

Prepared by the United Kingdom of Great Britain and Northern Ireland

Executive Summary

1. The issue of Explosive Remnants of War (ERW) is a current humanitarian concern. ERW (comprising of both fired, but unexploded, ordnance and abandoned explosive ordnance) pose risks to civilian communities and to military operations. International organisations are considering how to reduce the incidence of ERW in order that death and injury among civilian populations may be reduced or prevented. As part of this process the UK has offered to develop a methodology to assess objectively which munitions posed the greatest ERW risks to civil communities. Two objective methodologies (one for unexploded ordnance and one for abandoned explosive ordnance) are presented in this report for the assessment of the relative humanitarian risks from different generic categories of explosive ordnance. These are theoretically based and will require a significant amount of data compilation and computer modelling to allow them to be parameterised.

2. In order to undertake an assessment of relative risks, the generic categories of explosive ordnance need to be defined. An initial categorisation of explosive ordnance is made in this report (based on UK explosive ordnance). The categorisation should be finalised by review of the wider international use of explosive ordnance by experts in the area.

The methodology for unexploded ordnance

3. The proposed approach to assess the relative risk of generic categories of unexploded ordnance giving rise to humanitarian risks in a post-conflict environment combines together the following factors:

(i) the relative numbers of each generic category of explosive ordnance used in a conflict;
(ii) the failure rates for each generic category;
(iii) the depths of burial of the generic categories of unexploded ordnance and the relative probability of a person finding an item of unexploded ordnance at a particular depth of burial;
(iv) the lethality of the unexploded ordnance.

4. Limitations to the approach are that no account is taken of the likelihood of a person interacting with an item of unexploded ordnance once it has been observed or the likelihood of the item functioning when disturbed. These issues are not included at present because objective data are not considered to be available.

The methodology for abandoned explosive ordnance

5. The proposed approach to assess the relative risk of generic categories of abandoned explosive ordnance giving rise to humanitarian risks in a post-conflict environment combines together the following factors:

(i) the firing platform for the generic category of explosive ordnance (assigning a minimal relative risk to air or water based platforms);
(ii) the relative quantity of each generic category of *land platform* explosive ordnance used in a conflict;
(iii) the relative likelihood of an uninformed person detonating a generic category of explosive ordnance;
(iv) the lethality of each generic category of explosive ordnance.

6. Limitations to the approach are that it does not take into account purposeful re-use, issues relating to stability of damaged explosive ordnance or the potential for multiple detonation of abandoned explosive ordnance in an ammunition dump.

Introduction

Overview of the problem

7. The issue of Explosive Remnants of War (ERW) is a current humanitarian concern. It is being considered under the 1980 Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or have Indiscriminate Effects (the CCW Convention).

8. ERW (comprising of both fired, but unexploded, ordnance and abandoned explosive ordnance) pose risks to civilian communities and to military operations. Under the provisions of the CCW Convention, international organisations are considering how to reduce the incidence of ERW in order that death and injury among civilian populations may be reduced or prevented.

9. In 2004, the UK offered to consider how to assess which munitions posed the greatest ERW risks to civil communities. To date, assessments have been subjective and an objective methodology has not yet been identified to measure comparative risk between generic categories of munitions. The UK has therefore been asked to further develop its thinking on risk assessment. This report is the response to that request.

Definitions

10. For the remainder of this report the following terms are used:

(i) **explosive ordnance** means conventional munitions containing explosives, with the exception of mines, booby-traps and other devices;

(ii) **unexploded ordnance** means explosive ordnance that has been primed, fuzed, armed or otherwise prepared for use and used in an armed conflict. It may have been fired, dropped, launched, or projected and should have exploded but failed to do so;

(iii) **abandoned explosive ordnance** means explosive ordnance that has not been used during an armed conflict, that has been left behind or dumped by a party to an armed conflict, and which is no longer under control of the party that left it behind or dumped it. Abandoned explosive ordnance may or may not have been primed, fused, armed or otherwise prepared for use;

(iv) **Explosive Remnants of War (ERW)** means unexploded ordnance and abandoned explosive ordnance.

The scope of the work

11. The process of undertaking an assessment of the relative humanitarian risks in a post-conflict environment from generic categories of explosive ordnance is being undertaken in two Parts:

Part 1 – development of the risk assessment methodology;
Part 2 – implementation of the risk assessment methodology.

This report addresses Part 1.

The aim of the report

12. The aim of this report is to describe an objective methodology that may be used to assess the relative humanitarian risks in a post-conflict environment from generic categories of explosive ordnance.

The focus of the report

13. During this process individual zones of conflict and types of conflict are not being considered. The wish is to assess the relative risk averaged over all potential conflicts in all zones. However, it is recognised that there is likely to be considerable variability between different types of conflict and conflict environments.

14. Both unexploded ordnance and abandoned explosive ordnance are considered. There are very different issues associated with these two types of ERW. Hence, they are treated separately later in this report.

15. The focus of this report is solely on the accidental detonation of ERW by civilians. The re-use of abandoned explosive ordnance by combatants or civilians is excluded.

16. The methodology described in this report focuses solely on the terrestrial environment. Saline and fresh water environments are excluded, although it is recognised that ERW that may arise due to the firing or dumping of explosive ordnance into water may be accidentally retrieved and represent a hazard.

Overview of the assessment of risk in relation to ERW

17. Risk assessment is a systematic process for identifying hazards and the likelihood that those hazards will cause harm.

18. Risk assessments for any activity are generally carried out by combining two factors:

(i) the likelihood of an event occurring; and
(ii) the impact of an event.

19. In the context of ERW this equates to:

(i) the likelihood of a person in a post-conflict environment detonating accidentally an item of unexploded or abandoned explosive ordnance; and

(ii) the extent of injury or death caused by that detonation.

20. The likelihood of a person detonating an item of unexploded or abandoned explosive ordnance in a post-conflict environment will depend on a large number of factors. The extent of injury or death caused by detonation of an individual item of unexploded ordnance will depend on a smaller number of factors (principally the design of the item and the proximity of people). The factors influencing both of these components of risk are described in paragraphs 27 to 42.

Review of the literature on ERW risk assessment

21. A search of literature has been carried out to identify if any work has been undertaken previously to compare the post-conflict risks from different categories of unexploded and abandoned explosive ordnance. This work identified a very limited number of items of literature of direct relevance (see references [1], [2] and [3] of the List of References). The search also identified a wider number of reports related to the ERW and unexploded ordnance issue although not directly related to assessing risks from ERW. These generally relate to:

(i) the risks associated with clearance of unexploded or abandoned explosive ordnance from military sites (see, for example, the review of US unexploded ordnance risk assessment methodologies compiled by the RAND corporation, see reference [4]);

(ii) the risks from chemical contamination of the land by the chemical residues of explosives (again see reference [4]);

(iii) the legal/ political issues surrounding ERW (the majority of this documentation is available on the internet).

22. An outline, presumably subjective, ranking (low, medium, high) of the potential for various categories of explosive ordnance to give rise to humanitarian risks in a post-conflict environment has been made previously (reference [1]). In the same report, a methodology is presented that may be used for objective assessment of absolute[1] humanitarian risk. This is the only methodology identified in the literature and it focuses on the use of casualty data and reported quantities of different generic types of explosive ordnance present in particular post-conflict environments. There is a major problem with this approach, in that it is difficult to obtain objective data on which to base the analysis. The conclusions of the report (reference [1]) state that:

> 'There is no objective global overview of casualties and fatalities in post-conflict environments caused by ERW.
>
> The data that has been made available by interested agencies is generally not sufficiently detailed to allow any meaningful conclusions to be drawn about the relative lethality of one weapon system to another.
>
> Cluster bomblets (sub-munitions) and anti-personnel mines are the exception, but even then the allocation of casualties to specific munition types is generally too inaccurate to enable valid objective analysis.
>
> …. the grouping together of all types of munition other than the groups of immediate interest to the organisations collecting the information, may mask the presence of a less numerous munition or method of deployment that is, item for item, more deadly.'

23. Given the problems of obtaining the data necessary to implement the approach described in reference [1], a new approach has been developed.

The adopted risk assessment approach

24. Objective data on post-conflict casualty rates for all generic types of explosive ordnance are not thought to exist. Hence, the approach adopted in this report is significantly different from that adopted in reference [1]. The approach adopted here to ranking explosive ordnance in relation to its risk to civilian populations (i.e. assessing the relative risk) is more theoretical and uses ordnance specific information rather than information on casualties and the environment of deployment. In particular, the approach has been developed to use available data or data that can be reasonably reliably estimated for all generic types of explosive ordnance.

[1] Note: For the remainder of this report, absolute risk is used to describe the quantification of real risks (e.g. the number of deaths per unit area of ground in a particular country due to the explosive ordnance) and relative risk is used to describe the comparison of risks between generic types of explosive ordnance (e.g. generic type A has a 10 times greater risk than type B).

Categorisation of explosive ordinance

25. To assess relative risks, explosive ordnance needs to be sub-divided into a number of generic categories with similar properties and methods of deployment (reference [1]). Based on the experience of the authors an initial categorisation of different types of explosive ordnance is given below:

(i) small arms ammunition;
(ii) pyrotechnics and burning fuses;
(iii) HE Projectiles under 40mm calibre;
(iv) HE Projectiles (excluding mortar bombs) greater than 40mm calibre;
(v) HE mortar bombs;
(vi) carrier (pyrotechnic smoke and illuminating compositions) projectiles;
(vii) projectiles containing white phosphorous;
(viii) HE sub-munitions;
(ix) HE hand grenades;
(x) HE Rifle grenades;
(xi) surface to surface guided missiles;
(xii) air to surface guided missiles;
(xiii) surface to air guided missiles;
(xiv) free flight rockets;
(xv) aircraft bombs;
(xvi) 'cruise' missiles;
(xvii) demolition explosives;
(xviii) detonators, bursting caps etc.

26. The above categorisation is based on not only the generic name and method of deployment of the explosive ordnance, but also on properties such as size. The final categorisation should be undertaken during implementation of the risk assessment methodology when data on the full range of explosive ordnance employed by the international community should be reviewed (for example through reference to data sources such as Jane's Explosive Ordnance Disposal – http:\\jeod.janes.com).

Summary of factors influencing the potential for explosive ordnance to give rise to post-conflict risks

27. Below is presented a summary of the major issues that effect:

(i) the potential for different generic categories of explosive ordnance to become ERW;

(ii) the risks associated with different generic categories of ERW.

28. There are major differences between unexploded ordnance and abandoned explosive ordnance that will give rise to very different risks in a post-conflict environment. Because of this, two risk ranking methodologies need to be developed (one for unexploded ordnance and one for abandoned explosive ordnance). The factors affecting the humanitarian risks are summarised in paragraphs 29 to 42 for unexploded ordnance and abandoned explosive ordnance respectively. The methodologies for assessment of the relative risks for different categories of explosive ordnance are described in paragraphs 43 to 90 for unexploded ordnance and abandoned explosive ordnance respectively. The implementation of the methodologies will lead to two rankings of the generic categories of explosive ordnance in terms of their potential to give rise to humanitarian risks.

Unexploded ordnance

Factors influencing the numbers of unexploded ordnance that are present in a post-conflict environment

29. It is likely that the most important factor in determining the relative risk of death or serious injury to civilians due to unexploded ordnance is the number of items of each generic category of explosive ordnance fired. Although the reliability of explosive ordnance continues to improve there will always be a link between the numbers fired and the numbers that are present in a post-conflict environment as unexploded ordnance. This is inevitably linked to the number of post-conflict casualties. The number of munitions fired from each generic category will depend on a number of factors, including:

(i) type of conflict;
(ii) size of forces involved;
(iii) availability of munitions;
(iv) tactics used; and
(v) duration of conflict.

30. Explosive ordnance becomes unexploded ordnance when it fails to detonate as intended. There are many reasons why this may happen. These include reference [1]:

(i) design faults;
(ii) production faults;
(iii) poor storage;
(iv) improper handling;
(v) poor firing drills;
(vi) incorrect launch profiles;
(vii) poor strike angles or insufficient impact force;
(viii) environmental factors; and
(ix) interaction with other items of explosive ordnance.

Factors influencing the risk from unexploded ordnance

31. There are a large number of diverse factors affecting the risk of death or serious injury to a person due to detonation of an item of unexploded ordnance. These can be broken down into four overall issues:

(i) the probability of a person finding an item of unexploded ordnance;
(ii) the probability of that person interacting with the item;
(iii) the probability that the interaction causes detonation;
(iv) the damage caused by the detonation.

32. Each of the above issues can be further broken down. The probability of a person finding an item of unexploded ordnance will relate to:

(i) the depth of burial of that item (is it visible at ground surface?);
(ii) the location of that item relative to centres of population;
(iii) the activities undertaken in that region;
(iv) the density of vegetation.

33. The probability that a member of the civilian population touches the item of unexploded ordnance once it has been identified will relate to:

(i) wealth of the local population;
(ii) knowledge of the local population;
(iii) the environment;
(iv) the shape and composition of the item of unexploded ordnance (does it look like a 'bomb', does it look like something a child would like to play with, does it contain valuable metal, is it too big to lift or move).

34. The probability that interaction of a person with an item of explosive ordnance will cause detonation will relate to the type and violence of interaction and the reason for failure of the item. For example, on seeing an item of unexploded ordnance a person could avoid it, step on it, pick it up, kick it, hit it, cut it up, shake it, throw it, dismantle it or put it on a fire. If the item is not observed due to it being buried or covered in vegetation, it may be stepped upon or ploughed.

35. The reason that the mechanism of failure of the item is important is that if the item failed prior to arming it should pose less of a risk of accidental initiation compared to if it failed after arming. However, damage to the arming mechanism caused by impact after flight may be enough to leave the explosive ordnance in a dangerous state. If it has been armed, it may be in a very unstable state, with the possibility of detonation given the slightest disturbance. The damage caused by detonation of an item of unexploded ordnance will relate principally to the design of the item and to the proximity of people to the item when it detonates.

Abandoned explosive ordnance

Factors influencing the potential for abandoned explosive ordnance to be present

36. The likelihood of a generic category explosive ordnance being abandoned will be principally related to the platform from which it is deployed (land, sea or air) and it's proximity to the forward edge of the battle area.

37. Explosive ordnance that may be deployed, in the close battle, from land platforms such as infantry, armoured vehicles or artillery will be more likely to be abandoned than explosive ordnance that can only be fired from air or water based platforms (i.e. aircraft or ships). In addition, it can be hypothesised that explosive ordnance fired at the forward edge of the battle area (infantry and AFV weapons) are more likely to be abandoned than those fired from artillery weapons that may be many kilometres away. Only a limited number of scenarios occur where air or sea launched explosive ordnance may be abandoned. These are: supply chain attack, aircraft crash/ forced landing, naval base over-run, airforce base over-run. In the cases of military base over-run, it is likely that the armed party taking control will either guard or destroy any ammunition dumps on the site.

38. Therefore, abandoned explosive ordnance is most likely to occur in one of the following scenarios:

(i) abandoned fighting vehicles;
(ii) ammunition supply points;
(iii) ammunition caches;
(iv) small quantities of small arms and light weapons (SALW[2])at locations of death, injury or retreat of individual combatants.

39. In general, ammunition supply points are controlled stores for quantities of explosive ordnance which are guarded by the appropriate armed party. If they are over-run they would then, in most circumstances be guarded by the other armed party or destroyed. However, there are examples of poor destruction of ammunition dumps leaving munitions scattered around the area.

40. In addition to the above factors affecting the types of explosive ordnance that may be abandoned, the relative quantity for each generic category is likely to relate to the overall quantities of each category used in the conflict.

[2] Defined as: all lethal items of conventional explosive ordnance that can be carried by an individual combatant or light vehicle and that do not require a substantial logistic and maintenance capability.

Factors influencing the potential for abandoned explosive ordnance to give rise to injury/ death of civilians

41. A number of factors affect the potential for an item of abandoned explosive ordnance to injure or kill civilians. These include:

(i) its accessibility;

(ii) its stability – the potential for spontaneous detonation or detonation due to disturbance (influenced by environmental factors, any damage that the explosive ordnance may have incurred, the generic type of explosive ordnance, and time);

(iii) its potential for uninformed detonation[3] (its integral nature, the number of steps required for activation, ease of activation).

42. A limited number of the above factors are specific to the type of explosive ordnance and can be evaluated to assess relative risk. However, other factors are specific to the type of conflict and the post-conflict environment and they cannot be assessed in a generic manner that has applicability to all conflict areas.

Methodology for objective assessment of the relative risks associated with unexploded ordnance

43. In order to develop a methodology for an objective assessment of the relative risks associated with the various generic categories of unexploded ordnance, the factors detailed in Section 4.1 were reviewed to evaluate:

(i) those parameters for which data might be available; and
(ii) those parameters which are important in the assessment of relative risk.

44. To objectively assess absolute risk, the various factors need to be combined together in a logical manner to give a single value of real risk for each generic category of explosive ordnance. This process is difficult because quantitative data are not available for all factors and subjective judgement has to be used, potentially giving rise to significant uncertainties. However, the aim of this report is to develop a methodology to compare different generic categories of explosive ordnance, i.e. to assess the relative rather than absolute risk. This is useful, because factors that are effectively the same for all generic categories of explosive ordnance can be ignored, i.e. it can be assumed that all categories of explosive ordnance are used in the same environment, with the same population.

[3] Note, as described in 1.3, purposeful re-use is excluded from consideration in this report.

The relative quantity of unexploded ordnance produced by different generic categories of munitions

45. For a particular generic category of explosive ordnance, the number that may be present as unexploded ordnance within a former conflict zone will relate to the numbers fired and the percentage that have failed to detonate:

$$Q^e = n^e \times f^e$$

Where:

Q^e is the quantity of generic explosive ordnance category e present as unexploded ordnance;
n^e is the quantity of generic explosive ordnance category e fired; and
f^e is the failure rate of generic explosive ordnance category e.

46. There will be uncertainty in both n^e and f^e. However, the degree of uncertainty in n^e is likely to be more significant. Reported figures for failure rates for explosive ordnance are generally in the range 1-30%, i.e. just over one order of magnitude. However, the quantity of explosive ordnance fired could potentially vary by many orders of magnitude.

47. It is the aim of the current study to develop a methodology to assess the relative risk for all generic categories of explosive ordnance, averaged over all types of conflict and conflict environments. We are therefore interested in the relative quantity of explosive ordnance of generic category e fired, on average across all conflicts, compared to other generic categories of explosive ordnance.

48. $$rQ^e = rn^e \times f^e$$

Where:
rQ^e is the relative quantity of generic explosive ordnance category e present as unexploded ordnance averaged across all conflicts; and
rn^e is the relative quantity of generic explosive ordnance category e used on average across all conflicts.

49. Obtaining values for rn^e and f^e is not straightforward. This is discussed further in paragraph 84 to 89. The value rQ^e only relates to the numbers of unexploded ordnance present. It does not tell us anything about the potential for that unexploded ordnance to detonate. The factors relating to the potential for detonation and injury are discussed below.

The probability of a person finding an item of unexploded ordnance

50. The probability of a person finding a particular item of unexploded ordnance relates to a number of factors, as discussed previously in paragraphs 31 to 35. The majority of these factors relate to the environment and the population. In order to calculate a relative risk for the different generic categories of explosive ordnance we must assume that they all reside in the same environment, with the same population. The environment and population related factors can therefore, for the purposes of risk ranking, be ignored. The one factor that is strongly related to the type of explosive ordnance is the depth of burial (which in turn relates to the velocity of impact, the shape of the item, the mass of the item, the strength of the casing, the strike angle and the soil density and strength at the impact location). Hence, the depth of burial must be considered.

51. Unexploded ordnance lying on ground surface is likely to have the highest probability of being found by a person; the probability will generally decline with depth of burial. There is some uncertainty in the relationship between depth of burial and probability of item being found. Unexploded ordnance buried at significant depths (say greater than 1m) will be a much lower risk to civilians than that at or near ground surface. However, items of unexploded ordnance buried just below ground surface may be inadvertently trodden upon and detonated. Those on ground surface may be either touched on purpose (children playing or adults moving them) or may be avoided. It is likely that those lying on ground surface present a significantly higher probability of being found than those buried just below, because the probability of inadvertently stepping on one or ploughing one up is significantly less than observing one that is visible.

52. At present, it is assumed that items visible at ground surface have a 90% relative probability of being found within a reasonable period of time (say 10 years), that items buried within cultivation depth (defined here as <30cm depth) have a 10% relative probability of being found and that at greater depths the relative probability is 1%. These figures are estimates and it is recommended that during Part 2 (implementation of the methodology) a literature review is carried out to evaluate issues such as areas of land turned over (to shallow depth) by agriculture and (to greater depths) for building foundations.

53. The probability of an item of unexploded ordnance coming to rest at a particular depth interval (surface, 0-30 cm or >30 cm) may be calculated using the factors given in the first paragraph of this Section (further details of parameterisation are given in paragraphs 66 to76. Based on the above, the overall relative probability of a person finding an item from a particular generic category of explosive ordnance that exists in a post-conflict environment is:

$$rP^{e} = D_{s}^{e} \times rp_{s} + D_{<30}^{e} \times rp_{<30} + D_{>30}^{e} \times rp_{>30}$$

where:

rP^{e} is the relative probability that an item of generic explosive ordnance category e, which exists in a post-conflict environment, will be found;

D_s^e is the probability that an item of unexploded ordnance category e will rest at ground surface;

$D_{<30}^e$ is the probability that an item of unexploded ordnance category e will rest at 0-30 cm depth;

$D_{>30}^e$ is the probability that an item of unexploded ordnance category e will rest at >30cm depth;

rp_s is the relative probability of an item of explosive ordnance lying on the ground surface being found;

$rp_{<30}$ is the relative probability of an item of explosive ordnance lying at <30cm depth being found; and

$rp_{>30}$ is the relative probability of an item of explosive ordnance lying at >30cm depth being found.

If rP^e is then multiplied by the calculated rQ^e value from paragraphs 45 to 49, this will give the relative probability of generic category of explosive ordnance e being found in a post-conflict environment.

The potential for disturbance of an item of unexploded ordnance

54. Once an item of unexploded ordnance has been found by a person, that person will either touch/disturb the item or they will not. If they decide to touch/ disturb the item there are a number of ways in which they may do this. These have been discussed previously in paragraphs 36 to 40. If the person decides not to touch an item of unexploded ordnance they may mark its location to prevent another person disturbing it and/or inform unexploded ordnance clearance organisations.

55. However, if items of unexploded ordnance are not marked and/ or cleared it is likely that through time and with human activity the probability of disturbance of an item of unexploded ordnance will approach 100%. This is almost certainly the case for buried unexploded ordnance, where the action of finding will almost certainly be linked to disturbance.

56. Over relatively short timescales, and in the case of visible items the main factor of importance to a relative assessment of the risk from unexploded ordnance is the degree to which the

shape and composition of the item affects the potential for a person to interact with it[4]. For example, it may be more likely that an item of explosive ordnance, which looks attractive or has a known re-sale / re-use value will be picked up or that one containing a valuable metal will be dismantled. Unfortunately, these factors are difficult to assess in an objective manner.

57. Given the uncertainties in determining the relative potential for a person to disturb an item of explosive ordnance that has been found, this parameter is not included in the assessment methodology. However, it is noted that it is likely that 100% of buried items will be disturbed (in the action of finding), compared to a lesser amount of surface distributed items.

The potential for detonation of the disturbed item of unexploded ordnance

58. The potential for an item of unexploded ordnance to detonate once disturbed will depend on the sensitivity of the failed item and the magnitude of disturbance. The sensitivity of the failed device will principally relate to:

(i) the point during firing at which the item of explosive ordnance has failed, i.e. has the arming mechanism failed or has the device armed but the fuze failed;
(ii) the type of fuze (chemical, mechanical, electrical);
(iii) the reason for failure.

59. Although the magnitude of disturbance may vary slightly for different generic categories of explosive ordnance, it is assumed at present that, in most cases, disturbance comprises of movement, shaking or dropping of an item of unexploded ordnance.

60. Data are not available on the sensitivity of unexploded ordnance of most different categories, although limited data are available for some munitions types (see for example reference [5]). Given the lack of data, the potential for disturbance to cause detonation cannot be evaluated in an objective manner and hence is excluded from the current methodology.

61. Whilst it is not possible to identify numerically the sensitivity of a particular generic category of unexploded ordnance, it should be possible to review the arming and fuze mechanisms to identify those categories that are likely to be relatively stable and those that are likely to be very unstable. It is recommended that further work be undertaken with the aim of determining if there is an objective way in which the likelihood of detonation of unexploded ordnance on its disturbance can be evaluated.

[4] Issues such as the education and wealth of the local population and the environment are not relevant for an assessment of relative risk because, for the purposes of comparison, it can be assumed that each generic category of unexploded ordnance lies within the same environment.

Lethality

62. The damage that will occur during detonation of an item of unexploded ordnance will depend on the design of the ordnance and the number of people in its proximity. For the purposes of the risk assessment methodology described here it is assumed that in all cases one person is in close proximity to the item of explosive ordnance (in the case of surface items in contact and in the case of buried items within say 5m) and that there may be other people in the general vicinity of the detonation. Given the uncertainties in the potential distribution of people in the vicinity of a detonation it is assumed that damage/ lethality relates solely to the radius of effect of the item.

63. For the majority of items of explosive ordnance the degree of damage associated with detonation will have already been evaluated and parameters such as mean area of effect or lethal radius have been calculated.

64. The selected lethality factor for a generic category of explosive ordnance can be multiplied by the relative likelihood of generic categories of explosive ordnance being found in a post-conflict environment to give an overall ranking of risk.

65. Unexploded ordnance relative risk for category e $= L^{e} \times rP^{e} \times rQ^{e}$

Where $\mathbf{L^{e}}$ is the selected lethality factor for generic category of explosive ordnance e (Note, $\mathbf{rQ^{e}}$ and $\mathbf{rP^{e}}$ are defined previously in paragraphs 45 to 49 and 50 to 53 respectively).

Parameterisation

66. Based on the risk assessment approach described in paragraphs 45 to 65 there are four important sets of data that require collection in order to undertake the objective risk ranking of different generic categories of explosive ordnance. These are:

(i) the relative quantity of each generic category of explosive ordnance fired on 'average' across all conflicts;

(ii) the failure rate of each category;

(iii) the depth of burial of each category;

(iv) the lethality of detonation of each category.

67. In addition, there are three additional sets of data, which if they were possible to obtain, would add significantly to the robustness of the approach. These are:

(i) the relative areas of disturbance of the ground (to various depths) by agricultural and other activities;

(ii) the relative probability of a person picking up a generic category of unexploded ordnance;

(iii) the likelihood of an item of unexploded ordnance detonating if it is moved.

68. For the first four items it is likely that objective data can be obtained. However, for the three latter items objective data are unlikely to exist. Hence, any evaluation of these issues is likely to be to some degree subjective.

69. The principal methods of parameterisation are described below.

The relative numbers of each generic category of explosive ordnance fired in an 'average' conflict

70. The relative quantity of each generic category of explosive ordnance fired in on average across all conflicts would be obtained from war games modelling data, backed up where possible by historical data. Because conflicts vary so much in both their size, the aims of the armed parties, and the weaponry at the disposal of the combatants determination of the relative quantities of a generic category of explosive ordnance used in an average conflict may be difficult to assess. It is proposed that data would be obtained for a number of different conflict scenarios/ types. These data would be presented in the final report on the risk ranking approach and would be worked through to provide a risk ranking for each conflict type. The data would be averaged and used to provide an overall, combined, ranking.

Mean failure rates

71. Mean failure rates would be principally obtained from data held by the Procurement Authorities and compared with widely available international data. Failure rate data have not been compiled to date and there would be a requirement to undertake a significant data searching exercise. Records requiring searching would include munitions design information, munitions incidents and defects reports, and acceptance testing reports. These sources of data would provide the baseline data for undertaking the risk ranking of the various generic categories of explosive ordnance. The data would be compared to available open literature data to give an indication of uncertainties.

72. It should be noted that 'because conditions during acceptance testing are generally favourable, failure rates during operations are often substantially higher' (reference [6]) and that 'it is very rarely possible to establish an accurate ammunition failure rate during or after a conflict'. However, because the methodology described in this report aims to provide a *relative* assessment of the risks from different categories of explosive ordnance the acceptance testing data should be adequate.

Depths of burial

73. Depths of burial would be calculated for different generic categories of explosive ordnance by computer modelling. The modelling would take into account variation in the input parameters that relate to the environment (i.e. the strike angle and the soil density and strength at the impact location) to give probabilities of burial at different depths. The variation in the soil density and strength would be related to various generic environment types such as desert sand, marsh, agricultural soil and exposed bed rock.

Lethality

74. Lethality factors are available for most munitions types. These data should be obtained and reviewed. In most cases, the damage is assessed in terms of a mean area of effect or a lethal radius. The same lethality criteria should be obtained for all generic categories of explosive ordnance. If data are not available they should be determined from computer modelling.

Limitations

75. The objective risk ranking methodology for unexploded ordnance described above has necessarily included a large number of simplifications principally due to the lack of objective data for some factors. However, the authors believe that this is the most objective approach to ranking the potential risks of the various generic categories of unexploded ordnance that can be undertaken at present.

76. The principal limitations are as follows:

(i) the approach does not take into account the relative likelihood of a person disturbing an item of unexploded ordnance once it has been observed;

(ii) the approach does not assess the probability of an item of unexploded ordnance detonating once disturbed.

Methodology for objective assessment of the relative risks associated with abandoned explosive ordnance

77. Many of the factors that influence the absolute risks from abandoned explosive ordnance cannot be assessed in an objective manner. This is because many of the issues will be very conflict dependent. However, a number of factors can be evaluated to give a reasonably objective *estimate* of the relative risk associated with different generic categories of explosive ordnance[5].

[5] It should be noted that, as stated in Section 1.5, the potential for intentional re-use of abandoned explosive ordnance has been excluded from evaluation.

78. Firstly, the generic types of explosive ordnance can be subdivided by the platform from which they may be fired.

79. Secondly, for those generic categories of explosive ordnance fired from a land platform the relative quantities used in an 'average' conflict can be evaluated.

80. Thirdly, the relative probability of an uninformed person causing functioning of an item from a generic category of explosive ordnance can be evaluated. The basis for this it the integral nature of the item of explosive ordnance and the number of steps required for detonation. For example, it is significantly more likely that a grenade will be detonated than a high-explosive projectile from an abandoned vehicle.

81. Fourthly, a lethality factor for the generic category of explosive ordnance can be determined.

82. The methodology would comprise of assigning explosive ordnance fired solely from sea or air platforms a minimal risk because they are unlikely to be abandoned without first being 'captured' (see paragraphs. 41 and 42). The remaining factors described above would then be multiplied together to give an overall risk weighing for each generic category of explosive ordnance.

83. Abandoned explosive ordnance relative risk for category e = $L^{e} \times rU^{e} \times rn_{l}^{e}$

Where:

L^{e} is the selected lethality factor for generic category of explosive ordnance e;
rU^{e} is the relative probability of an uninformed person causing functioning of an item from generic category of explosive ordnance e;
rm_{l}^{e} is the relative quantity of generic category of explosive ordnance e fired from land platforms in an 'average' conflict.

Parameterisation

84. There are four items of data that would require compilation in order to provide an assessment of the relative risks from abandoned explosive ordnance.

Platform from which explosive ordnance is fired/ launched

85. There are large quantities of public domain data on the platforms from which different types of explosive ordnance are launched/ fired (see for example Jane's online, www.janes.com). These would be compiled for the various generic categories of explosive ordnance.

Relative numbers of different categories of 'land' platform explosive ordnance fired in a conflict

86. These values would be calculated following the approach described in paragraph 70.

Relative probability of an uninformed person causing functioning of an item of abandoned explosive ordnance

87. This is the most difficult parameter to evaluate, given that unfired explosive ordnance is designed to be 'safe'. The potential for an uninformed person to cause an item of explosive ordnance to detonate will be related to 2 main factors:

(i) the integral nature of the item of explosive ordnance (does it need to be fired from a gun, which may not be present);

(ii) the number of steps/ actions required for functioning of the item of explosive ordnance.

88. These factors should be assessed for each land-based generic category of explosive ordnance by an expert panel and a relative likelihood factor assessed for each.

Lethality

89. Lethality factors would be obtained as described in paragraph 74.

Limitations

90. There are a large number of limitations to this approach. These include the fact that:

(i) the type of conflict could have a significant impact on the potential for explosive ordnance to be abandoned and the type of explosive ordnance that may be abandoned;

(ii) the approach does not address the issue of the stability of abandoned explosive ordnance that may have been damaged or stored incorrectly. Damage to explosive ordnance could lead to some types being significantly more likely to detonate when disturbed than others;

(iii) the damage / lethality is treated in a simplistic manner, assuming that only the item of explosive ordnance being disturbed will detonate. In a case where the item is in a cache, it is possible that the initial detonation may cause multiple other detonations, giving rise to a significantly larger effect;

(iv) the potential for an uninformed person to detonate an item of explosive ordnance would have to be assessed by an expert panel rather than by the use of purely objective data;

(v) the approach only assesses the post-conflict health risks to civilians that have accidentally accessed items of abandoned explosive ordnance. The risks due to re-use of abandoned explosive ordnance are not included in the approach.

Conclusions

91. The theoretical factors affecting the relative risk of generic categories of explosive ordnance giving rise to a humanitarian impact have been compiled. Review of these demonstrates that the risk factors for unexploded ordnance are significantly different from those for abandoned explosive ordnance. Hence, two assessments of the relative humanitarian risks from categories of explosive ordnance need to be carried out (one for unexploded ordnance and one for abandoned explosive ordnance), with the probable output being two very different rankings of risk.

92. Methodologies for the objective assessment of the relative humanitarian risk from different generic categories of explosive ordnance have been developed for unexploded ordnance and abandoned explosive ordnance. These are theoretically based and will require a significant amount of data compilation and computer modelling for parameterisation. There are a number of limitations to the approaches. However, the authors believe that adoption of the approaches should lead to a reasonably robust and objective assessment of the relative risks.

Recommendations

93. It is recommended that:

(i) the methodology described in this report for the objective assessment of the relative risks from generic categories of explosive ordnance be implemented;

(ii) a final generic categorisation of explosive ordnance be made by persons with knowledge of the range of explosive ordnance types that are available internationally;

(iii) a literature review be carried out to evaluate issues such as average areas of land turned over (to shallow depth) by agriculture and (to greater depths) for building foundations;

(iv) further work be undertaken with the aim of determining if there is an objective way in which the likelihood of detonation of unexploded ordnance on its disturbance can be evaluated.

List of References

[1] Wilkinson, A. 2002. Explosive Remnants of War (ERW) – A Threat Analysis. Report of the Geneva International Centre for Humanitarian Demining. ISBN 2-88487-003-2.

[2] Geneva International Centre for Humanitarian Demining and International Committee of the Red Cross. 2002. The types of munitions that become explosive remnants of war - factors which contribute to the occurrence of explosive remnants of war. Discussion paper at the Group of Government Experts to the States Parties to the Convention on prohibitions or restrictions on the use of certain conventional weapons which may be deemed to be excessively injurious or to have indiscriminate effects. First Session, 21-24 May 2002. CCW/GGE/I/WP.5.

[3] Blagden P. and Wilkinson A. 2001. Explosive remnants of war (ERW) – a quick look threat analysis. Geneva International Centre for Humanitarian Demining.

[4] MacDonald, J., Knopman, D., Locwood, J., Cecchine, G. and Willis, H. 2004. Unexploded Ordnance – A critical review of risk assessment methods. Report of the RAND Corporate. ISBN 0-8330-3432-4.

[5] Eimer, D.H. (No date). TR-xx, Unexploded Ordnance (UXO) Study. Army Material Systems Analysis Activity (AMSAA), DSN 298-5676.

[6] King, Colin. 2000. Explosive Remnants of War: A Study on Submunitions and other Unexploded Ordnance. Commissioned by the International Committee of the Red Cross (August 2000).

———