Journal of Conventional Weapons Destruction

Volume 5
Issue 3 *The Journal of Mine Action*

Article 26

December 2001

The Quantification of Safety and Risk: A Critical Review

Peter Schoeck

Recommended Citation

Schoeck, Peter (2001) "The Quantification of Safety and Risk: A Critical Review," *Journal of Mine Action* : Vol. 5 : Iss. 3 , Article 26.
Available at: http://commons.lib.jmu.edu/cisr-journal/vol5/iss3/26

Journal of Mine Action

Wednesday 13th July 2016Wednesday 13th July 2016 Issue 5.3 | December 2001

Contents
Focus
Notes
Features
Staff
Call
Journal
Home

The Quantification of Safety and Risk: A Critical Review

Current measures of safety for demined areas are inadequate because they do not accurately reflect the safety of a demined area. A new standard, termed "risk factor," better describes the results of demining processes. However, even this equation works poorly when dealing with the small numbers in a demined field.

by Dr. Peter A. Schoeck

Summary

It is shown that the concept "safety factor," as presently used as a criterion for declaring a demined area safe for use, is impractical and should be replaced by its complement, called "risk factor," which stands for the ratio of the size of the mine-polluted portion of a demined field to its total area. An equation expressing the risk as a function of the efficiencies of the demining processes applied is developed. The limitations of applying this equation in the quantification of the risk are then shown by means of a case study. The necessity of an error analysis for all figures quoted to express the efficiency of detection methods is emphasized, while the limitations of advanced scientific approaches with respect to the ultimate goal of humanitarian demining—zero risk—are discussed. A revision of demining standards is proposed.

Introduction

According to the "Standards for Humanitarian Demining Operations" as issued by the Geneva International Center for Humanitarian Demining, "safety factor" is a measure of the efficiency of a certain demining, or more precisely, mine detection method. The prescribed standard is an efficiency of 99.6 percent, meaning that of all mines present, 99.6 percent must have been detected and removed before an area can be considered safe. It is obvious that such a definition makes no sense for the simple reason that the safety of an area does not depend on how many mines it contained in the beginning, but how many mines are left undetected after the detection process.

Therefore, a reasonable definition of safety would be the ratio between that portion of the total area on which one could safely set foot, denoted by Am, to the total area, A. With this definition, the safety factor s, is expressed by:

$$s = 1 - Am / A \quad (1)$$

The area Am is the sum of all individual "sensitive cross sections" (denoted by a), which are defined as the area around each mine that would cause an ignition when subjected to a minimum pressure force. With this definition and denoting the number of mines left undetected after i demining processes as ni, we can write:

$$Am = a\ ni \quad (2)$$

with the simplified assumption that *a* represents an average value for all ni mines. Inserting (2) into (1), we obtain:

$$s = 1 - a\ ni / A \quad (3)$$

To calculate the value of s, we must know besides A (the area of the mine field) the quantities ni and *a*. Leaving for the moment the question as to their determination, we shall show in the next section why the concept "safety" should be replaced by the concept "risk."

Introduction to the Risk Factor

Let us assume that a mine field of size A=100m x 100m = 10,000 m2 has been demined up to a degree that ni= 10 AP mines are left undetected. The sensitive cross section of each mine will be a= 0.05m2 corresponding to a circle of diameter 0.25m. Nobody would dispute the fact that entering such a "demined" area, which is approximately the size of a football field, entails a tremendous risk, a fact that should manifest itself by the safety factor. But surprisingly its calculation by (3) yields the deceiving value of s = 99.995 percent, which is so close to 100 percent that one might be tempted to consider the safety of the demined field to be sufficient for all practical purposes.

Let us now apply a further demining process to the mine field by which we succeed in detecting and removing half of the mines left. Undoubtedly, the risk of an accident will thereby be reduced by 50 percent. How does this reflect on the safety factor? Our calculation based now on ni = 5 yields s = 99.9975 percent. In other words, a risk reduction by 50 percent expresses itself with only a minute rise of the safety factor.

This example shows that the application of the safety factor s as a measure for the degree of safety when entering a demined area is impractical. Its replacement by its complement Am/A, which may be called "risk factor," expressed by:

$$r= Am / A \quad (4)$$

therefore suggests itself. With (2) it takes on the form

$$r= a\ ni/A \quad (5)$$

Quantification of Risk

When defining the safety factor s and replacing it by the risk factor r, the essential point was that both are unrelated to the original number of mines (n0) or, for that matter, to the original density of mines on the field expressed by n0/A. For the safety of an area does not depend on its demining history, but solely on its present state.

Let us now assume that by a sufficient number of experiments, in each of which the number of mines was large enough for achieving a result based on statistics under typical average conditions, we have found that a certain demining process leads statistically to the detection of a fraction of the original number of mines expressed by:

$$d=(n0 - n1) / n \quad (6)$$

where:

n0= original number of mines, and

n1= number of mines left undetected.

We can then define an efficiency of the respective demining process by:

$$h1= 1- n1/n0 \quad (7)$$

Applying three demining processes successively, the number of undetected mines left is expressed by:

$$n3 = n0 (1-h1) (1-h2) (1- h3) \quad (8)$$

with h1, h2, h3 standing for the efficiency of each process.

To minimize the influence of system inherent errors, the Standards for Humanitarian Demining Operations prescribe that the three processes applied in succession must be independent of each other. This means that processes applied in a row must be based on different principles. As an example, if a mine field was first probed manually by prodding the ground, the subsequent process applied must be detection by using dogs or ground-penetrating radar, for instance.

From (5) and (8) it follows that the risk of stepping on a mine after the application of three consecutive demining processes would be:

$$r3 = (n0/A) a (1-h1) (1-h2) (1- h3) \quad (9)$$

The question now arises as to the usefulness of (8) and (9) in practice. We shall attempt to answer this question by a practical example. Let us assume that a demining process has been applied to a mine field of A=100,000 m2, the efficiency of which had been experimentally determined to be h1= 0.9, and that 100 mines have been detected and removed. This justifies the assumption that approximately 10 mines are left undetected in the area. If we now apply a second process, its efficiency also being 0.9, we must take into account that this efficiency has been statistically determined with a large number of mines representing average conditions. But with only 10 mines left to be detected, the application of the statistical efficiency value of 0.9 is not tolerable. In other words, the assumption is not justified that the number of mines left undetected after application of the second demining process will be reduced to one, as would result from (8). From this we can conclude that the calculation of the remaining risk by (9) leads to a value not corresponding with reality. What, at a glance, had the appearance of a neatly derived formula for expressing the risk of stepping on a mine in a "demined" area turns out to have limited practical value as far as its accuracy is concerned.

Conclusions

Because experimentally determined statistical values of demining efficiency always refer to a large number of mines, they are not valid after a minefield has been cleared to such an extent that only a small number of mines are left undetected.

Furthermore, quantitative results obtained by measurements are of no value without an error analysis. Applied to the efficiency of a certain mine detection method expressed by h= 99.6 percent = 0.996, corresponding to a risk of 0.4 percent= 0.004, implies that this figure must be measured with an accuracy of 10-3. Which method applied in the field of mine detection would justify such an assumption?

In humanitarian demining, each mine left unidentified and unremoved represents an unacceptable safety risk, as opposed to military operations, where casualties are taken into account from the beginning. With due respect for all efforts regarding the application of advanced technologies in optics, electronics and chemistry to mine detection, they inevitably contain systematic and random errors. The aim must be zero risk. This can be guaranteed only by probing the soil in such a manner that every item, down to the smallest possible sized mine, is detected and removed.

While achieving this objective is extremely difficult in demined residential areas, it represents no problem in the case of mechanized demining of farmland where all of the soil is being milled. If, down to the smallest possible size of a mine, all soil has been subjected to a mechanical impact, the risk factor defined above has been reduced to zero. To apply a second independent process merely to comply with standards established by reasoning not valid for this case makes no sense. For the sake of avoiding unnecessary costs while demining, a re-examination of present demining standards seems therefore advisable.

Biography

Dr. Peter A. Schoeck, a U.S. citizen, received his scientific education in Mechanical Engineering and Physics at the University of Karlsruhe/Germany and at the University of Minnesota. He has been active in Polar Geophysical Research in the Arctic and Antarctic and in the field of Thermodynamics of Jet Propulsion, holding a professorship at the University of Tennessee Space Research Institute of Tullahoma, Tennessee. From 1966 to 1974, he was Director of Research and Development of the BOSCH Group of Companies, Stuttgart/Germany. He is now a consultant to a Scandinavian firm engaged in the development of demining equipment and the demining of farmland in the Balkans.

Contact Information

Dr. Peter A Schoeck
Runkelsstr.27 FL Triesen / Liechtenstein

E-mail: schoeck@schoeck.lol.li

Publisher: MAIC **Contact:** MAIC@jmu.edu **Last updated:** 07/13/2016 13:31:33**Last updated:** 01/11/2016 20:48:37