Remote Explosive Scent Training:

Genuine or a Paper Tiger?

This article briefly discusses many of the research challenges presented by the Remote Explosive Scent Training (REST) concept. These challenges were reviewed at a recent workshop (8–12 February 2003), hosted by APOPO at the Sokoine University of Agriculture in Tanzania, and attended by all current players involved in developing or using REST for demining purposes.

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Introduction

REST is the process of taking scent from a source for remote analysis. The scent is obtained by using a pump to draw air containing scent or particles from the soil surface through an absorbent filter. Filters are analysed using specially trained sniffer dogs or rats, or potentially any other natural or artificial odour-sensing system.

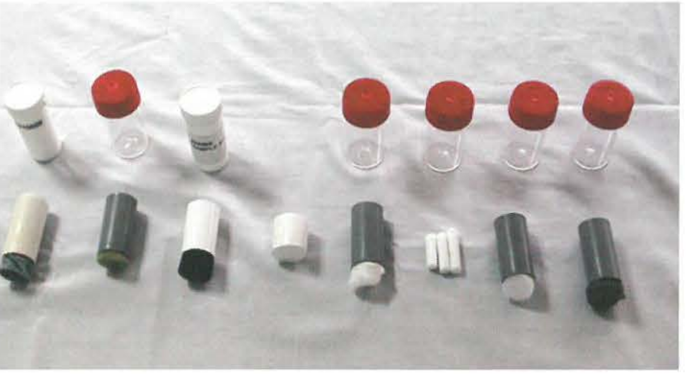
The REST concept was originally conceived and developed in South Africa.[1] First used to detect explosives, weapons and drugs in contained units—cars, containers, houses—the system was adapted by Mechem, a South African demining company, for detecting landmines and UXO. Originally known as the Mechem Explosives and Drugs Detection System (MEDDS), it has since been given many names, although the official name in the demining arena today is REST.

REST dog analysing filters.

Mechem used REST extensively in southern Africa from 1990 to 1996. Although not fully tested and verified, REST was used to search for landmines on roads and routes in Mozambique and Angola and along power lines in Mozambique. At least some of those routes had been inadequately cleared using manual techniques. REST proved to be fast and efficient, eliminating vast areas of road much more quickly and cheaply than any other known technology. Justification of its efficacy included finding anti-vehicle mines in previously cleared areas.[1] At least some of these projects were funded by the United Nations, suggesting considerable faith in the capability of the system at the time.

In the mid-1990s, the humanitarian demining industry was rapidly evolving and there was a strong push towards increasing the speed and efficiency of global demining. It is thus surprising that a field-tested system that apparently offered both of these objectives remained isolated and essentially unknown in southern Africa. Despite its potential, REST cannot yet claim to have a significant impact on the global demining process. On the contrary, it is fair to say that it has almost slipped into disuse, as at the time of writing it is not being used operationally anywhere in the world. In early 2003, just four organisations had capacity for mine detection using REST. Two of these are research centres and have never undertaken operational demining, although they may do so in the future. Of the other two, Mechem is using its REST capacity to support a research contract, and Norwegian Peoples Aid (NPA) is rebuilding its capacity after the program had difficulties in 2002.

The Geneva International Centre for Humanitarian Demining (GICHD) runs a multi-facetted program of research and operational support aimed at improving the overall quality of mine detection



APOPO has started trials of different filter material. Seven different materials have so far been tested. The results show relatively good scores on all filters. More testing is required to determine the full potential of these and other materials.

dogs—perhaps more appropriately called mine detection animals, now that the rat program of APOPO is supported. REST is a central element of this program. An important restriction on the implementation of REST by demining agencies is lack of information on its true potential and limitations. Some relevant research had been undertaken 10 years previously by Mechem, but that information was inadequate, poorly documented or unavailable. For the GICHD, the key incentive was the great potential of REST for area reduction. Implementation of research has involved identification of the central elements of REST, which are:

- The sampling technique
- The sampling equipment and filters
- Storage and transportation of filter cartridges
- Training of the detector
- Methods to ensure reliability in the final analysis process

Animal and Artificial Detection—Pros and Cons

An animal is a complex detector that responds to a variety of substances (whether in a filter or elsewhere), some of which the trainer may be unaware of. A recent example: Mechem dogs trained on "pure" TNT responded to DNT at very low concentrations.[2] Although tuning an animal sensor relies on extensive practice and carefully constructed training schemes, it is impossible to guarantee that the animal sensor will detect exactly what we believe it has been trained for. The flexibility of animal detectors during the learning process imposes severe constraints on procedures for sampling, transport, storage and training—requiring rigidly applied standards mimicking those found in a sterile laboratory environment, double blind testing, standardised handling of all targets and carefully applied internal controls. Artificial analysis procedures do not have such flexibility, recognising traces of individual substances and degradation products more precisely than animals, although the requirement for similar laboratory standards may still apply. There are, however, no artificial chemical detection methods that can compete with the detection thresholds of dogs or rats. In simple terms, it can be said that animal detectors are sensitive but unreliable whereas artificial detectors are more reliable but less sensitive. "Reliable" here, is used in a limited sense to mean accuracy of detecting target odours. It remains to be seen whether artificial odour detection technology offers the same operational reliability as animal sensing systems.

Promising artificial detection systems currently under development include the Nomadics Fido Detector (USA) and the Bio-sensor (Sweden). Gas Chromatographs (GC) are under constant improvement, becoming easier to operate, more mobile and cheaper, and they have been built into some mobile odour detection systems. It has been suggested that artificial odour-detection systems, such as FIDO, will eventually replace animals. Such suggestions naively ignore the option of using alternative detection systems in complementary ways, such as for quality assurance (QA) or quality control (QC), or in different but overlapping applications. For example, artificial detection (such as a GC) can be used to determine levels of different compounds in soils around landmines, offering independent calibration when attempting to check the reliability of animal detectors in relation to varying circumstances, such as environmental conditions. Using complementary artificial detection, we may be able to identify clues that generate false indications by animals. We may further be able to link the availability of different substances to situations where mines are missed, which is an essential objective in any calibration process.

Of all the many technology options "developed" for demining purposes,[3] it is notable that the only device currently in regular use in minefields today is the simple metal detector. Minefields are routinely found in remote locations where industrial support is primitive at best, and environmental conditions can be extreme. The need for simple detection technology with high reliability is imperative under such conditions. The requirements of simplicity and reliability impose strong challenges on artificial odour detectors. However, it could be argued that the REST concept also removes some of those requirements, because the detector is separated from the difficult conditions found at the minefield. If artificial detection systems ever achieve the detection capabilities of animals, the first direct competition could be in REST detection centres. On the other hand, it is also at such centres that the two technologies might first be used in a complementary way.

The Sampling Process

It is easy to ignore the sampling process in favour of the more complex analysis process when examining the components of REST. However, the analysis process depends on availability of a scent sample of high quality, suggesting the need for quality sampling procedures, quality equipment and an understanding of the effects of the environment on the sampling process.

Filter Properties

A good REST filter must adsorb molecules during sampling and desorb molecules during detection (analysis by animal). Filter design must optimise the trade-off between these two requirements. It is generally believed that the highest adsorption of target molecules is achieved when collecting particles rather than airborne molecules. The only filter in operational use today, produced under licence to Mechem (this filter can also be purchased in the United Kingdom), is believed to function in two stages.[4] Scent is first trapped in a coated PVC net that functions as a scent storage magazine. Explosive molecules desorb only slowly from the net, but during storage (in a sealed container) an equilibrium is established where molecules are deposited

onto a solid PVC core, which functions as a highly desorptive "releaser." Once removed from the container, the molecules begin desorbing from the PVC, which will eventually discharge its load (or more strictly, discharged concentrations of target molecules reduce progressively until they drop below the detection threshold of the animal). Returning the filter to its container results in the PVC core "recharging," as a new equilibrium is established.

If the filter material desorbs easily into air, then there are two potential issues to be considered. First, desorption may occur during the sampling process due to the flow of air through the filter, resulting in a low availability of target molecules for testing. Second, desorption may occur quickly once the filter is removed from its container. The second factor could be an advantage if testing occurs quickly (i.e., within a few minutes), but would be a disadvantage if testing takes some time (e.g., because several animals are to be used), or is to be undertaken at different times. Different filter materials will offer different possibilities on the trade-off for molecule availability described above, and those differences could benefit different applications.

The Perfect Filter

An ideal REST filter would be cheap to purchase, allow high adsorption and desorption, allow particle collection without becoming clogged, and support both animal and artificial detection systems. In some operational situations, the filter must tolerate long-time storage prior to detection testing. Some of these desirable properties are contradictory, and the optimal filter design will need to balance competing requirements.

Testing of alternative filter materials has recently been undertaken by the Swedish Defence Research Agency (FOI) in Sweden and APOPO in Tanzania. APOPO's tests compared detectability of explosive odours on the Mechem filter as a standard, with other filters, using rats as the detector. Results were similar to or better than the Mechem filter for all but two of the materials tested. The filters developed by FOI are primarily for research applications, and are unlikely to be used for operational detection in minefields. They offer the advantage of being tested using laboratory equipment such as the GC. Most or possibly all of the filters tested by APOPO were of commercially available materials that are not designed to be used in the GC—although extraction of explosive molecules should be possible from some of them.

It was suggested at the workshop that "the Mechem filter works, so there is no need to develop alternative filters." This argument has some merit, although the cost of the Mechem filter—about $1.00 (U.S.), regarded by some as cheap and others as expensive—was a significant factor influencing APOPO's search for alternative filter materials. It may be that almost any filter material can be used when sampling is undertaken under optimal conditions, but conditions are not always ideal, and optimising filter quality could maintain detection reliability under sub-optimal sampling conditions. Different applications might allow different materials to be used. APOPO's application is for research—filters are tested within three hours of being produced and are immediately discarded. In this application, there is no requirement for long-term storage or multiple testing, which are two benefits of the Mechem filter.

Sampling Units

Sampling machines were originally integral units on mine-protected Casspir vehicles. The suction unit was inside the vehicle and flexible tubes with filter holders where threaded through a channel system and lowered to the ground in front of the vehicle. The tubes were pulled back into the vehicle for every filter exchange. This design provided a safe operator platform, but the trade-off was limited control over the sampling zone, which was restricted to the immediate front of the vehicle. In response to this problem, portable backpack suction units with handheld flexible tubes were developed, allowing broader ground coverage, but introducing the risk of requiring the operator to walk through the minefield. On roads, the operators were able to walk in the vehicle tracks provided by a Casspir. However, this option is unlikely to support minimum safety requirements in heavily vegetated terrain, potentially restricting the application of REST technology for area reduction. Certainly, new concepts need to be developed for obtaining effective samples from open terrain while ensuring the safety of the sampling personnel. This issue requires further consideration and development.

The portable backpack suction device is a small two-stroke petrol engine (modified from a Husquavarna chainsaw) driving a small pump. Results from testing by APOPO suggest that exhaust may cause contamination problems if the sampler does not move consistently upwind. Constant machine juddering, high maintenance and the need to keep fuel and filters separated are other negative factors. An alternative battery-driven pump has been trialed by FOI and APOPO, but the trade-off is increased weight, short battery operation and long charge times. Battery

Casspir with an integral sampling system, used in the early days. The filter cartridges are seen hanging to the front of the vehicle. This is safe for the operator but offers limited control of the sampling zone. Portable sampling units are used behind, to ensure suction from vegetated areas.

units are cleaner and quieter, but the disadvantages are likely to restrict their use for operational demining. If the sampling unit is mounted on a vehicle, then the vehicle compressor (which supplies power to the air brakes) could be used to power the pump. This option has been used in the past by Mechem for some applications.

There have been suggestions that under at least some conditions, a pump is unnecessary. Wind action and convection could bring enough molecules to the filter for detection to be successful if the filter is placed in the minefield for some period. A development of this possibility, a passive sampler, was demonstrated by IVEMA at the REST workshop. The principle remains unproven, but tests will continue.

Suction Pressure and Sampling Technique

Mechem originally decided to use a pumping rate of 60 litres/minute, based on the concept of emptying all the air from a car in a short amount of time so that the car could be tested for explosives. Although this suction rate apparently gives effective filter samples (using the Mechem filter), higher or lower suction rates could give even better samples. Higher sampling rates allow the vacuum operator to move at a quicker pace, and/or change filters more frequently. Possible disadvantages are blow-through of target molecules (molecules passing through the filter without being trapped), and clogging in dusty environments. Lower sampling rates will likely have the opposite effects. Clearly, there is a need to optimise the relationship between sampling vacuum rate, sampling efficacy (which may vary with filter design) and the advantages of collecting dust.

Work with free-running dogs shows that a dog can miss mines if its nose is too far away from the mine during the search. It appears that under at least some conditions, the detectable plume of scent over a mine is small and localised. Mine detection using REST may therefore require that all ground be covered by the vacuum operator in much the same way as the nose of a field search dog covers all of the ground. Apart from the obvious safety implications of such a requirement for the sampling personnel, it is possible that different filters can be used in different conditions or in different ways to optimise the sampling process. These issues need further research.

Sampling Conditions

It is known that variability in environmental conditions affects detectability of mines for animal sensing systems working in the field.[5,6] It is sensible to assume that the known environmental effects on direct animal detection will similarly affect filter detection. Research undertaken for the GICHD by NOKSH in Bosnia (using dogs) supports this contention, with lower humidity at the time of sampling producing higher probabilities of detection. APOPO has similarly found that lower humidity gives better detection (using rats). One possibility is that sampling during dry conditions facilitates a higher rate of collection of dust particles, which has a greater impact on the quality of the sample than collection of air.

Surprisingly, preliminary analysis of the Bosnia data set did not show any effect of temperature on detection probability, apart from decreasing detection probabilities at ambient temperatures below about 15°C at the time of sampling.

The analysis is not yet completed and more research is planned.

Vegetation

The possibility that vegetation in the sampling area affects the quality of the filter sample has been much debated, but remains unresearched. Mechem's field experience suggests that vegetation has a positive effect. Vegetation potentially acts as a reservoir for explosive molecules, which are attached to leaves (particularly on the underside where they are protected from the sun). The vegetation may filter wind-blown molecules out of the air, or molecules could be taken up through the roots and deposited on the leaves during transpiration. Wind-blown pollen may also carry explosive traces. More research is needed to fully understand the importance of vegetation as a reservoir of target molecules. The results could significantly alter the way sampling is undertaken in the future.

The Analysis Process

The analysis process involves two central components—a training program

A REST dog licking the filter to be sure of detection—effectively leaving a clue for the next dog. The result: the next dog may detect the salivary from the first and not the explosive trace in the filter. Clues are difficult to identify and require careful examination of the training and analysis process.

for the detector and a testing concept. Both of these components vary among the four organisations currently training REST detectors. NPA originally used principles developed by Mechem, but has recently modified its approach to the system developed by NOKSH. Unfortunately, to date, the only one of these training and operational concepts that has been formally documented in a way that is accessible to the demining community is the NOKSH program.[7] At the time of writing, REST dogs were about to be accredited in the United Kingdom (although not for mine detection), but again no documentation of the training program or use concept for those dogs is available. Thus, understanding of the use of animals for REST detection is improving, but this knowledge is not generally being formally documented in an accessible way. Only limited comments on training issues can be made here.

Training Issues

Animals are good detectors, but they require careful tuning and calibration. Having produced the detector, maintenance of its skills requires daily attention to the details of its operational use, including internal QC to monitor its daily reliability. Small mistakes during training or testing could introduce "clues" that tune the animal onto different scents. The word clue deserves further explanation. In this context, a clue means an aid that the animal uses to discriminate target filters. A clue can be a scent, the lack of scent, an unconscious signal from the handler or simply a non-random placement of filters in an analysis array. An animal will use any clue to aid filter detection, even if detection mistakes are introduced by doing so. Under training or some research conditions (where the odour on the filter is known), such mistakes are likely to be treated as false positives. But in some research situations and any operational testing situation, it will probably be necessary to treat such mistakes as true indications. Clearly, the testing procedure must be rigorously designed to eliminate any possibility of clues. Independent laboratory analysis (using artificial detection procedures) can also support clue identification.

Philip Eskeland (IVEMA) demonstrating a modified sampling machine with integrated gauge at the workshop in Tanzania.

An alternative mistake is that positive filters are neglected (missed) by the animal. Such misses may be because odour availability on the filter is below the sensory threshold of the animal, because of factors affecting the sampling process (see above), or because the detector is not working to peak performance (a training problem).

Controlling the Analysis Environment

Animal analysis was initially an outdoor affair. Both Mechem and NPA now use indoor analysis facilities, which give much greater control over the environment in which testing is undertaken. Humidity and temperature are key factors affecting vapour availability. As research on vapour detection progresses, experiments with manipulated indoor climates may help to optimise detection using REST technology.

Pre-heating of filters is likely to increase the release of the target scent from the filter and thus aid detection. Manipulating humidity in the filter or in the room might also improve detection, although it is still unclear what the optimal humidity levels should be. A combination of the two factors could have a real impact on detection probabilities and should be further investigated.

REST for Area Reduction

Two tests areas (in Angola and Tanzania) have been prepared under GICHD sponsorship to facilitate investigation of area reduction applications. A similar test field has been prepared for similar purposes in Croatia by Nomadics (with Mechem support). The two African test fields have the same general layout. To prevent cross-contamination between boxes with landmines, the minimum distance between mines is 35 metres. Testing is currently being undertaken in both locations to determine the potential of REST for area reduction.

Size and shape of the plume put up by a mine are the central issues being addressed using these test fields. Large plumes (or plumes that increase in size over time) mean that REST sampling may have to be rather coarse-grained (each filter

Table 1: Areas needing further research before REST can be considered proven.

Filter

- Optimise the filter to allow highest adsorption during sampling.
- Optimise the filter to allow highest desorption during analysis.
- Develop a filter that can be analysed both chemically and by animals.
- For some applications, make the filter able to tolerate long-term storage without significant quality reduction.
- Investigate the relationship between vacuum flow rate and quality of the sample.
- Conduct filter testing to determine how filter exchange frequency will affect the quality of the sample.

Sampling machine

- For some applications, develop a low-weight battery-driven sampling machine with long operational time and easy charging.

Sampling technique

- Undertake tests to determine the most reliable sampling technique(s).
- Develop a new sampling concept for area reduction that will ensure quality sampling and high safety for the operators.

Environmental factors during sampling

- Continue sampling in test fields under different environmental conditions to determine the full environmental effects on detection.
- Investigate whether some filter options may work better under certain conditions than others.
- Investigate the effect of vegetation.
- Investigate the leakage (flux) rate from landmines and use this information to determine the potential for vapour detection.

Training

- Document and compare training test results to determine optimised training solutions.

Analysis– environment

- Determine the effect artificial modification of temperature and humidity in the analysis environment has on detection.
- Examine all aspects of the environment to identify potential clues that may jeopardise the analysis process.

Analysis—testing

- Identify procedures to provide effective internal controls on the detection process.
- Further develop and test filter handling procedures to ensure optimal testing.

Table 2: Alternative routes to establishing a REST analysis capacity supporting demining operations.

	Advantages	Disadvantages
Centralised analysis	• No need for demining organisations to develop costly and difficult analysis capabilities • Quicker response time (need only to establish sampling teams initially) • Higher cost effectiveness	• Logistical burden in transporting filter cartridges (internationally) • Demining organisation has little/no control of the analysis process • No global analysis concept in place
Decentralised analysis	• Full control of the analysis process • No dependency of other organisations • Less filter transport requirements	• Requires high skills and a more complex demining process • Likely to result in limited use of REST worldwide • High initial costs • Time-consuming process of developing capacity • No system for external QA in place

samples a large area). Small or localised plumes may require that sampling be relatively fine-grained. The primary use of REST is to identify areas that do not contain mines (area reduction) rather than to find mines, thus a reasonably coarse-grained sampling approach is desirable. It was suggested at the Tanzania workshop that contamination would eventually cover the entire test field, even with mines laid an average of 40 metres apart. If so, then the potential for using REST for area reduction in areas with widely dispersed mines or UXO might be limited. In wetter areas, flooding events can disperse contamination widely, making the detection process even more coarse-grained. Both APOPO[8] and Nomadics[9] have experienced this problem.

These issues may limit the applicability of REST for area reduction, and they may not. The central issue for the moment is to improve understanding so that operational recommendations can be made in an informed way.

REST Research Challenges

The REST workshop aimed first to identify areas requiring further research, and second to establish a forum for exchanging ideas and information between people involved in REST at all levels. Delegates included researchers, dog trainers, operational and management demining personnel, and equipment manufacturers. Discussions centred on three themes, each addressed during one day: equipment issues, training issues and operational applications. Table 1 summarises research objectives from all of these areas needing further attention before REST can become a proven area reduction alternative.

The Future of REST

The future of REST relies on proving the technology and facilitating its use. The latter is potentially difficult in an industry based on free market principles. Humanitarian mine action differs from most established industries in being small, artificial and donor driven. Realistically, demining organisations can continue operating without using REST, even if the system proves more efficient than other methods. So REST must become a proven alternative before demining organisations will consider using it. However, even once proven, it is not realistic to expect that many demining organisations will establish the required analysis capacity, due to the time and investment involved. It is more realistic to suggest that if demining organisations have access to a centralised analysis facility, the far easier sampling process could be supported. There are two potential routes to follow if REST is to gain ground in demining. Each has pros and cons (Table 2).

Setting up sampling teams is relatively easy and could be done efficiently by most demining organisations. It is, however, unlikely that the industry itself will develop centralised facilities for analysis of filters. A range of questions will first need to be addressed, some of which are listed and discussed in the Table 3 below. These points go beyond the issues discussed at the workshop in Tanzania, and are prospective, being raised here as issues for future discussion.

Table 3: Issues for future consideration if REST is to be established on a broad or global scale

How big is the market and how many analysis capacities are required?
The market will depend on the application of REST. If REST can be used for accurate area reduction, there is potential for a relatively large market.

Who should undertake the analysis?
There are currently four organisations involved in analysis of REST filters for humanitarian demining: NPA-Angola, NOKSH-Norway, APOPO-Tanzania and Mechem-South Africa. Preliminary arrangements could be made with these four organisations. There may be more organisations with an interest in becoming centralised REST analysis providers.

Who will test and accredit these organisations?
There is a need to ensure that the same standards are followed by all organisations involved in REST. Each analysis centre must be accredited on a regular basis. Criteria for the accreditation process will be required. An impartial accrediting body must be identified.

How can the demining community be ensured of a high-quality analysis process?
A QA system of the analysis process will be required. This could be a responsibility of an objective independent institution. Alternative QA measures could be to develop a system to cross-check filters between centres and compare the results.

How can the analysis centres be ensured about a high-quality sampling process?
International procedures for quality sampling will be required. QA of the sampling undertaken by demining organisations is another question to be addressed. There may not have to be a need for analysis centres to perform QA on the sampling as long as there are recognised QA mechanisms in place.

How should a global logistic system be developed?
It is not too difficult to send filters overseas today. There should be agreement regarding packing and marking of filter boxes during transportation. Analysis centres should solve their own problems in receiving the filter boxes in their respective countries.

How to reach a consensus regarding the pricing and timing of analysis.
There must be a general understanding within the group of analysis centres about the costs for analysing filters and response time before returning results to the demining organisations.

There must be international standards and guidelines for the sampling, the logistics, the analysis and the QC requirement.
Standards on sampling and analysis could become part of the International Mine Action Standards (IMAS) series in the future. The current REST standard would be inadequate and would need to be revised.

How to train demining organisations to carry out quality sampling, storage, transportation and filter shipment.
There will be a need to train demining organisations in correct sampling techniques and to take environmental conditions into account. It is further important to develop a recording and logistics system. This will also require some training.

Conclusion

There are currently four organisations with an analysis capacity for REST in place today: three in Africa and one in Europe. Among them, they currently have a total of 30 individual detectors (12 rats, 18 dogs)—an impressively small capacity considering the potential of the REST concept and its historical precedence. Although some of these organisations could potentially expand their capacity, the limited number of detectors available today severely restricts the further development of REST in the near future. Of these four organisations, one is strictly commercial, one is a broadly focussed humanitarian aid organisation and two are research agencies. To at least some extent, all depend on sponsorship money for their operations, and humanitarian aid sponsors do not usually support research. Thus, maintenance of even this limited REST capacity could depend on a requirement to use the detectors operationally, further limiting their availability for research. Given the comments above, use to support demining operations could even be regarded as premature.

The Tanzania workshop was not in a position to make a formal list of recommendations, but it strongly supported the principle that REST will not be implemented on a broad scale unless it is firmly founded on quality research. Not only is there still no properly structured research and development program in place, but some of the few organisations with functioning detectors are working on shoestring budgets and are in danger of being closed down irreversibly. Clearly, if REST is to be further developed, the industry needs to get behind it and support it at all levels, including explaining its value to the sponsors.

On a more positive note, these four organisations could be encouraged to establish a coordinated analysis capacity, supporting the required research in the short to medium term, and then moving on to supporting demining operations. A few companies are using REST for other purposes, such as Chilport in the United Kingdom who is implementing REST at docks and airports, hotels and cargo storage sheds under the name Vapour Odour Detection System (VODS). Such companies may also be interested in analysing filters from minefields, and/or supporting research on further development of the REST concept. Most importantly, the expertise currently available for training REST detectors must be nurtured if REST is to have any chance of showing its true potential.

REST remains a paper tiger, caged by inadequate investment, poor development and secrecy among the few organisations with relevant expertise. The key to the door of the cage is effective research, properly undertaken and properly resourced. The Tanzania workshop was a valuable preliminary step towards building that key. The next challenge is to feed the tiger, giving it the energy to escape. ■

**All photos courtesy of the authors.*

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