Technology Needs - Egyptian Mine Clearance

This report describes some of the problems facing mine and UXO clearance teams in Egypt which has one of the largest problems of this kind in the world. The aim of this research is to assess technologies which may help to solve the problem, given appropriate financial support and research if necessary.

I visited Egypt between 11^{th} and 18^{th} October 1999 to perform this research. The Egyptian Military Engineering Organisation is responsible for all mine clearance work in the country, reporting to the Egyptian Army and Ministry of Defence. I arranged the visit through the Egyptian Government, the Australian Department of Foreign Affairs and Trade, and the Night Vision and Electronic Sensors Directorate of the US Army at Fort Belvoir, Virginia.

My only field visit was to the Western Desert area near El Alamein. Information on other areas was provided by the Military Engineering Organisation, and several other sources.

Summary of Recommendations

Organisational Change

Like many demining organisations, the MEO could be adapted to better favour the investigation and development of improved techniques. Staff need English skills, internet access, and travel to see mine and UXO clearance operations in other countries. While specialist training courses provided in the USA are attractive to MEO staff, they are likely to be less effective in the long term without organisational change. Assistance with new technologies is unlikely to provide cost benefits with the current organisational structure and staffing.

Significant funding support is needed within the MEO to support innovation and change. Outside agencies could assist in making such funding available.

Mine Detection Dogs

In my opinion, of all the technologies considered, mine detection dogs offer the best chance of significant improvements in clearance production rate and quality level. Because of cultural sensitivities and cost factors, the most attractive options to pursue this are:

• A trial of Afghan or Iraqi mine detection dogs (with handlers) in Sinai Desert and Western Desert areas of Egypt. Iraqi handlers would be able to communicate in Arabic. Afghan handlers have more experience and a common religious background. Such a trial should be coordinated with similar trials in Yemen, Lebanon and Jordan where similar problems exist and dogs could make effective contributions.

• Investigate whether sufficient dog capacity exists in Egyptian Customs and counter-terrorist organisations to build an indigenous mine detection dog capacity.

Aerial Photography

Although the officers I met claimed they had tried aerial photography, I think that the techniques demonstrated by ITC in the Netherlands should be evaluated. It is likely that the Egyptian air force has the necessary equipment and capability. Aerial photography would show where there is little or no sand cover and clearance teams can work without the need for detection equipment. It is possible that sand cover may change during the year, so repeated photographic surveys may be useful. High precision GPS registration of photographs will be essential as there are no permanent landmarks in most areas.

Special detectors for deeply buried mines

By using a larger diameter coil on a metal detector, the detection depth can be increased almost in proportion to the coil size. Detector manufacturers need to be approached to see if they will provide optional large diameter metal detector coils.

Ground Penetrating Radar (GPR) should be evaluated for special mine detection problems in deep sand. The British Government may be willing (if approached carefully) to provide some financial assistance for a British company to supply experimental radar equipment.

It may be possible to use ultrasonic imaging technology to detect the deeply buried mines that are causing problems in wet marshland and mud. Considerable experimentation may be needed. However, these mines are currently very expensive to clear (in terms of time, machinery and manpower) and improving location ability may help to reduce costs.

Slurry Pumping and Water Jets

Evaluate water jets and slurry pumping technologies used in modern mining operations in countries such as Malaysia and Australia for mine and UXO clearance tasks.

Long Term Research

In the longer term, careful research is likely to result in large cost savings in the demining program. Apart from slurry and water jet technologies, research into the manipulation of wind for removing sand cover and into risk factors for civilians is likely to substantial reduce operational costs.

Regional Cooperation

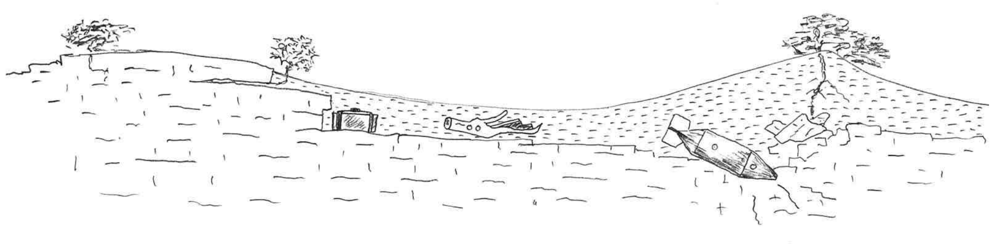
Since there are extensive mine and UXO clearance problems in most of the countries in the region, there could be extensive benefits from regional cooperation, especially for countries trying to provide cost-effective assistance. This could best be achieved by being sensitive to the political and cultural differences in the region.

Demining Machinery

Since officers of the MEO suggested they were considering the use of demining machinery, I should make some reference to current developments. Machines such as 'Minebreaker' have been used extensively in Croatia and more recently in Bosnia, but expert users are cautious about recommending them except for vegetation clearance (not a problem in Egypt). Aadvark Flails are being used in Jordan in the final stages of mine clearance to neutralise mines which have not been located by manual deminers. All demining machines have failed to achieve their makers expectations, except in certain limited circumstances.

The particular problems of demining in Egypt have made me extremely cautious about the use of large machines of this type.

The variable depths of mines under wind blown sand (many areas more than half a metre) make these machines of doubtful effectiveness for mine clearance. They can be expensive to operate (approx US$0-30 per sq metre) with high maintenance costs, particularly if mines and UXO are detonated by the machine. Evidence from other countries shows that the presence of rock or large stones greatly reduces the effectiveness of mechanical clearance.



Drawing: Risks for mechanical demining in the Western Desert. Mines may be protected by nearby rock, and large UXO's may damage machines if they explode.

However, in the long term, using mechanical clearance could be an effective means of *risk reduction* where manual demining (or other methods) cannot be used. However, this can only be effective with careful research and evaluation of the risks, costs to reduce risks, degree of risk reduction actually achieved, and the relative effects of spending funds on other ways to reduce risk to health.

Risk analysis is covered in more detail later.

1. Mine and UXO Problem in Egypt

Egypt has been listed as the country most contaminated by landmines in the world with an estimate of approximately 23,000,000. However, this includes unexploded ordnance (UXO) and the number of landmines is a much less than this. However the number of devices which needs to be cleared is not a useful indication of the magnitude of the problem.

Development projects in Egypt are significantly constrained by mine and UXO contamination and, in the affected areas, the civilian casualty rate seems high in proportion to the populations in those areas. (No precise figures were available to the author.) The old age of much of the UXO may result in much greater hazards to civilians, so it is not useful to consider the mine and UXO problems separately. There are very large areas of land affected, and some estimates put the total area at 25,000 sq kilometres. (Croatia, for example, may have between 6,000 and 10,000 sq kilometres of contaminated land. Croatia is considered to be one of the worst mine-affected countries in the world).

Brief History of Recent Conflicts

During the 2nd World War (called the 2nd International War in Egypt) Britain and its allies conducted a series of military campaigns to defend themselves and the vital Suez Canal from several invasion attempts by German and Italian forces. Most of the fighting was along the northern fringe of the Western Desert between the Qatara Depression and the Mediterranean Sea, between 1941 and 1943. The well-known battle at El Alamein was only one of many. A wide coastal strip is affected by mines and UXO, all the way to the Libyan border (and beyond).

In 1956, Israeli forces invaded the Sinai Peninsula and advanced almost to the Suez Canal in a joint operation inspired by Britain and France to attempt to recover the recently nationalized canal. British and French troops occupied the canal zone in the face of vigorous Egyptian resistance. Shortly afterwards, Israeli, British and French troops were withdrawn under strong international pressure.

In 1967, Israel again invaded the Sinai Peninsula in a pre-emptive strike. Eyptian and Isaeli forces confronted each other along the canal zone, with extensive intermittent bombardments between them. In October 1973 Egyptian forces fought a more successful campaign but Israeli forces continue to occupy practically all of the Sinai peninsula. Following extensive negotiations, Israeli forces withdrew from Sinai to the current border. In 1979 Egypt and Israel signed a treaty (Camp David Accords) which has ushered in a new era of peace and cooperation.

Geographical Distribution of Problem

The map shows approximate locations of mined areas collected from several sources. I did not have an opportunity to confirm these with the Egyptian Military Engineering Organisation (map from CIA web site). Extensive clearance operations have been carried out already to ensure that roads, residential areas and other infrastructure is safe to use. Known records are incomplete and inaccurate so it is likely that other areas of contamination exist. UXO contamination extends over much larger areas than the known minefields.

The coastal fringe of the Western Desert region was contaminated between 1941 and 1943, and mines and UXO are spread out over the entire area of fighting. Although many minefields were mapped, many others were not, or the records have been lost. UXO posing significant hazards to civilians is distributed across the entire area.

Most of the remaining contamination is in the Suez Canal zone, and nearby coastal regions. Much of the contamination in the coastal region is in salt lakes, salty mud and swamps which are difficult to work in. The local environment is very unpleasant for manual work with high summer temperatures, high humidity and salty dust on windy days. Other mines lie under deep wind-blown sand as in the Western Desert.

Other minefields have been reported along the Red Sea coast, and formerly mined areas along the Israeli border and military strong points in the Eastern Sinai will need to be carefully checked.

Social Impact

Until recently the only major social impact has been on nomadic (Bedouin) people who are mostly very poor and live on the socio-economic fringe in Egypt. However, the development of the tourism industry in the 1980's and 1990's is bringing new wealth to the upper classes of Egypt. The Mediterranean Sea coast is warm and has a very comfortable year-round climate, particularly in summer. Development is taking place along most of this coastline. This development is creating a new demand for adjacent land for irrigated agriculture and recreation. Because of this, the nomadic Bedouin are being pushed into yet more contaminated land. Therefore, mine clearance has recently become more important for the government.

Similarly, recreation tourism along the Gulf of Suez and Red Sea coasts is creating a demand for improved port facilities and clearance of coastal land.

The Egyptian government, like many poorer countries, has a hard time raising tax revenues and faces strong political pressure to invest in infrastructure for large population centres such as Cairo and Alexandria. At the present time, there seem to be limited prospects for channelling some of the huge financial investments along the coast towards demining projects.

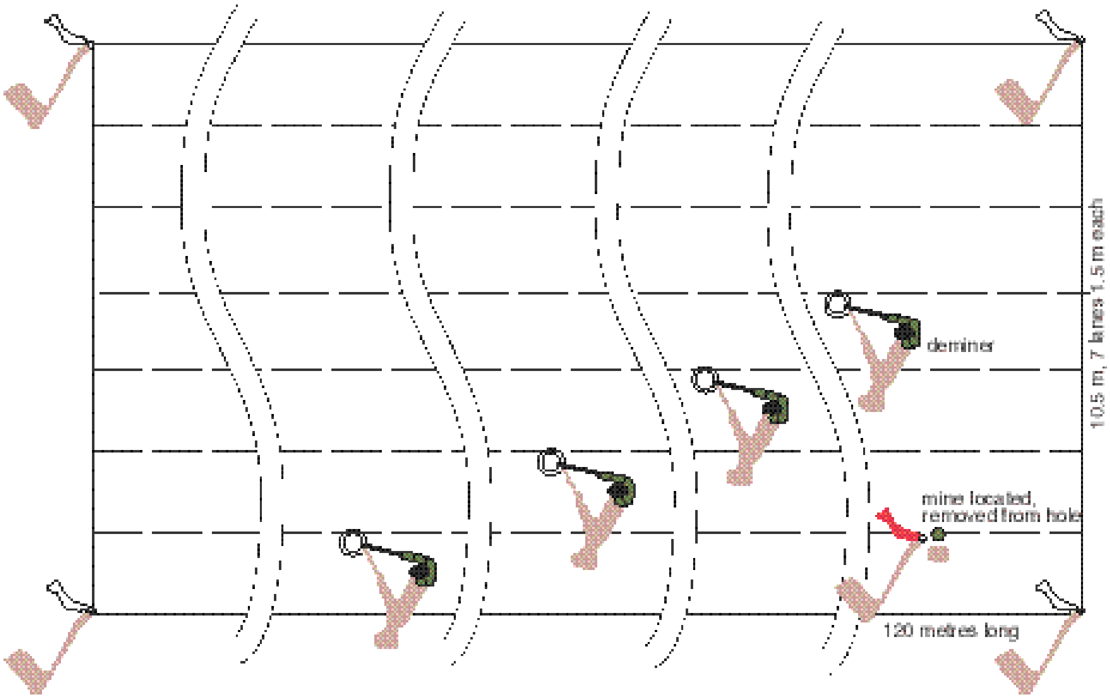
Current Solutions

The Egyptian Army has developed techniques for demining which are different from those used by most humanitarian demining organisations. However, they are fundamentally similar in principle, and are affected by the well known limitations of metal detectors and prodding methods. UXO clearance follows conventional techniques which would be familiar in any other country.

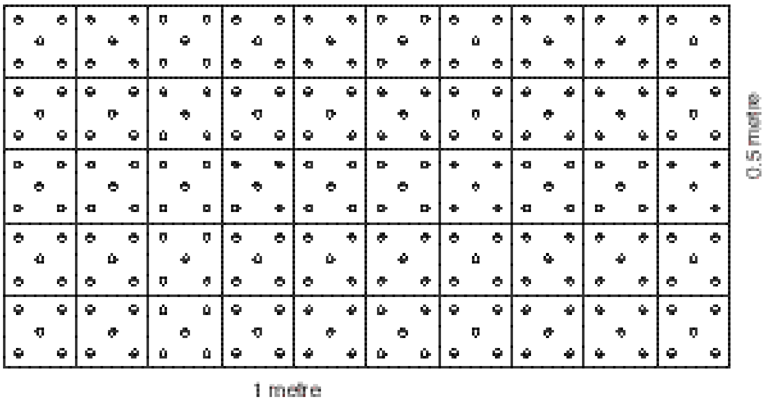
The procedures are changed from time to time, and are adapted for local conditions.

Quality assurance has been performed with tanks equipped with American mine rollers. However, this is now considered too dangerous after several large unexploded bombs were found.

Accidents have occurred while using metal detectors. This could be due to the fact that the deminers are expected to work along lanes which are not marked - see diagram which follows. The areas which I inspected had relatively few fragments, so the deminers could cover large areas of ground in a reasonable time. A convenient ground marker device that could be used to mark the lane edges while a deminer is working could help to prevent these accidents.



Drawing: Egyptian procedure for mine clearance. A rectangular area is marked out, if necessary by deminers using metal detectors to ensure they are on safe ground. White flags mark the corners: no other markings are used. Deminers are assigned to 1.5 metre lanes and stay about 20 metres clear of each other in a diagonal line as shown. The deminers are expected to work relative to the foot steps which the leading deminer leaves behind him in the sand. If one finds a target, the others wait while the team leader comes forward with a probe and trowel to investigate the target which is placed on the ground beside the hole from which it came. If it is an explosive device (mine or UXO) it is marked with a red flag. Mines or UXO are destroyed later with explosives.



Drawing: Guide for probing in soft sand made from wood. The deminer probes through each of the 250 holes before turning the board over and proceeding with the next half square metre. Deminers use this method when there are too many fragments (false alarms) to use metal detectors.

Problems with Current Solutions

For an Army which has developed *minefield breeching* methods, the prospect of demining thousands of square kilometres of wind-blown desert and salt marsh is a huge challenge.

The major problem is that the cost required to achieve a 'satsfactory' level of clearance is too great. Appeals to Britain and Italy have yielded little assistance so far. Germany has been more generous: in 1998 the German Government provided about 100 modern detectors (Föster 4400) and is currently offering to try the 'MineBreaker' machine in the Western Desert. The US Government is contributing US$500,000 in the current year ('99) for training and some equipment such as mine rollers.

Most minefield problems are seen by the Army engineers in terms of detection. They need better ways to detect and locate mines and UXO in deep sand and mud. Once the ordnance has been located, neutralisation or destruction is well within their capacity. They seem reluctant to look at alternatives such as processing the soil to remove mines and UXO.

Accidents are also a problem, but there was insufficient time to discuss this in detail. Accidents to deminers occur while using metal detectors, and may be due to the lack of lane marking techniques as mentioned before.

2. Western Desert Problems

Each region of Egypt has special technical problems. The principal technical problems in the Western Desert are:

> Wind blown sand burying mines and fragments up to 2 metres deep in places, though mostly less than that.
>
> High fragment density in many areas.
>
> Age of mines - up to 60 years.
>
> Unknown, or partially known location of minefields.
>
> Many, large and sometimes unstable UXO's distributed across area, many UXO's considered to be more dangerous than the mines.

Photo: eg24-19a: The back end of a large British bomb can be seen inside the hole. The bomb was dropped on a British position heading south. The bomb was discovered during routine mine clearance in the area. It is awaiting an EOD team to destroy it in place, and the evacuation of the adjacent bedouin camp.

Photo: eg24-20a: Close up of bomb in hole showing compacted sand with small limestone pebbles embedded in it.

Photo: eg24-27a: Minefield being cleared. Each red flag denotes the position of a mine, all AT mines in this instance. Each mine has been located and removed from its position and placed alongside each hole. This can be a dangerous procedure as some mines have mechanisms which, if badly corroded, can activate the mine with the slightest movement.

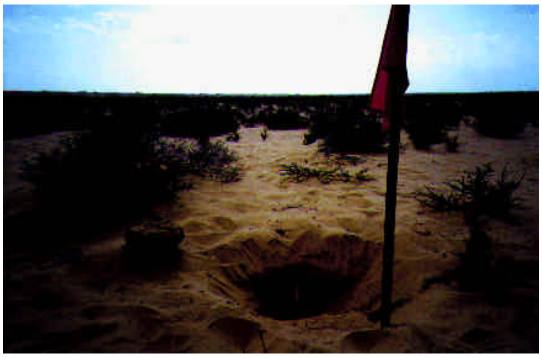


Photo: eg24-22a: Mk 4 AT mine removed from hole. The depth of sand above the mine was approximately 320mm here. Normal metal detectors should have no difficulty locating this kind of target.

Photo: eg24-21a: Close up of hole showing lower layers of compacted sand which can easily be rubbed away by fingers. The upper 10 cm of sand is loose. All this sand would blow away under appropriate conditions.

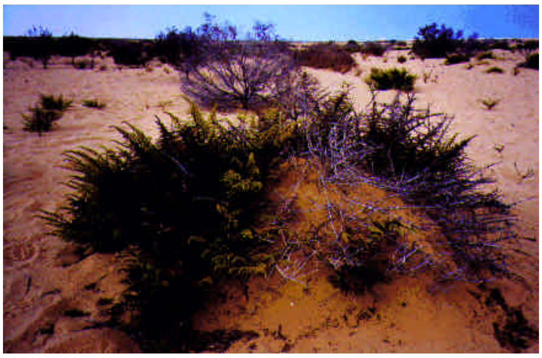


Photo: eg24-23a: Typical small bush. On the downwind side sand has built up in the bush. The prevailing winds are from the north west.

Photo: eg24-24a: British Mk 5 AT mine removed from its hole.

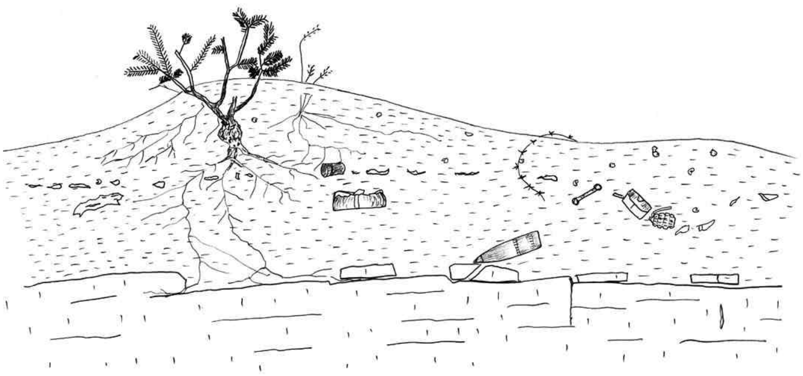
Photo: eg24-25a: Close up of Mk 5 AT mine showing advanced corrosion.

Photo: eg24-28a: Hole where a large fragment was found. This is one of very few such holes, indicating that there were few false alarms in searching for mines here.

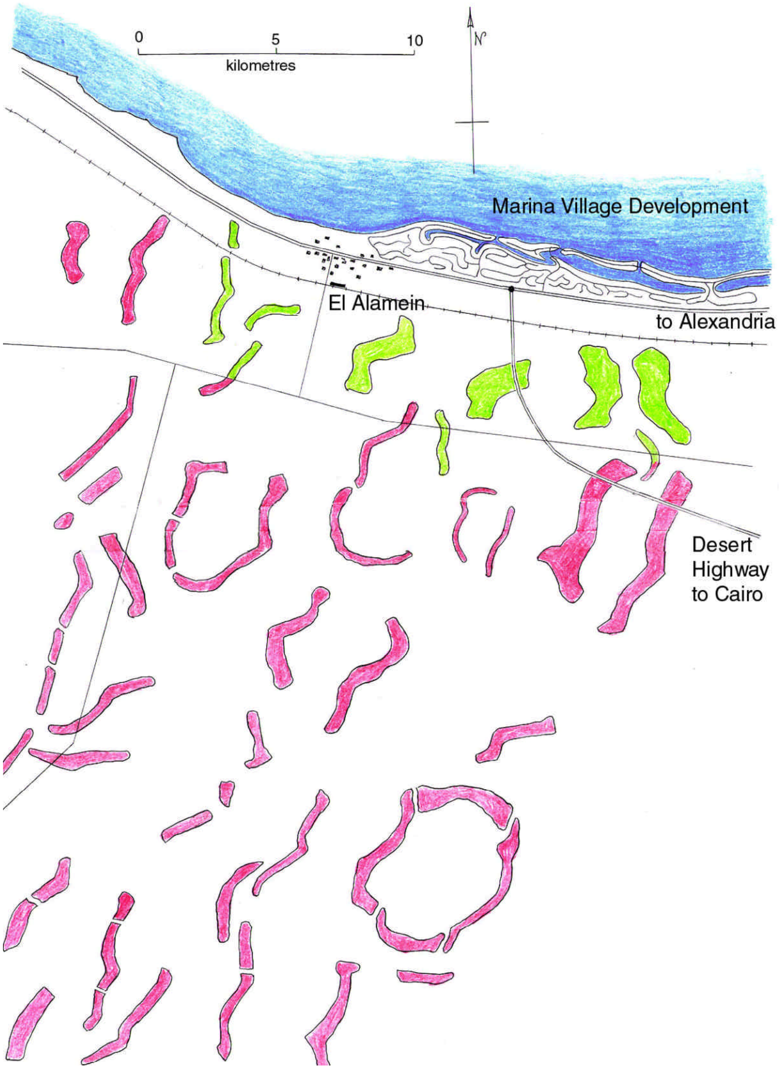
Photo: eg24-29a: Metal spring (found by deminers). The white flag behind the red flag indicates the edge of the minefield boundary.

Photo: eg24-30a: New irrigation canal under construction through mined areas. The government wants to release land here for irrigated crops, using underground water. Note the blown sand indicating that sand is very mobile here under the right conditions.

Photo: eg24-31a: Col. Mahrous, Commanding Officer, Engineers Brigade responsible for demining Alamein area, echanging gifts with author.



Drawing: Typical ground structure in Alamein area. Windblown sand surrounds small bushes in shallow soil over limestone bedrock. This shows typical demining problems in the Western Desert: mines lie close to bedrock, and UXO's lie in minefield area. Extensive frag from fighting, lying on what was the surface in 1941-1943, generates many false alarms. In places, the sand has drifted to depths of up to 2 metres.



Drawing: Map of area drawn from memory. Shapes are indicative only of minefield records which are partly misleading because of the limited accuracy of those records. UXO (and some mines) lie scattered across entire area so the entire area has to be cleared.

3. Salt Mud Problems

The principal technical problems in the Suez Canal and coastal areas are:

Mines and UXO lie in grey mud that is either occasionally or daily flooded by salt water. Mines may lie on surface or deep under mud surface.

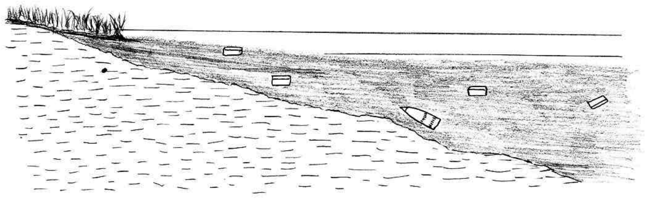
The mud is extremely difficult to traverse. Feet either sink right in, or slip sideways.

High fragment density in many areas.

Age of mines - up to 45 years.

Unknown, or partially known location of minefields.

Many, large and sometimes unstable UXO's distributed across area, many UXO's considered to be more dangerous than the mines.



Drawing: Salt mud problems. Tides or floods cause the water level to rise and fall from time to time. Mines and UXO may be visible in some instances, or may have sunk well below the mud surface. In some areas, the mud may have a dry salty crust lying on top of slippery mud.

4. Sinai Problems

The principal technical problems in the Sinai Desert are:

Medium and low metal content mines. Egyptians refer to PMN mine as minimum metal, though it contains much more metal than many other mines.

Wind blown sand burying mines and fragments up to 2 metres deep in places, though mostly less than that.

High fragment density in many areas.

Age of mines - up to 45 years.

Unknown, or partially known location of minefields.

Many, large and sometimes unstable UXO's distributed across area, many UXO's considered to be more dangerous than the mines.

5. Some New Solutions Available Now

Mine Detection Dogs

<u>Recommendation</u>

In my opinion, of all the technologies considered, mine detection dogs offer the best chance of significant improvements in clearance production rate and quality level. Because of cultural sensitivities and cost factors, the most attractive options to pursue this are:

• *A trial of Afghan or Iraqi mine detection dogs (with handlers) in Sinai Desert and Western Desert areas of Egypt. Such a trial should be coordinated with similar trials in Yemen, Lebanon and Jordan where similar problems exist and dogs could make effective contributions.*

• *Investigate whether sufficient dog capacity exists in Egyptian Customs and counter-terrorist organisations to build an indigenous mine detection dog capacity at, for example, the Cairo Police Academy.*

Dogs are now used in several countries for mine and UXO clearance operations. Procedures vary from one country to another, but the following general principles apply in all of them.

First, each dog requires extensive training, together with his handler. This is usually done at a combined dog breeding and training centre. The dogs are tested within a few weeks of birth to assess their potential. After a few months, as skills improve, a selected dog will live with his handler 24 hours per day. (This is recommended by most experts but is not always the case.) The dog comes to see himself as another type of human, and the partnership formed with the handler will be a lifelong one. So strong is the bond between handler and dog that if the dog is killed or injured in a mine accident, the handler may be emotionally upset for many months afterwards. The dog becomes acutely sensitive both explosive vapour smells *and* human behaviour around him. This becomes important in testing the dog's performance later.

Once a dog and his handler reach the required level of performance for field work after about 2 years, they will be assigned to a demining dog field centre. This centre has appropriate accommodation and medical support for handlers and veterinary support for the dogs. The cost up to this stage is about US$8,500, though more recently, it is claimed, the training cost has been reduced to $1200 (in Afghanistan, where typical deminer pay is US$150 per month — costs are substantially higher elsewhere).

Afghanistan Puppy Training Program

1-6 Month	Social training and ball play
6-12 months	Obedience

12-18 months Ball & explosives

18-20 months Mines

20-22 months Handler

Other training programs use similar techniques, but it appears that each is different.

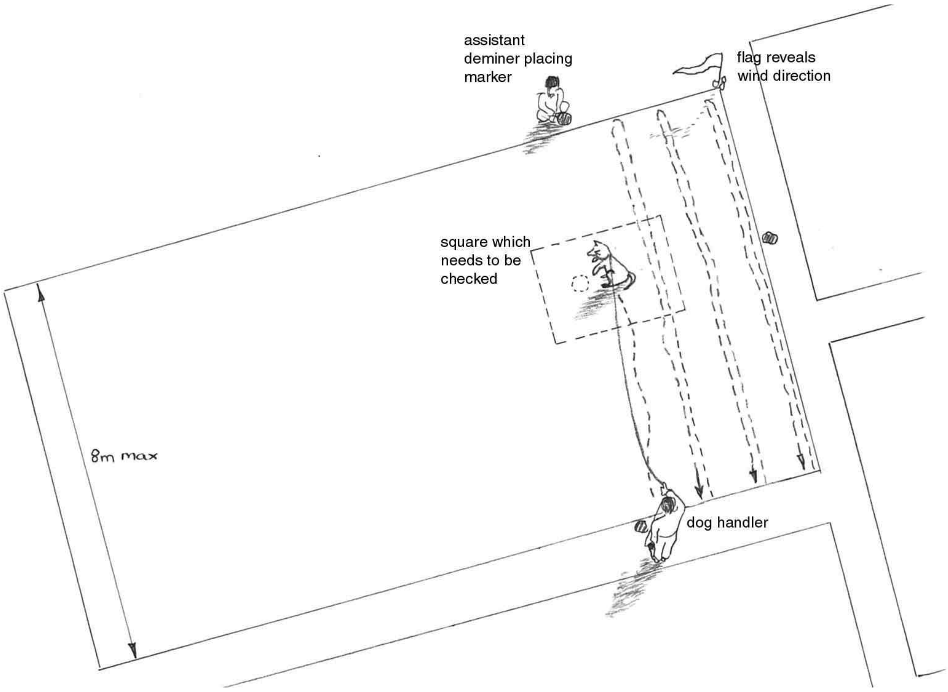
The dogs work best in dry, clear open country with vegetation no higher than calf to knee height (depending on vegetation and dog abilities). In Afghanistan, dogs are not used in wet conditions, thick vegetation or residential areas where, it is thought, the profusion of strong scents is likely to confuse the dogs.

The dogs will need supplementary training all the time, particularly if they are to work with different mines and/or devices containing different kinds of explosives. There is some debate about the length of training needed to 'convert' a dog to a new type of explosive or mine. In Afghanistan, daily refresher practice is part of the normal schedule, and a major refresher course is scheduled every two months.

The dog's reward for finding explosive is not food. It is a ball – “the Dutch method” – and this seems to be common to Afghanistan, South Africa, USA (Ronco) and European trained dogs. It is the appreciation and excitement of the handler which rewards the dog. Affection and food are always provided by the handler. Since finding explosives is, for the dog, a game or form of entertainment, the dog's performance will depend on his mood and level of interest in playing. On some days, a particular dog may not feel like playing (or may be unwell), in which case other dogs will be needed. Naturally, if the handler is not well, the dog cannot work. After some time, usually between 1 and 2 hours, the dog will be bored and will need some time to recover his interest in the 'game'.

A clearance task for dogs is set up by manual demining (which may require hand prodding if minimum metal mines cannot easily be detected by metal detectors). The manual deminers will clear safe access lanes (usually a metre wide) around the task area. The width of the task (across the wind direction) must be no longer than the length of the leash on the dog. In Afghanistan this is 8 metres. In Bosnia 10 metre and 15 metre lengths are common.

Another reason for manual clearance around the task is to check for tripwires. Some dogs have been trained to find tripwires, but there is disagreement on whether they can do this safely, particularly if the tripwire is extremely thin, or half buried under fallen vegetation. Since the average tripwire is 15-20 metres long, the size of any area to be checked by dogs must be less than this. In instances where short tripwires are encountered, dogs should not be used.



Drawing: Mine dog clearance task layout: Afghanistan.

The dog is introduced to the task and commanded by the handler to traverse the upwind edge of the task. The handler then steps about 60 cm sideways, and the dog performs another traverse, and so on. If one dog completes an entire task area (see diagram), another dog is introduced with his handler and again checks the same task area. If neither dog indicates explosives, the task area is declared to be safe and clear.

A dog is trained to indicate the presence of explosive by calmly sitting a short distance from the location where the scent was discovered. When any dog indicates, the location is marked by placing markers on the edges of the task area. If this is the first dog, another dog will be introduced and will traverse the area up to the indicated location again. Manual deminers can safely approach the location across ground which has been 'cleared' by both dogs. Maybe the second dog will indicate a location which was missed by the first dog. In this case, it is this location which is checked first by manual deminers.

In Afghanistan, procedures require deminers to check an area 2 metres square around the location point, to a depth of up to 50 centimetres, or greater if there is evidence indicating a suspect target. They will use metal detectors (if possible) and manual prodding or probing (if possible). At all times they will only stand on the side which has been cleared by both dogs. Often this process reveals a shell fragment with a tiny piece of unburnt explosive adhering to the inside. However, the false alarm rate is low, and the total clearance cost using dogs is about one quarter (or less) that of manual demining using conventional methods. (Approx US$0.15 per sq metre with dogs, $0.65 per sq metre using manual demining).

After a location is checked by manual demining, clearance resumes from the location point, continuing to work downwind. The task is 8 metres (m) wide across the wind direction, but can be quite long along the wind direction. Ronco use 15 m x 15 m square boxes (a dog works at it from both sides on an 8 m leach, which allows for 1 m overlap.)

In Bosnia and Croatia (and Northern Iraq) deminers use 10 m x 10 m square boxes. If one dog indicates an explosive device in a square, then current procedures require the entire square to be cleared manually. Well organised dogs can check up to 3,000 sq metres per day each. However, this is very rarely achieved because manual deminers can never clear safe lanes and mark working boxes at this rate. The normal arrangement is one dog team (2 dogs/handlers) to a demining team of eight men. Some demining groups bring dogs in only on selected days after manual teams have cleared sufficient boxes to provide the dog team with enough work.

Another common kind of dog task in Croatia is ruined houses which have been deserted for up to 10 years. When the houses were wrecked, some militias left some mines to deter people from trying to return to their homes. Other times, fighting in the area resulted in UXO being left inside or around the houses. Typically it costs about US$2,000 to check a house and yard with dogs, including the cost of clearing vegetation beforehand. Often the exterior vegetation can be cleared mechanically using a remotely controlled mini-flail. Clearing the interior is more time-consuming. One operator explained to me that "dogs don't know where to expect booby traps so they check everywhere….my men think they know where the booby traps would have been placed so they don't look elsewhere".

Known Problems in Using Dogs

Dogs do not find every mine. Even in Afghanistan, where the mine detection dog program has been operating since 1989, there are reports of missed mines from time to time. Elsewhere, the results are varied. Recent testing in Bosnia and Herzegovina has shown very poor performance by dogs. However, there are other test results which show satisfactory results. There are no standards which apply to dog performance testing.

The depth at which dogs can find mines also varies. There are reports of dogs finding AT mines as deep as 1 metre beneath unsealed roads, but then there are also reports of dogs missing similar mines less than 20 cm below the ground elsewhere (and even on the surface in some regions).

Dogs have not always been successfully introduced into demining theatres. Several known problems have been encountered, and it is important to be aware of these.

First, there may be disease problems. In Africa, mosquito and insect-born diseases have caused severe problems for dogs (and handlers too!). Food supplies need to be checked very carefully, and hygiene standards appropriate for 'foreigners' are essential. Veterinary support can be helpful in preventing some diseases through vaccination.

Quarantine restrictions can be troublesome in some countries, particularly if the dog needs to be keep quarantined for some time before entry. The handler needs to be with the dog during this period.

Dogs need to acclimatise after arrival in a new country and environment. They need time to orient themselves to a new world of sights, sounds and smells, just as the handler will. There is much disagreement, and few objective tests on the length of time needed. Times claimed for acclimatisation are between 2 weeks and 6 months.

Dogs will need to be trained on the types of mines and other targets they are expected to find. It is important to remember that the dog does not only smell explosive. In fact there is much discussion on what the dogs actually do smell. In some instances, dogs have been trained to find metal fragments when their number is small, and there has been trouble with training them to find particular UXO types. Some people claim that the dogs are sensitive not so much to explosives, but also to chemical by-products contained in the explosives or other parts of the mine, and even the smells associated with plastic packaging of the mine, or lubricating oils in the casings of UXO's. Some hardened skeptics claim that it is the human odor that the dogs pick-up and that is why they tend to find recently buried items that their trainer deposit but seem to miss even the landmines that are uncovered.

Training sites need extreme care. Practice targets need to be buried several weeks (at least) before the dogs are tested (or trained). The targets must be representative samples of the mines which the dogs are to locate. We do not know exactly what the dogs smell. Some people argue that the smell of additives in the plastic mine casing dominates the smell of explosive, but we know that human noses can smell some compounds much easier than others present in the same concentration.

The targets need to be handled carefully and with clean plastic gloves to avoid human scents contaminating them. Dummy targets need to be buried as well to ensure that the dogs are not simply finding places where something has been buried recently. Some targets can simply be hidden rather than being buried - this helps to avoid unnecessary distractions for the dog. Another issue is the order in which targets are placed. Some people attempt to arrange the targets such that the dog will encounter the hardest targets to detect first. Finally, there must be adequate separation between the targets - at least 20 to 30 metres.

There is some suspicion that dogs cannot work in certain soil and vegetation conditions where most if not all the explosive vapour is absorbed by the soil, running water, or plants, and cannot then be found by the dog. This may be associated with heavy clay soils with extremely fine particles.

Many of these issues are the subject of ongoing arguments between different people in the international demining community. Inevitably there are some vested interests which colour opinions stated from time to time. However, it is apparent that there are performance problems and more research is needed, with careful testing by dog users.

Given our very limited understanding of canine physiology and behaviour, these issues may not be resolved clearly for some time.

Aerial Photography

Recommendation

Although the officers I met claimed they had tried aerial photography, I think that the techniques demonstrated by ITC in the Netherlands should be evaluated. It is likely that the Egyptian air force has the necessary equipment and capability. Aerial photography would show where there is little or no sand cover and clearance teams can work without the need for detection equipment. It is possible that sand cover may change during the year, so repeated photographic surveys may be useful. High precision GPS registration of photographs will be essential as there are no permanent landmarks in most areas.

Recent research completed by ITC (see web address http://www.itc.nl/research/) has shown that aerial photography can be extremely effective in locating the boundaries of mined areas, and even in locating exposed devices, particularly UXO.

This research also showed that highly sophisticated radar and infra-red technology (which is currently under export restrictions in any case) contributes almost no additional useful information. The aerial photographic techniques are readily available from specialist companies or defence establishments.

ITC used large format stabilised image cameras flown at a height of 300 metres and 150 knots air speed to obtain colour and infra-red stereo images of the ground beneath. Modern equipment and films can produce a resolution of about 2 millimetres under these conditions. ITC asserts that the cost of obtaining the photographs is about US$0.0001 per square metre, or about US$100 per square kilometre.

If vegetation is an issue (not in Egypt) the photographs need to be taken at a time and season when vegetation effects are minimised. In some climates this is winter time. In tropical climates, it may be the end of a hot dry season.

The photographs, in essence, provide a means to conveniently obtain a close-up view of the ground from above. Any evidence of mines visible from above can be seen in the photographs. Many old minefields are clearly visible because a proportion of the mines are exposed by weather and erosion. Others are visible through indirect evidence: trip wires are often visible, packaging may still be lying around, the remains of old fences (if any were constructed) may be visible.

In some areas, local people know where the mines are, and keep their grazing animals away. However, they may not be able to articulate a description of the locations for mine clearance personnel. Aerial photographs will reveal the evidence left by grazing patterns.

Sometimes, buried objects, particularly if buried in a regular pattern, will show clearly in aerial photographs, even though it seems impossible to see this at ground level. Many famous archaeological sites have been found under grazing lands or fields of crops through patterns showing up in aerial photographs.

Warfare leaves plenty of evidence in the ground which can be seen in photographs. Foxholes and trenches, even though almost completely eroded and filled in, can clearly be seen decades after fighting has finished. Sometimes, scatted items such as ammunition clips, cartridge cases, ammunition boxes or even army style cooking equipment will reveal the location of military installations long afterwards, and thus indicate where mines are likely to be found.

Egyptian possibilities

The first possibility is that in some areas buried mines and UXO may have been exposed by wind or water and are lying on the surface where they can simply be collected by demining personnel. However, it is highly likely that sand will be moved again and after some time the material will be buried again. Aerial photography could reveal if these areas exist and how significant they are. Naturally, the photography will need to be repeated to monitor sand movements. The same may be true in coastal areas due to the effects of tides and currents. However, careful timing will be essential to ensure that low tide occurs when the photographs (and manual collection!) is carried out.

Aerial photographs could provide precise and useful maps for guiding conventional demining operations. Areas already cleared can be made to show up on the photographs with appropriate marking techniques. GPS should be useful in the flat desert and coastal areas for registration of photograph locations.

The relatively low cost of obtaining good aerial photographs (if local capabilities are adequate) makes this an attractive aid to demining operations.

No predictions for cost savings can be made without seeing the results of trial photographs.

Special Detectors for Deeply Buried Mines

Recommendations

By using a larger diameter coil on a metal detector, the detection depth can be increased almost in proportion to the coil size. Detector manufacturers need to be approached to see if they will provide optional large diameter metal detector coils.

Ground Penetrating Radar (GPR) should be evaluated for special mine detection problems in deep sand. The British Government may be willing (if approached carefully) to provide some financial assistance for a British company to supply experimental radar equipment.

Large Coils on Metal Detectors

Most current metal detectors work at limited depths with coil diameters of about 200 – 250 mm. The reason for the coil size is that most mine or metal detection tasks can be accomplished with a coil of this size, and that larger coils are inconvenient to use, particularly in thick grass or other vegetation.

By using a large diameter coil, the detection depth can be increased almost in proportion to the coil size.

The non-existent or sparse vegetation cover in Egypt may make this a practical approach for deeper objects.

However, it will not be possible to distinguish mines from fragments.

Manufacturers need to be approached to see if they will provide optional large diameter metal detector coils.

Specialist metal detectors used by keen gold hunters often provide for several different coil sizes. While these machines are essentially the same as current generation mine detectors, they incorporate many more user adjustments and therefore require specialised knowledge and training to operate them. They are usually extremely robust and reliable machines since gold hunters often need to operate in extremely remote areas. Therefore, it is quite feasible to test some of these detectors for locating deeply buried mines. If required, we can provide commercial contacts who can be approached for these specialised detectors.

Finally, if required, we have the capacity at the University of Western Australia to build specialised detectors if required.

A research project currently under way at the University (which is privately funded) is seeking to develop a metal detector which can distinguish mines from other fragment material commonly found in minefields. When a prototype has been successfully demonstrated (perhaps in late 2000), we would welcome the opportunity to test it in Egyptian minefields.

Ground Penetrating Radar

A further suggestion is to try using Ground Penetrating Radar. Equipment currently available from several manufacturers (such as ERA Ltd in Britain) would be sufficient to locate and measure the depth of UXO and some mines. This equipment was developed partly with the aim of locating minimum metal mines, but the results were disappointing, particularly in very dry conditions with small plastic mines close to the ground surface.

What makes Egyptian conditions more promising?

First, if the mines are buried deeper, in dry sand, they are likely to be easier to detect because surface-induced reflections will not be so troublesome.

Second, the 1941-1943 vintage mines have high metal content, making them easy to detect with radar.

Once again, metal fragments will cause problems. However, if appropriate frequencies are used for the radar (so that small metal objects disappear) the number of false alarms might be substantially reduced. This means that fuses, detonators and other potentially dangerous but small items may be missed.

This will require experimentation and some development in collaboration with a company which has expertise and can make appropriate equipment. Since ERA is a British company, a carefully planned approach to the British Government may result in appropriate financial support.

Side-scan ground penetrating radar carried on an aircraft might enable this technique to be applied for wide area coverage. However, experience in other projects suggests that it would be more prudent to test these methods with lower cost hand-held equipment first to find appropriate frequency and signal processing methods. The signal losses from ground reflections make this method rather unreliable in many situations.

Water Jets and Sand Mining with Slurry Pumping Technologies

Modern sand and coal mines often transport material in the form of a water/earth mixture called 'slurry'. The material is usually converted to a slurry with a high-power water jet aimed at the working face.

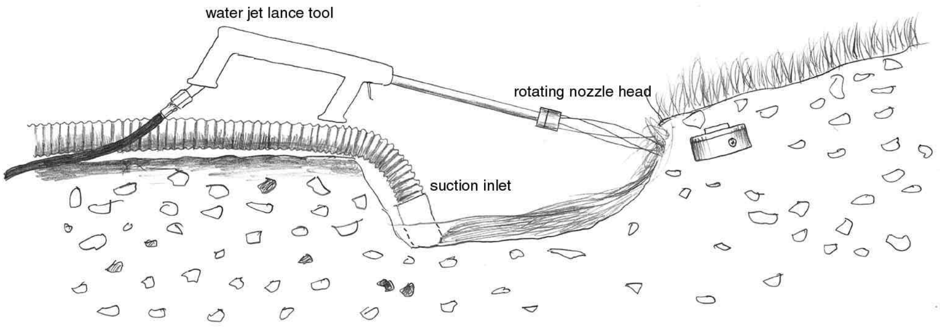
Special pumping and pipeline technologies have been developed to prevent the high wear rate which would happen if normal pipes and pumps were used. This form of transport can be very efficient and inexpensive, particularly if water jets are used to dislodge the material in the first place. Special equipment has been designed to separate different classes of material: mud, stones, gravel, sand etc.

There are three ways this technology could be used in mine clearance tasks.

Soil Sucker

The first is being developed at the Institute for Mining and Rock Mechanics at the University of Missouri-Rolla under a contract to the US Department of Defense. The device is called a jet-sucker. It has been designed for use by individual deminers who need to quickly investigate a suspect object. A man-portable pump unit supplies water (which can be salty or muddy) at a pressure of about 35 Mpa (5000 psi). The water is directed through several rotating jets at the suspect object, rapidly breaking down any soil or mud into a slurry. A sucking nozzle placed nearby removes the slurry from the work area so the deminer can clearly see what has been revealed. The water jets cannot disturb any object enough to cause an accidental explosion.

This type of device could be very useful for working in salty and muddy areas, particularly for the final phases of approaching a buried target suspected to be a UXO. It is likely to be much faster than normal manual digging.



Drawing: Soil sucker being developed at the University of Missouri Rolla

Mining mines

The second is entirely different approach. The current approach to demining is:

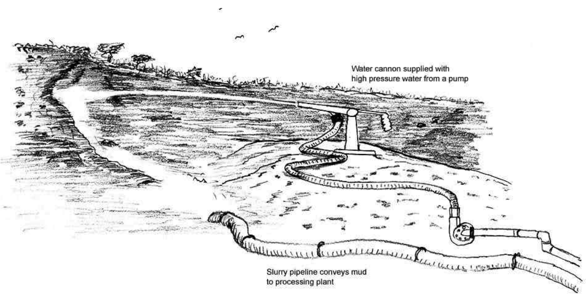
Detection and location of mines or UXO.

Destruction in-situ or disarming and transport to central disposal site.

An alternative to step a) is to process the entire top level of ground, as is done by machines such as Minebreaker (currently being evaluated in Croatia).

Machines like these cannot work in very soft or muddy conditions. However, this type of ground may be easy to convert to a slurry (it may already almost be a slurry) and then pumped through large diameter pipes to a separation plant where mines and UXO's could be removed from the slurry.

This is basically the method used in many mineral sand mining operations.



Drawing: Sand mining operation using water jet and slurry pumping. This type of operation can be very cost-effective, particularly in soft or wet conditions when vehicle movement is difficult.

The density of a slurry is much greater than clear water. Therefore, heavy objects are much more easily transported by slurry than in a stream of water. Provided there are no sharp bends in the pipe, mines are unlikely to be activated while being transported.

The cost of moving the soil with this mining method is between US$0-17 and $0-40 per tonne of material removed. Assuming that, on average, about 1 metre of material needs to be removed from the surface layer of the minefield, this works out to a cost range of US$0-35 to US$0-80 per square metre. The cost will depend on many factors, and dealing with surface vegetation will require some ingenuity, but these costs are far less than existing techniques. The major operating cost is electricity to drive the pumping machinery. These figures are based on electricity at US$0-055 per kilowatt hour.

The water jet can be up to 50 metres from the soil face, and up to two kilometres from the pumping station and separation plant. (source: mining industry in Western Australia).

These methods are widely used in Malaysia and Indonesia for alluvial tin mining, for bauxite mining in Surinam where the water jets are used to remove the soil lying on top of the bauxite, and for tailings mining in Australia to recover gold left by earlier imperfect separation plants.

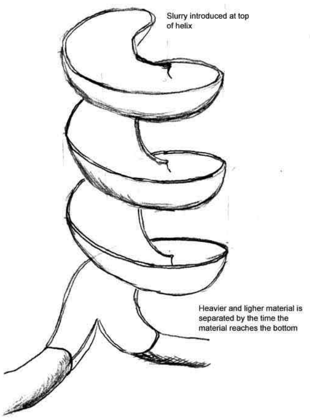
A separation plant could use the following methods:

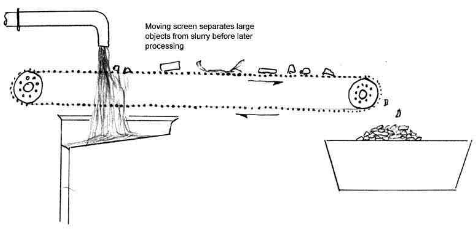
Magnetic separation - ferrous objects can esily be removed in this way.

Screens - slurry, mud, sand and gravel fall through the screen which has holes sized so that mines and larger objects are trapped. Typically a screen can be in the form of a conveyor which transports the objects to a position where an operator can visually inspect them.

Cyclones - vortex action separates material of different size and density. This is used to separate sand and gravel from mud.

The water jet and slurry intake can be remotely operated to keep operators at a safe distance in the event of an accidental explosion at the slurry intake.





Drawing: Helix vortext separation and screening used in sand mining operations.

The costs of using this technology are well known in the mining industry. Therefore, the costs of using this method can be evaluated relative to conventional demining methods.

Covering minefields

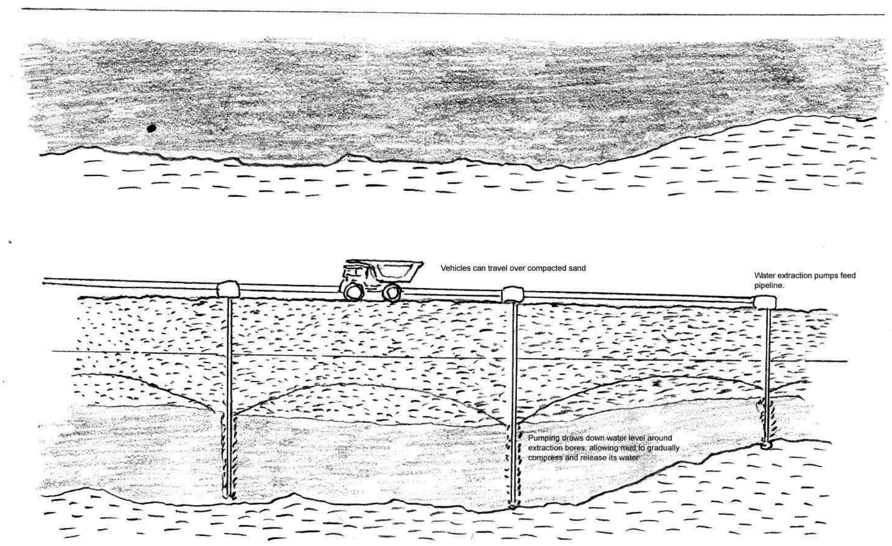
In recent decades, many large civil engineering constructions have been performed on top of marsh land which was originally soft mud by compressing the mud into a firm foundation. The mud has usually be compressed by:

Laying 5–10 metres of sand over the mud for up to 24 months to apply vertical pressure

De-watering the mud by carefully planned pumping

After the mud reaches sufficient density to support structures above, some of the sand is removed to achieve the required elevation profile.

The sand can be relatively easily placed over the mud by pumping it is a slurry. Usually the sand is obtained by dredging from the sea bed with a suction pump. In Egypt, and example of this can be seen at the Marina Village development near El Alamein, where artificial beaches and reclaimed land have been constructed using this method.



Drawing: Dredging technology: compressing mud for construction purposes. In the top drawing we see water lying over mud which rests on solid strata. The in the bottom drawing we see several metres of sand which has been pumped over the mud by a sand dredge (using water to transport the sand through a pipeline). Later, the surface is firm enough for trucks to continue the process more cheaply. Pumps are used to extract water from the layers of mud. After about 1 - 2 years, the mud becomes a solid strata underlying the sand.

Once mines and smaller UXO are overlaid with several metres of sand or mud the risk to land users (above) is almost negligible. It is extremely unlikely that the devices will explode before they corrode and become harmless. However, there must be stringent regulations which are enforced to prevent construction contractors from excavating too deeply. Contractors need to be aware of the risk of digging deep below the surface.

All these methods may be very useful for processing salt mud areas (rather than detecting individual mines and UXO) and some research and experimentation could reap huge cost savings in the long term.

6. Some Research Topics

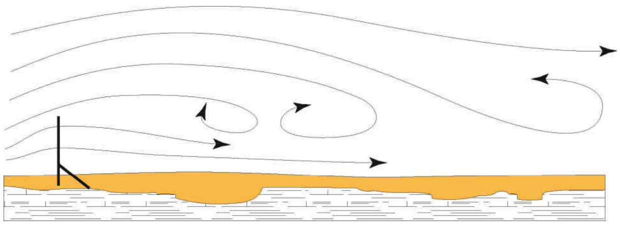
All the technologies mentioned so far rely on readily available technologies. There are some longer-term solutions which require research.

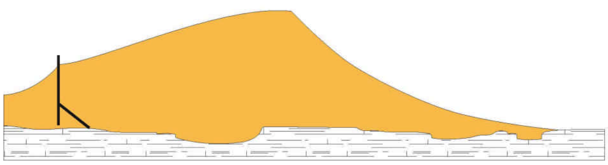
Using the wind to remove sand cover

Potentially at least, the wind can uncover objects buried in sand as easily as burying them. However, this requires some control to be exercised over sand movements.

Some control measures can be seen around irrigated farming areas on the fringes of the Western Desert. Sand control fences (which are similar to snow drift control fences used in snowy countries) slow the wind close to the ground for some distance in the down-wind direction. This causes sand carried by the wind to be dropped so that houses and farmland further away is protected from drifting sand.

With some research and experimentation, it may be possible to devise ways to use the wind to remove sand covering minefields, particularly in the Sinai Desert and Western Desert. The sand would be blown from limited areas: in essence the fences and other controls would *alter* rather than eliminate wind-blown sand movements.





Drawing: A fence which slows the wind, but still allows it to pass through, can create a sand drift in strong wind conditions. Control measures like this are often used around farms in desert areas, and in snow-affected countries. These techniques may offer a way to control sand movements and expose mines presently covered by sand. Note that in the western desert, sand movements are limited because the low scrub reduces wind speed close to the ground. Selectively removing scrub (using chemical spray, for example) could remove this impediment to sand movement. Stabilising sand after this needs careful attention however!

However, once the mines and UXO has been exposed, collection by teams of sappers would be very easy.

This method will take time to develop and will also take time in practical use (if that turns out to be achievable). However, by using the wind in this way, the costs are likely to be much less than current methods. Also, since most of the land is not needed in the short term, there is time to use methods like this.

From what I could see in my visit to the Western Desert area, the sand covering the mines will easily be removed by appropriately controlled wind. The sparse vegetation currently covering the land is just sufficient to slow the wind close to the ground to prevent sand dune formation. At the same time, the vegetation is too thin for wild fires to harm it, as is common along the coast of Australia. Selective removal of vegetation (for example, by spraying small areas about 500 metres square) may be all that is needed to enable the wind to blow the sand covering the mines.

Actual levels of risk

At the moment, the only methods used to reduce risks to civilians in mined areas are:

Complete removal of all mines and UXO

Fencing to keep civilians out of affected areas

Mine and UXO awareness campaigns to prevent civilians from touching or stepping on mines or UXO.

These methods are expensive, and the effectiveness of fencing and mine awareness campaigns is debatable and controversial.

In the absence of careful documentation of the circumstances of civilian accidents, the actual risks may be hard to determine. Often this is difficult because the government officials responsible for civilian accidents (e.g. police, ambulance officers, doctors, hospital staff) have little if any knowledge of mines and UXO. Therefore it is common that the cause of an accident is wrongly attributed, or the victim may not be able to explain why the accident occurred at all. Injured victims in remote areas may die of injuries before being rescued, or before they reach hospital. Bodies may not be discovered until after the evidence has disappeared: evidence which is necessary for accurate documentation of the cause.

From a health policy point of view, we can view mines and UXO as a risk to health in the same way as disease factors, accident factors, lifestyle factors and environmental factors. Most of these factors are under human control to some extent and can often be influenced by government policies and spending priorities. For example, a government could decide to install a better supply of drinking water and provide sewerage to a community to reduce health risks from water-born diseases.

Therefore, it follows that a government can equally decide to spend money clearing landmines and UXO to reduce the risk of death and injury from this cause.

By gathering data needed to analyse the relative risk of death and injury from mines, in relation to other causes, government agencies can better allocate scarce development funding to obtain the greatest improvement in public health. For example, careful analysis may show that improving road design and driver training may reduce deaths and injuries in a community much more than the same money being spent on mine clearance.

From what I could understand of the current situation in Egypt, there is insufficient data to perform this analysis at the moment.

There is some recent research in Lebanon which demonstrates that much of the data can be obtained by community-based research for relatively little expenditure. Also, there is considerable research literature available on risk analysis methods and their application to public health issues.

To be useful in Egypt, there must be locally based research, either in a University or government agency, or a non-government organisation which has the confidence of government health agencies.

Once the risk factors are known, the other side of the analysis is to consider alternative methods for reducing civilian risks.

From what I could see, there is no clear understanding of the risks posed by different ordnance littering the Egyptian deserts. In the Western Desert, the ordnance is very old. Some individuals stated that it was extremely hazardous. Yet operators are regularly moving mines and UXO in spite of the apparent hazards. Have tests been conducted to evaluate the actual risks? The military personnel who stated the most cautious views were being conservative for quite understandable reasons, and were quite alarmed that this topic should be raised at all. However, since the size of the problem vastly exceeds the current capacity to deal with it, some analysis of this kind seems essential.

7. Avoiding Some Difficulties

Military Engineering Organisation

The MEO has highly competent and dedicated staff dealing with the mine problem. While there are many detailed aspects which could be improved, the choice of priorities for this must remain with the Egyptian military.

In common with many other demining organisations, however, the MEO is not well placed to investigate or develop improved demining methods. For example, the Mine Action Centre for Afghanistan (MACA) needed independent research to identify and solve problems with protective equipment worn by Afghan deminers. Even with the results of this research, after two years, little change has been achieved by MACA. The MEO has quite different technical problems to solve, and an entirely different staff and administrative structure of course, but is not more able to embrace technical improvements.

This manifests itself as a demand for 'an off-the-shelf' magical detector which will solve all their problems. This form of solution is probably the only one which could easily be integrated within the current organisation. Unfortunately, there is unlikely to be a solution of this kind.

Therefore, the MEO must be equipped to explore alternatives. This means adapting the current organisation to allow technical improvements to be satisfactorily investigated.

Staff need English skills, internet access, and travel opportunities to see mine and UXO clearance operations in other countries. While specialist training courses provided in the USA are attractive to MEO staff, they are likely to be less effective in the long term without organisational change. Assistance with new technologies is unlikely to provide cost benefits with the current organisational structure and staffing.

It must be noted that companies which want to change their technological base common invest as much as 15% of their turnover on research and development. There is no reason why demining should be different. Therefore, the Egyptian Government and agencies providing assistance must allow for substantial resources to be devoted to finding better solutions to the mine and UXO clearance problem. The research and development must be carried out within the MEO (or defence scientific organisations) as there does not seem to be any other organisation in Egypt with the capacity, interest and experience to do this. I searched unsuccessfully for people within the leading Universities who could assist. The quality of research and development is likely to be greater if the Universities are involved.

Regional Cooperation and International Assistance

Since there are extensive mine and UXO clearance problems in most of the countries in the region, there could be extensive benefits from regional cooperation, especially for countries trying to provide cost-effective assistance. Unfortunately there are significant cultural and political barriers which need to be recognized before trying to achieve this.

The following countries are known to have significant mine and/or UXO contamination problems:

Jordan*, Lebanon*, Iraq*, Iran*, Kuwait, Morocco, Algeria, Libya, Sudan, Ethiopia*, Eritrea*, Yemen*, Afghanistan, Turkey, Georgia, Armenia, Azerbajan, Chechnya, and Israel.

Other regional countries not mentioned may also have problems.

Those marked [*] have military organisations responsible on demining like Egypt. While each country (and region within countries) has special and unique problems, there ought to be much to gain from regional cooperation. For example, if the USA can provide financial support for mine detection dogs from, say, Afghanistan to be tested in Egypt, similar tests in Jordan, Lebanon, Yemen and other nearby countries would also be valuable. It the tests prove successful, a major dog training centre could be a valuable asset for the region.

Current assistance is being provided on a bilateral basis with individual countries, and there could be savings by providing coordinated assistance programs to several countries. Queen Noor of Jordan has raised this possibility in recent speeches. (See for example, speeches made during her visit to Lebanon in October 1999).

While countries such as the USA, Britain and German could contribute technology (although there are no appropriate technologies available at the moment), there is much to be gained by regional cooperation to develop local solutions. While the inclusion of Israel may not be politically easy, Israel has technology resources which could be valuable.

The easiest way to start a cooperative approach may be to build links between organisations in the Arabic-speaking countries of the region to build on the strengths of institutions in those countries. Some of these strengths are:

Lebanon: epidemiological approach to mine injuries: treating land mines as a public health issue which can help with efficient resource allocation.

Kuwait: recent experience with large area clearance of mines and modern unexploded ordnance.

Jordan: Experience with mechanical clearance, experienced researchers in mechanical engineering, mining expertise.

Iraq: Experience with mine detection dogs

Egypt: Experience with deep sand conditions, mines and UXO in muddy marsh terrain, gathering historical military records to locate minefields.

Egypt has not been as successful as some other nearby countries in securing assistance with demining. It is possible that Egypt could increase the level of assistance by:

a) Clearly showing the current high levels of government support for demining by identifying the current financial expenditure through the defence forces on these operations.

b) Adopting better ways of communicating the problem and articulating its needs to the international community.

c) Reorganising mine clearance institutions within Egypt and promoting regional cooperation.

7.1 Articulating needs

Egypt's request for assistance could have been articulated more carefully. In Britain, for instance, many people misunderstand the way in which Egypt presents its landmine statistics. By including all UXO in the overall figure of 23,000,000 Egypt has been accused of 'inflating' the magnitude of its problem. This may be associated with confusion over terminology where the Arabic 'El-Gham' (bomb) is used for any explosive device: mines and UXO. According to well-informed sources, Egypt's attempts to justify this have been seen by individuals in Britain as 'evasion' and 'attempts to confuse'. By maintaining full military security over minefield information, and, for example, preventing members of assessment missions from taking photographs in minefields, the Egyptian Government has reinforced this mistaken impression. The recent filming of an Australian TV documentary in the El Alamein minefields represents a major policy change which is long overdue. The fact that I was permitted to take photographs reinforces this positive change.

In the USA, the fact that Egypt receives about $1,500,000,000 in direct military assistance (resulting from the Camp David Accords), and does not appear to allocate any of these funds to demining is seen by some as a sign that Egypt is not interested in spending its own resources solving the problem. In fact, Egypt maintains between 400 and 600 people continuously in demining operations. These people operate in remote inhospitable areas so the support costs and logistics represent a substantial investment from Egyptian resources which is not readily apparent. Further, the US has relatively little to offer in the form of cost-effective equipment which would meet Egyptian needs. German detectors, for example, seem to work much better in Egyptian conditions.

Many international donors refuse to provide funding to military organisations. Several countries in the region are known to conduct demining exclusively within their military organisations, including Egypt, and others are likely to continue this policy. Croatia is an example of a country which has changed its approach to overcome this problem. When the Yugoslav civil war ended in 1995, Croatia retained mine clearance under military (and Ministry of Interior) control. However, they changed this in 1997 and how have a separate demining organisation (Croatian Mine Action Centre or CROMAC) which reports directly to the President. Significant international humanitarian assistance funding is now being provided through CROMAC under the supervision of the UN and other International bodies.

8. Acknowledgements

The principal support for this visit came from the Egyptian Ministry of Defence and Military Engineering Organisation who contributed the time and enthusiasm of the many dedicated officers responsible for demining in Egypt.

Financial support for this research is provided by the Night Vision and Electronic Sensors Directorate of the US Army, private donations to the University of Western Australia, and a study leave travel grant from the University of Western Australia. My visit to Egypt could not have been so comprehensive without the support and encouragement of staff at the Australian Embassy, Cairo. Thanks are also due to many other sources who informally contributed background information, and to Samina Yasmeen for her understanding of the subtleties of Middle Eastern politics.

Finally, the research could not have been concluded without the efforts of my interpreter, Mr. Zahir Mohamad.