Gradual Dispersal of Explosives by Ants and its Possible Implication for Future Landmine Production

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Abstract

During hyperspectral imaging experiments on landmines and improvised explosive devices (IEDs), the authors unexpectedly discovered the gradual dispersal of loosely-laid explosives by indigenous ants (order: Hymenoptera). Similar ant-related phenomena were observed inside minefields in four geographically different and diverse countries. This phenomenon may present an opportunity to provide a natural means of neutralizing specially modified landmines in the long-term.

The ant-borne dispersal rate of explosives was measured to be 10 grams per day per ant colony. The extrapolated ant-borne dispersal rate of explosives, when applied to hypothetical minefields incorporating ant-accessible landmines, was estimated to be 19 kilograms per year per hectare, roughly equivalent to 95 antipersonnel or 4 antitank landmines per year per hectare.

Ant-accessibility to the explosives inside landmines may be accomplished via simple, low-tech and extremely low cost mine casing modifications which would not negate the short-term strategic effect of these devices. Such modifications may reduce the civilian and environmental impact of long-term situated landmines.

Introduction

In spring 2008, the authors, while performing hyperspectral imaging experiments on landmines and IEDs in the Pashtunistan region, noticed that ants were attracted to exposed panels of loose TNT and RDX explosive[1]. In fact, the ants were observed carrying away clumps of TNT and RDX to their nests.

After the experimental trials, this surprising and curious behavior led the authors to conduct an open literature search to see if a similar phenomenon had been previously observed. Unfortunately, there were no published accounts of ants dispersing explosives. Instead, existing publications focused on the use of biological systems such as insects, mammals, and single-celled organisms for the detection of explosives.

The authors then sought to see if a similar phenomenon had been observed by humanitarian deminers working in old minefields. Several of the demining groups that were approached reported seeing such phenomena in diverse regions ranging from Bosnia to Eritrea to Angola. For example, deminers recounted seeing ants removing pieces of TNT blocks from old Russian PMD-6 mines while other workers reported discovering that the explosives in cracked and weathered PPM-2s had been mysteriously 'cleaned-out'.

Based on the authors' observations and the deminers' anecdotal evidence, it seems that ants may have an affinity to collecting TNT and RDX. The reasons why ants collect these explosives are, as yet, unknown.

Further examination of this intriguing phenomenon has allowed the authors to speculate and formulate the following hypothetical question: If ants were allowed access to the explosives contained in landmines (via small prefabricated holes in the landmine's casing), then how long would it take a colony of ants to neutralize an appropriately modified landmine and/or a minefield containing such mines?

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Analysis of the ant-borne dispersal rate of explosives and ant phenomenology tantalizingly indicates that indigenous ants may be used as an effective long-term neutralizing solution for appropriately modified landmines. However, more research is needed to determine if this approach is truly viable. If so, then an amendment to the Landmine Protocol of the 1980 CCW (Convention on Certain Conventional Weapons) accord should be requested to constrain the manufacture of future landmines to include the appropriate casing modifications.

This paper describes the discovery of ants dispersing explosives, the search for similar phenomena, why ants are attracted to explosives, the rate of explosive dispersal by ants, and possible implications for the future production of landmines.

Discovery of Ants Dispersing Explosives

In the spring of 2008, while in the Persia-Pashtun region, scientists from DRDC Suffield and ITRES conducted systematic diurnal experiments on detecting surface-laid and buried landmines, improvised explosive devices (IEDs) and their components using shortwave and longwave hyperspectral imagers mounted on a personnel lift. As part of one of the experiments, explosives were spread in a thin, uniform layer over each of two plywood panels (one square meter each) placed on the native soil. One panel was covered with a layer of TNT (2,4,6 trinitrotoluene) on top of a layer of indigenous soil, while the other was covered with a layer of RDX (cyclotrimethylenetrinitramine), also on top of indigenous soil (Figure 1).

Day Zero Day Two

Figure 1. Experiment area showing panels of RDX (white-dotted square, lower left) and TNT (orange-dotted, lower right).

In the morning two days later, just after sunrise, personnel from the night shift were completing a set of measurements. From high atop the personnel lift they noticed a thin, linear trail of white explosive exiting from one corner of the RDX-covered panel. The trail was noticeable as it seemed out of place given the recent weather. A moderate, round-the-clock rainfall had occurred the day after the explosives had been spread on the panels. Light to moderate winds had also been seen over this period. Aside from this anomalous panel corner there was no suggestion of explosives having left the panels, nor would the weather have been likely to disperse the explosives in the thin, linear pattern that was observed. As soon as the hyperspectral measurements were completed, the RDX panel was closely examined and found to be teeming with ants, later identified to be ordinary Harvester ants (*Pogonomyrmex* sp.) as seen in Figure 2[2]. At close range, the wispy trail initially appeared to extend a short distance from the corner of the RDX panel (Figure 3). Upon closer examination, however, it was observed that the trail was composed of ants carrying individual clumps of the RDX from the panel to their ant hill, a distance of almost 20 m from the panel's corner (Figures 4, 5, 6, and 7).

The next evening, further examination of the site revealed a short section of a trail that led from the corner of the TNT-covered panel. It was seen that ants from a second hill (Figure 8), located about 30-40 m away from the first ant hill and 10 m from the explosives-covered panels, had found the TNT and were carrying it away one clump/flake at a time.

Figure 2. Harvester ants (*Pogonomyrmex* sp., seen as black specs) teeming on the RDX panel.

Figure 3. Faint white trail of RDX (outlined in red) dropped by ants. The trail extends from the upper right corner of the RDX panel towards the top right corner of the image.

Figure 4. Trail of ants carrying RDX lumps to their nest, located ~10 meters to the right of the image.

Figure 5. Close-up of Harvester ants carrying clumps of RDX.

Figure 6. Close-up of the entrance to the ant nest. Ants are black with some seen carrying white RDX clumps.

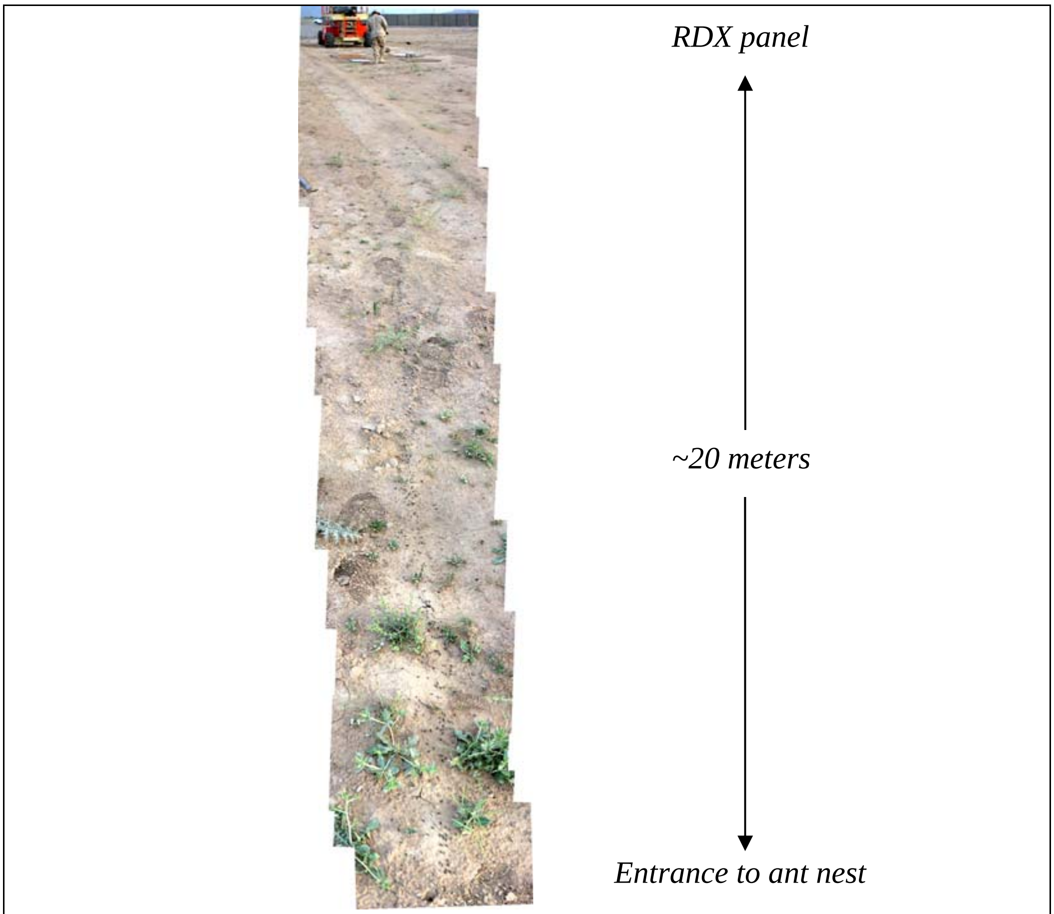

Figure 7. Video frame mosaic showing the RDX panel, ant trail, and entrance to the ant nest.


Figure 8. TNT panel (top) and ant nest with TNT flakes surrounding the entrance (bottom middle).

Figure 9. Close-up of TNT flakes at the ant nest's entrance

The ants carried away both types of explosives. They carried the RDX down the holes of their ant hill, but the flakes of TNT were piled around the entrances, apparently being too big to take down (Figure 9). Ants were observed swarming in large numbers on the explosives-covered boards. At times, the ants seemed to be writhing on the explosives, but it was not clear that they were in distress. This is supported by the fact that the explosives did not seem to be killing them immediately (very few dead ants were seen on the explosives) and that they continued to carry the explosives away to their nests. This behavior was seen until observations were stopped at the conclusion of the imaging experiments and removal of the explosives during the afternoon of the fourth day after the imaging experiment had begun.

Search for Similar Phenomenon

The authors performed an in-depth open literature search and did not find any descriptions of similar explosive-dispersing behavior by ants or other insects. The authors then asked experts in the field of humanitarian mine clearance if they or their co-workers had any anecdotal information or observations on the behavior of insects in old minefields. For example, the experts were asked if, when digging out mines, they had noticed an unusual number of ant hills or nests nearby. They were also asked, in the case of weathered or eroded mines, if there had been any evidence of current or former insect activity inside the mines.

The following are condensed anecdotal testimonials from three veteran humanitarian deminers:

Hendrik Ehlers, CEO of the well-respected humanitarian demining organization Menschen gegen Minen (MgM) and a person with many years of experience in humanitarian demining, was aware of such behavior. He recounted that, in southern Angola, ants seemed to love Russian TNT blocks such as those used in their wooden PMD-6 mines (the loose wooden boards of their cases possibly providing easy access to the explosives). He noted that he and his associates had found many landmine cases that had been cleaned out by ants. He also cited an experience in Angola where ants had eaten through the outer edge points of the kinks and sharp angles of the detonation cord in an IED. The cord, typically filled with Pentaerythritol tetranitrate (PETN), connected a BM-21 122 mm rocket to a South African R2M2 antipersonnel mine used as a trigger.

Magnus Boström, Head of Marketing & Operations at MDR Complete Demining AB Sweden, said that his peers at DDG (Danish Demining Group) had spotted the phenomena in antipersonnel minefields in Eritrea. He noted that DDG have observed that anthills were built over at least 50 antitank mines in South Africa.

Hrvoje Stipetić, Chairman of the Committee for Demining Osijek-Branja County in Croatia, said that during his group's many years of mine clearance he routinely came across minefields in Bosnia and Croatia where anthills were formed over landmines. They commonly came across anthills that were formed over bounding mines as well.

Why do Ants Find Explosives Appealing?

It is not yet known why ants are attracted to explosives such as TNT, RDX, and PETN. Ant experts suggest that three possibilities are likely [3,4]. The first is that the explosives may possess the smell and appearance that mimic plant seeds. The second is that explosives are nitrogen-rich and may help stabilize the chemistry and/or fertilize the soil that the ant colony is found in. The third possibility is that the ants may use the explosives as a construction material (bedding, insulation, structural, etc.) in their nests.

Calculation of Ant-Borne Loose Explosive Dispersal Rate

The following is a back-of-the-envelope calculation showing the daily ant-borne dispersal rate for loose explosives (D_{loose}) based on the authors' in-situ observations:

The average density of TNT and RDX ($\rho_{TNT/RDX}$) is 1.70 g/cm^3.

The average TNT/RDX 'clump' radius (r_{clump}) is 0.5 mm (based on the authors' observations).

If the clumps of explosives carried away by the ants are roughly spherical, then the mass per clump of explosives (m_{clump}) is equal to $4/3 \times \pi \times \rho_{TNT/RDX} \times (r_{clump})^3$. Thus, the mass of each clump of explosive (m_{clump}) is approximately one milligram (0.001g).

The average ant walking speed (v_{ant}) is 20.0 mm/s (based on the authors' observations).

The distance to the observed ant nest (d_{nest}) is 20.0 m.

The bi-directional linear ant density (υ) is 50.0 ants/m (this is a conservative estimate!).

The average foraging time (τ) of the ant colony is 10,000 s/day, ~2.8 hours/day. This, again, is a conservative estimate to facilitate a quick and easy calculation! The authors observed that ants were actively foraging explosives from a few hours after sunset to half-an-hour after sunrise (> 4.0 hours).

The average dispersal rate (loose) can be described by the following expression:

$$D_{loose} = m_{clump} \times v_{ant} \times \upsilon \times \tau$$

Thus, using all of the above numbers, the average dispersal rate of explosives (loose) of an ant colony is $\mathbf{D_{loose} \approx 10.0}$ **g/day**.

The dispersal rate of ten grams per day is gradual. Nevertheless, the significance of this gradual rate becomes apparent when one considers that an ant colony can effectively harvest a 'source' for hundreds of days. For example, one ant colony has the potential of removing one kilogram of loose explosives in 100 days.

Possible Application to Minefields Containing 'Ant-Accessible' Landmines:

Once an ant colony has found an ant-accessible landmine, the colony's ants may require extra time to break off clumps of explosives from the landmine's solid explosives block. This, however, may be offset by the authors' observations that the ants spent a significant amount time 'randomly' wandering around the panels' loose TNT and RDX before deciding which clump to carry-off to their colony. Thus, the dispersal rates for both loose and solid explosives may be similar.

In fact, the authors, based on similar problems in physics, assume that the ant-borne dispersal rate for solid explosives (D_{solid}) will be related to the root-mean-square of the dispersal rate for loose explosives:

$$D_{solid} = D_{loose} \div 2^{1/2} \approx 7 \text{ g/day}$$

The following is another back-of-the-envelope calculation showing the yearly ant-borne explosives dispersal rate per hectare (100 m × 100 m) for ant-accessible landmines containing solid explosives:

> The estimated average foraging period for an ant colony (P) is 180 days/year.
>
> The estimated average number of ant colonies per hectare (N) is 15 colonies/ha. This is a conservative estimate since the authors observed more than 45 colonies/ha in the experiment site.
>
> The average area dispersal rate for solid explosives (A) inside ant-accessible landmines can be described by the following expression:
>
> $$A = P \times N \times D_{solid}$$
>
> Thus, using all of the above numbers, the average ant-borne dispersal rate for solid explosives per hectare is:
>
> **A ≈ 19 kg/year/ha**
>
> There is, on average, 200 grams of explosives in each anti-personnel (AP) landmine and five kilograms of explosives in each anti-tank (AT) landmine. The above rate then translates to:
>
> **A ≈ 95 AP/year/ha (0.2kg/mine)**
> **A ≈ 4 AT/year/ha (5.0kg/mine)**

The rough and conservative calculation shows that indigenous ants may have the ability to gradually neutralize a minefield containing ant-accessible landmines at a rate of **~95 AP**, or **~4 AT** landmines per year per hectare.

Implication for the Future Production of Landmines

Countries such as the US, China, Russia, India and Pakistan have not signed the International Mine Ban Treaty because its terms would require them to give up a seemingly much-needed military capability. However, the US and China have agreed to the terms outlined in the Landmine Protocol of the CCW accord which call for the elimination of persistent landmines in favor of 'smart' landmines[5]. In fact, the US has approved the elimination of all persistent landmines from its arsenal by 2010. Unfortunately, the self-passivate/destruct mechanisms in the smart landmines are not 100% reliable. The Protocol allows for this and permits a failure rate of up to 10%!

Based on the authors' observations, one method to improve the self-passivation/destruction abilities of 'smart' landmines would be to provide some degree of biodegradability by allowing indigenous ants access to the explosives. This may help neutralize, over time, appropriately modified landmines, especially those that failed to self-passivate/destruct. After all, ants are found in almost every terrestrial environment, from the desert to the tundra to the rain forest. They are on every continent except Antarctica. Their total collective mass on Earth rivals that of humans!

The landmine modifications to permit ant-based biodegradability may be accomplished through the use of something as simple, low-tech, and extremely low-cost as strategically incorporating a few small holes in the landmine's casing (Figure 10). The holes would also facilitate the slow environmental 'erosion' (mainly through action of moisture and local microbes) of the explosives and ancillary mechanisms. In addition, the explosives and/or other components within the landmine could incorporate trace amounts of chemicals (such as milk powder… described in US patents 5618565 and 6274368!) that would further attract ants, yet not impede the landmine’s short-term functionality. The holes would also allow for vapors/volatiles to escape the landmine… facilitating future removal via dogs and/or chemical sniffers.

The proposed methodology would be ‘green’ since it would solicit only the local ‘bio-talent’ to biodegrade landmines and would not introduce any potentially harmful invasive species (microbe, or animal) into the local arena as would be the case with genetically-modified microbes, ‘trained’ honey bees, etc..

The inclusion of insect access holes into the landmine casing would add next to no extra cost to the manufacture of both smart and persistent (‘dumb’) landmines. This, in principle, should not be a deterrent to the landmine manufacturers.

Initial modeling, though very preliminary, shows that minefields with ant-accessible landmines may be biologically-neutralizable within a few years (in most cases, well after their initial strategic military importance). Further research (in-situ and anecdotal… more stories required from de-miners working old minefields) is required to ascertain the true viability of the ant-based bio-degradation. However, if viable, then lobbying for an additional amendment to the Landmine Protocol of the CCW accord for the ‘greening’ of landmines via the slight modification of landmine production to permit ant-based biodegradation should be pushed forward.

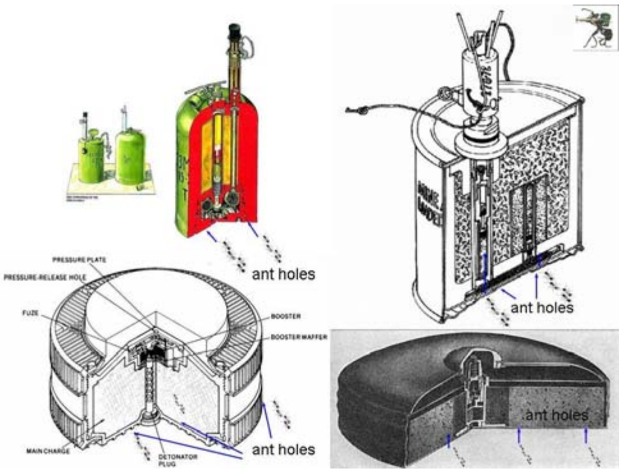

Figure 10. Basic schematic examples of ant-access ports.

Concluding Remarks

The discovery and possible application of the gradual dispersal of explosives by ants does not address the current, enormous, and tragic humanitarian demining problem. It does, however, have potential application to the production of future landmines via the incorporation small ant-access holes to permit gradual ant-based neutralization. The landmines with ant-access holes will not only lose their bulk charge over time, but will also emit vapors that dogs and future advanced chemical sniffers can easily detect, both which will facilitate future humanitarian demining. This will hopefully eliminate the scenario where old and forgotten landmines in future minefields remain civilian and environmental threats.

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