Complementary Training Method for Mine Detection Dogs

For the
D-BOX-project

Deliverable D6.13 Revision 1.0

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DOCUMENT HISTORY

Revision	Authors	Date	
0.1	R.Karlsson	16/01/29	First draft of report
0.2	M.Brantlind	16/02/03	Second draft of report
0.3	R.Karlsson	16/02/19	Third draft of report
0.4	R.Malcom	16/03/02	Ethical review and recommendations
	A.Sims	16/03/02	Report review
0.5	R.Karlsson	16/03/09	Implementation of reviewers recommendations
0.6	T.Kaime	16/03/17	Review of the section on Ethics
0.7	R.Karlsson	16/03/17	Final version of report
0.8	J.Schäfer	16/03/21	Technical review
0.9	A.Sims	16/03/21	Report review of final version
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1. EXECUTIVE SUMMARY

The DBOX project and EU funding have made it possible to further enhance the complementary MDD[1] training method, developed by FOI, together with the SAFDTC[2] . It is complementary since real buried landmines will always be needed, as the last step in training and validation of MDD performance. Variation is crucial in the training of the MDD, teaching generalization for the capability of detecting a variety of landmines under different conditions. It is a proven method, enhancing the MDD quality and efficiency. The success of this method have relied on input from dog trainers from the SAF, NPA and GICHD[3]. The tool described in this DBOX report delivery D6.13 is a water solution of purified TNT, (2,4,6-TNT water) to be put on top of the soil[4] but under the vegetation. The water needs to evaporate/dry/soak into the ground, before presenting it to the dog. This report includes a manual/protocol on how to use the tool for MDD training. Instructions on how to prepare and store the 2,4,6-TNT water, how to use it in training and also the limitations.

It validates the dogs ability to detect the least common denominator in most landmines, the explosive 2,4,6-TNT. The 2,4,6-TNT water is a proper training aid, *specific for the target and always present* in the odour signature of landmines containing TNT[5]. Easy preparation of purified TNT (for field conditions) is possible by ventilating flaked TNT or a piece of commercial TNT, crushed into fine powder and aired. Thus getting rid of the volatile by-products, letting pure 2,4,6-TNT dominate the gas phase. Place the TNT flakes or powder on aluminium foil, outside *in the shadow*[6] and ventilate it for at least one week. Put the ventilated TNT in an amber glass jar, boil some water and, pour it over the TNT. Carefully decant the TNT water and thereby achieve separation from the small TNT particles that still remains. The concentration of the prepared solution is in the region of 40-80µg/ml.

For deployment in different countries, it is easy and fast to set up new training areas. The TNT water is not explosive, safe, less toxic to dogs/handlers and easy to handle. No security issues are related to it. The broader MDD community will get access to this tool, thanks to DBOX. If used orderly, it can be of tremendous importance to the humanitarian demining community. How this method has been interpreted, by the Mine Detection Centre in Kabul, assisted by GICHD is an evidence of bettering the odds, in a challenging environment.

The DBOX ethical committee and DBOX end user group, especially Alan Sims from Karenswood Ltd, have improved this delivery significantly, as well as Steve Nicklin.

[1] Mine Detection Dog
[2] Swedish Armed Forces Dog Training Center
[3] NPA is Norwegian Peoples Aid and GICHD, the Geneva Centre for Humanitarian demining.
[4] Without causing any surface disturbances of the soil, by using a syringe to pour out the TNT water.
[5] The landmine containing the explosive TNT, is still the most common type threatening civilians.
[6] TNT *must* be kept out of the light, since it will start to degrade when exposed to UV-radiation.

2. ACRONYMS AND TERMINOLOGY

Word	**Description**
Background/negative neutral	A disturbance, a compound, solution or item that is not explosives or target related. Something with an odour that the dog shall ignore.
Concentration	Here, a measure of on how much TNT the sand or solution contains e.g amount of TNT per volume unit of water; µg/ml
Contamination	When TNT is adsorbed to something
Degradation products	The compounds produced when TNT breaks down (degrades) due to the influence of bacteria, sunlight or chemicals.
Discrimination	The dog’s ability to discriminate backround/negative/neutral items from targets (positives, explosives or ERCs).
DNT	Dinitrotoluene, a by-product in TNT, originating from the manufacturing process
EDD	Explosives Detection Dog
ERCs	Explosives Related Compounds, in example the non-explosive by-products in TNT such as DNT
FOI	Swedish Defense Research Agency
Generalisation	The dog´s ability to recognise/indicate explosives (targets) or ERCs similar but not exactly the same as the targets it´s been trained on
GICHD	Geneva Centre of Humanitarian Demining
IMAS	International Mine Action Standards
Indication	When a dog shows a response (sitting), detecting a target (landmine) or training aid (TNT contaminated water/sand), also called alert
MDD	Mine Detection dog
NPA	Norwegian Peoples Aid
Odour signature (of the explosive)	Here; the chemical compounds being the explosive or ERCs present in air, sand/soil, originating from a target (landmine) or a training aid
pH	A measure on the acidity or alkalinity of water based liquids. A pH between 6-8 is normal (neutral)
Pink water	TNT water, exposed to UV-light (sun/lamp)
QA	Quality Assurance
SAF DTC	Swedish Armed Forces Dog Training Center
SOP	Standard Operational Procedure
SRSA	Swedish Rescue Services Agency
TNT	Trinitrotoluene or trotyl
TNT contamination of sand or soil	The procedure for adding TNT-solution to sand or soil, to be used as a MDD training aid
TNT start solution	The saturated, initial target solution prepared, after removing the TNT piece or containing dissolved purified 2,4,6-TNT crystals.
TNT water	Water contaminated with TNT
µg/ml	10^{-6} g/ml, or 0.000 001g/ml (in this report often g TNT/ml of water)
ng/ml	10^{-9} g/ml, or 0.000 000 001g/ml
pg/µl	10^{-12}g/10^{-6}L, equivalent to 10^{-9} g/ml

3. INTRODUCTION

FOI have performed research and development targeting the detection of landmines, since 1990. This knowledge has transformed into the complementary training method for Mine Detection Dogs (hereafter also referred to as MDDs). It is developed in collaboration with the Swedish Armed Forces Dog Training Center (SAFDTC) and the method is presented in this DBOX report. The tool or training aid of this method, is purified TNT[7] (trotyl) solved in water. This TNT water is put out on top of the soil/ground surface, using a syringe. After the water in the solution has soaked into the ground, evaporated and left a dry surface, the training area is ready to use. This training method improve the quality of MDDs and Explosive Detection Dogs (EDD) performance and ensures that the dogs are trained on and recognise the odour from the explosive itself, the 2,4,6-TNT.

The DBOX project and EU funding from the European Union's Seventh Framework Programme, have made it possible to further enhance and remodel this method, adjusting it to the needs of organisations involved in humanitarian demining. The method has been discussed in an international workshop[8] organised by GICHD[9]. The DBOX project also made it possible to reanalyse an extensive amount of FOI material, some previously reported in Swedish and some only documented in house (lab journals). The training method also benefited of input from DBOX end users and reconnecting with former contributors, advisors and contacts. During this DBOX project filmed material (both new and old), have been gathered with the intention of making them accessible through the DBOX website.

The greatest value of this EU funding, is the exploitation opportunity of this report through the DBOX website, to get this method publicly accessible for everybody involved in humanitarian demining. The broader Mine Detection Dog community will for the first time get access to this information that could be a game changer, if used properly. This may be seen as a bold statement, but the example of how this information has already been used, by the Mine Detection Centre in Kabul (see section 11.2) and the outcome, is a strong point of proof. It is an opportunity to easier, cheaper and faster training and deployment of MDDs for demining missions, and EDDs. Access to real landmines and other explosive items are often a limiting resource. The use of landmines is strictly regulated. There are also security issues/costs related to buried landmines for training of MDD:s.

Detection dogs are a widely used tool for close range detection of landmines. The dog and its handler can be utilised as a standalone method, or in combination with other detection techniques. The detection limit of the MDD is difficult to establish, and varies due to climate conditions, odour availability, type of landmine, soil and the individual dog and it´s physical condition. With that stated, the MDD is a true explosive trace detector.

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[7] TNT is an abbreviation of trinitrotoluene, also called trotyl
[8] IMAS Animal Detection Systems (ADS) Revision Workshop, 7th-11th of October 2013, in Eksjö
[9] GICHD is the Geneva International Centre for Humanitarian Demining

FOI measurements of TNT in the gas phase above buried landmines, where dogs have indicated them, shows detection capabilities in the range of nano grams (10^{-9}g) and even pico grams (10^{-12}g) of TNT (see section 14.1).

Fundamental for all detection, is to understand the targets signature, what is there to detect and what is available to the sensor? Using and further developing chemical analysis and sampling, to study the release, migration and degradation of explosives and related components (ERCs), have been the FOI source of new knowledge, in this context. Equally important is to *understand the capabilities, limitations and operational challenges of the sensor, in this case the Mine Detection Dog (MDD) and not to forget it´s trainer and handler.* FOI do not have any dogs, nor expertise in dog training. Therefor we have been depending on working closely together with people who do know these things.

The success of this method have relied on the input from dog trainers and handlers involved, both from the SAF[10], NPA[11] GTC in Bosnia with Terje Groth Berntsen and staff and especially the advisory board of Conny Åkerblom and Bertil Ljungqvist, both working for the GICHD at that time. Without the information, questions and problems presented to FOI, by SAFDTC, GICHD, NPA and travelling the world, visiting organisations and operations involved in humanitarian demining, to learn more and get a first-hand understanding – FOI could never have done this R&D work, see Fig 1. It is truly an interdisciplinary science.

Fig 1. Bertil, Conny, Terje, Anni Båth & Siw Rudén(SAF), Erik Holmgren (FOI) and Zainuddin Shamsuddin, MDC Kabul – advisors, dog trainers (SAF & MDC Kabul) and analytical chemist (FOI) working together.

The protocol on how to use this complementary training method is summarised, for practical use, to anyone who wish to enhance the quality and capability of MDDs, in the annex of this report. To fully understand the instructions in the annex, the more detailed and comprehensive information in the report is necessary.

It is equally crucial to understand the science behind this complementary training method. To understand why it is a safe, cheap, simple yet beneficial method for MDD training and especially when there is a need to quickly set up high quality training areas in foreign countries. This will benefit dog teams deployed for humanitarian mine detection. With this method it is possible to instantly begin the process of calibrating and adjusting detection dogs to the local conditions of the operational area. The mimicking of the odour signature

[10] SAF is the Swedish Armed Forces
[11] NPA GTC is the Norwegian People´s Aid Global Training Center in Bosnia

of 2,4,6-TNT released from locally buried mines will ensure this. It is also necessary to understand the limitations of this training method, and what to think of, to make it work properly, see sections 5.3 and 12.1.

The EU funding have made this knowledge available and documented for reference, but the method of using TNT solved in water, for MDD training is known and has been used before, see section 11.1, 11.2.1 and 13.4.1 in this report. To what extent the TNT has been purified before used in a water solution and knowledge about the good reasons for this, is less clear. Regardless of this, *there are still many dog user organisations across the world who are not familiar with this training method*.

A very important reason why it is called a ***complementary*** training method, is to make clear that this will never be a *"stand alone, single method"* for training of MDDs, see section 12 for more information.

The FOI tools for gathering the information have been sampling and chemical analysis, of soil, and with improved analytical methods, also sampling of the gas phase/air above landmines and analysing its explosives and ERCs. Studying the explosives leakage, migration and degradation from and around buried landmines of different; types, soil, climate, countries, manufacturers, buried time and depths. These are all factors affecting the chemical signature of the explosive and ERCs, degradation and migration. It is beneficial to understand the chemical signature from a landmine, to know what is available for the sensor (dog) to detect. The unique and dangerous feature of the landmine, is the explosive component. This separates landmines from just any piece of metal, plastic, rubber, wood and/or paint material that human activities has spread.

The EU funding of DBOX have made the results from many FOI research projects available and presented here, with its extracted knowledge, analysed and discussed by end user experts' in different forums. The research projects were mainly sponsored by the SAFDTC, but also by the GICHD and Swedish Rescue Services Agency, (SRSA). This gathered knowledge have had very limited impact in the world of humanitarian demining until know, since it has been published in Swedish and mainly in reports delivered directly to the SAFDTC.

4. THEORY OF THE COMPLEMENTARY TRAINING METHOD

Dogs will detect what they have specifically been trained on, as shown in several studies, see references [1], [4], [11]. If the odour signature of the target or training aid is complex, it is difficult to know what the dog is responding to. This is the reason why it is so important to control exactly what is presented to the dog – and what the dog is rewarded for, when detecting something. This is not as easy as it sounds, since we cannot ask the dog what it is responding to.

The theory of the complementary training method is based upon the FOI research on the chemical signature of trotyl (TNT) and buried landmines. The development of the complementary training method started, due to some problems identified by the SAFDTC. Their mine detection dogs had no problem to detect the landmines they were trained to find, when buried in the training area in Sweden. However, when the SAF MDD teams went to Bosnia, the dogs did not show the same capacity to detect the local buried landmines. Another observation from the dog handlers' was that the dogs seemed to have more difficulties finding flaked TNT, unless it was really fresh, than finding one bigger piece of TNT. FOI got the research task to try to find the answers to these questions and how to improve the quality of the SAF MDDs, find more in section 10, 13 and 14.

Traditionally, the SAF MDDs have been trained on military grade TNT, which is a piece of TNT shown in Figure 2. Analysing the explosive and its related compounds (ERCs) in air samples taken above flaked TNT, that had been in use for some time, and comparing it with the content in air samples taken above a piece of TNT, gave interesting information. In Figure 2 below the result is presented in two diagrams. Each of the bars represent one air sample, showing the content in five samples in total. The height of the bar corresponds to the relative concentration of each compound, a higher bar means a higher concentration (expressed in pico grams, 10^{-12}g).

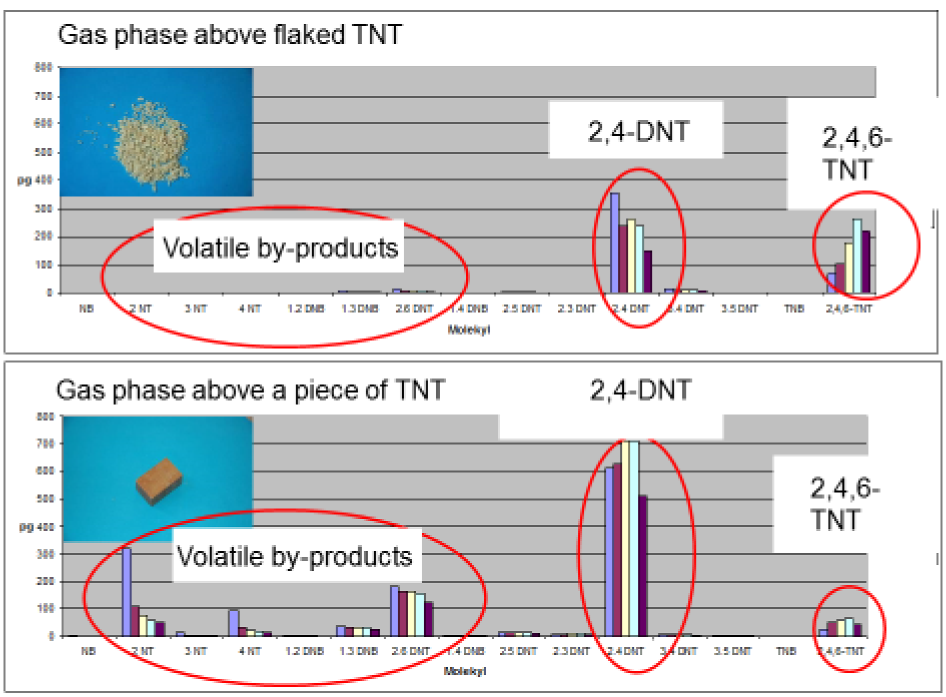


Fig 2. The explosive and ERCs in air samples taken above flaked TNT and a piece of TNT.

When comparing the two diagrams in Fig. 2 one can see that the most volatile by-products as well as 2,4-DNT (dinitrotoluene) are present in higher concentrations, relative to the 2,4,6-TNT content – in the air above the piece of TNT. The surface of the flaked TNT is bigger and therefore it is releasing its volatile components faster, compared to the piece of TNT – when exposed to the air, and not stored in a bag. So when being used in the training of dogs for a while, the more volatile compounds of the flaked TNT will be gone (released) to a higher degree, than the less volatile 2,4,6-TNT. On the other hand, the piece of TNT has a greater reserve of the more volatile compounds that will be released more gradually during training. When a piece of TNT is being handled, new reserves of the volatile compounds will be exposed to the air and released.

In the next experiment, the gas phase content above a new piece of TNT was compared with the gas phase content from an old piece of TNT. The older piece of TNT had been used in training for a while and more exposed to the air. The two pieces of TNT was of the same type of military grade TNT, the age and air exposure time was the only difference. The gas chromatograms from the two analyses are shown in Figure 3.

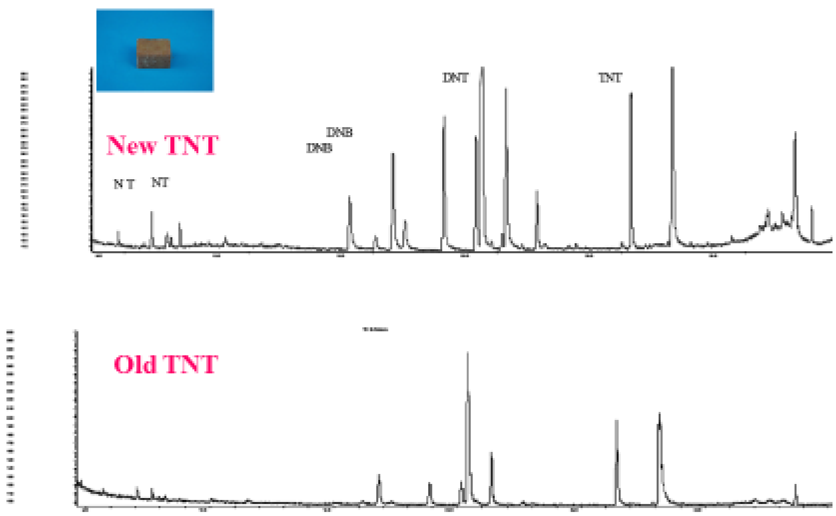


Fig 3. The explosive and ERCs in air samples taken above a new and an old piece of TNT.

Each peak in Figure 3 represent a compound, the explosive itself TNT and the more volatile by-products (DNT, DNB, NT). The height of the peak corresponds to its concentration in the gas phase. When comparing the two chromatograms, it is obvious that the odour signature of old and new TNT differs, even if the TNT has the same origin and shape.

To see for how long the different compounds in the Swedish military grade TNT stayed in the air above a piece of TNT, an experiment was performed, presented in Figure 4. A piece of TNT was exposed to the open air, and air samples were taken above it immediately after removing it from the storage container (time zero), after one hour, four days, one week and two weeks. The results are presented in Figure 4. The upper graph shows 2,4,6-TNT and DNT and the lower graph the more volatile by-products nitro toluene (NT) and dinitrobenzene (DNB).

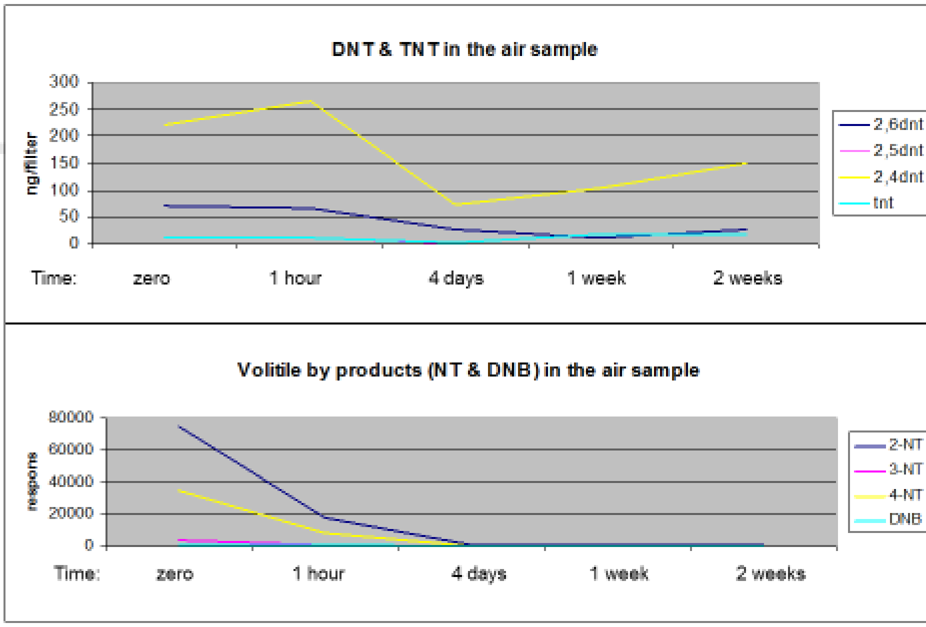


Fig 4. The explosive and ERCs in air samples taken above the same piece of TNT, left out in the open air for two weeks.

The results displayed in Fig. 4 shows that 2,4-DNT remains present in the gas phase in higher concentrations than 2,4,6-TNT for the whole time period. The concentration of 2,4-DNT has decreased significantly after four days. For the more volatile by-products in the lower graph, the highest starting concentration at time zero has the 2-nitrotoluene (2-NT). After just one hour, the concentration in the gas phase has decreased significantly and after four days all of the most volatile compounds are merely detectable. From this we can learn that the odour signature from the same piece of TNT will change over time, if left out in the open air and noticeable after just one hour of exposure.

When we asked the staff at SAF DTC what they were training the MDDs on, they would answer that it was pure TNT, as being the same explosive present in most landmines. That was correct in a sense, since the solid military grade TNT, as most commercial TNT, contains about 99% of 2,4,6-TNT and only 1% of the by-products. The problem though, is that this 1% of by-products are more volatile and more easily released to the surrounding air than 2,4,6-TNT, and therefore dominating the odour signature. The chemical signatures of TNT and ERCs in the air, presented in Figure 2-4, reveals this relationship.

Though exaggerating a little, one could say that the odour signature of commercial TNT is presenting the opposite relationship in the air above, compared to the content in the solid phase. The 1% of by-products, represents 99% of the odour signature in the gas phase, due to their higher volatility, see Figure 5.

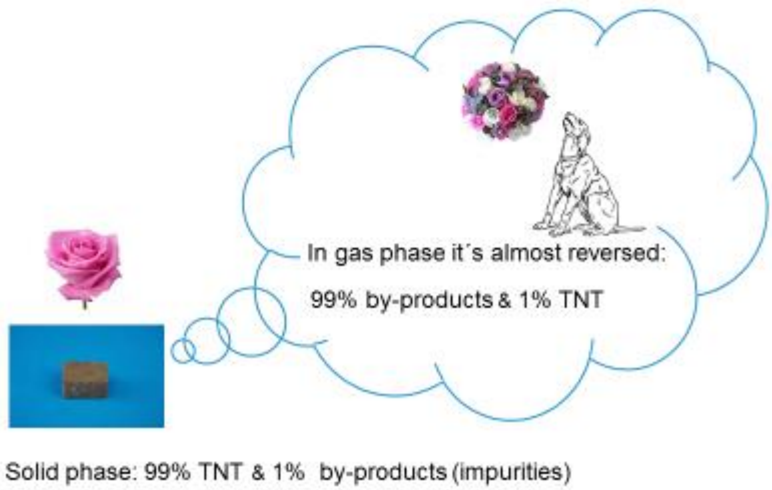


Fig 5. The difference in the ratio between 2,4,6-TNT and the impurities, when comparing the content of the solid piece of TNT and the content released to the air above it, available to the dog.

To illustrate the difference between the gas and solid phase of TNT, one could say that the solid TNT represent a single rose. In the gas phase though, this is no longer true and the odour signature in the air, is a bouquet of flowers, where the single rose is just one part of the bouquet. So what does the dog search for, when it is only trained on commercial and not purified TNT. Is it possible to be sure of that the dog acknowledge and choose to indicate the 2,4,6-TNT, the explosive itself, in this bouquet of flowers?

FOI wanted to know how trained explosive search dogs would react, if all the 14 components of TNT including the by-products and its degradation products in soil, were to be presented to the dogs in 14 sepearate searches.

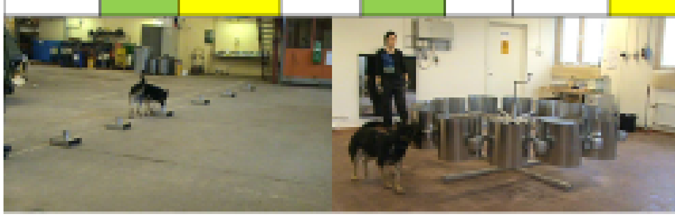
In order to investigate if the dogs choose different compounds in the odour bouquet a test with seven dogs were performed at SAFDTC. The dogs were presented to 14 single and purified components, including purified TNT and the military grade TNT that they normally are trained on. The results revealed that it varied in how many components that the dog recognized.

This odour recognition test was done either in a linear search setting or by using a carousel – depending on what the dog was familiar with. Each search contained only one explosive or explosive related target, the rest of the containers/cups contained neutral items (for EDDs) in example, sand, wood, plastic, coffee, anything with an odour but without any explosives contamination or relation. No cups/containers were left empty. This to make sure that every sample, to be analysed by the dog, had an odour. Only one of them though, should be able to relate to a target, in each search set up. The result is shown in Figure 6. The three upper dogs in the table (Acca, Basse and Astro) were trained as mine detection dogs. They all showed an interest in some of the three single components at the right end of the table, the amino compounds (2a-4,6 DNT, 4a-2,6-DNT and 2,4-diamino, 6-NT). This made sense since the amino compounds are biodegradation products from TNT in soil. The dog in the middle of the table, Charlie, was the only experienced MDD, but showed no interest in the amino compounds. This could imply that experienced dogs might be rationalising and choosing to respond/indicate to fewer compounds in an odour bouquet. The other three dogs in the test (Certa, Alea, Abba), were trained ammunition/weapons search dogs.

The indications of the single components 2,4-DNT, could be explained by this being a volatile byproduct in commercial/MTG[12] TNT and often present in the odor signature of cemmercial TNT. The nitroluenes (NT) and dinitrotoluene (DNB), are more volatile in comparison with DNT and the least volatile of them all – is the 2,4,6-TNT.

Another observation is that the individual dogs all indicated the MTG, military grade/quality of TNT, which they all had been trained on. Other than that, it is clear that none of the dogs responded exactly the same to all of the single components tested. This test was repeated at other occasions as well, with similar results.

Dog	MTG TNT	Pure TNT	2,6-DNT	2,4-DNT	NB	2-NT	3- NT	4-TN	1,3-DNB	1,4-DNB	TNB	2a 46dnt	4a 26dnt	24 dia6nt
Acca														
Basse														
Astro														
Charlie														
Certa														
Alea														
Abba														



Indication/alert = the dog is sitting down

Interest = the dog shows interest (stops and sniffing a bit extra), but there is no indication

Fig 6. The single component test, of military grade TNT, purified TNT, and TNT by-products and degradation products.

[12] MTG is short for military grade, indicating the quality and origin of the TNT

The results of the single component test shows that to be able to verify that the dog will indicate on pure 2,4,6-TNT, it needs to be trained on the purified crystals, or as second best alternative; TNT that has been purified by airing.

The more volatile components associated to TNT is of course known to others than FOI and there has been attendances at conferences and workshops, actually suggesting that 2,4-DNT could be a useful training aid for MDDs. The argument that was used, was the convenience of DNT not being an explosive compound, but still related to TNT in landmines. Although this is being true there is a problem with that, illustrated in Figure 7. There are TNT producers that manufacture TNT in such a way that there is no DNT left in the final product. In Fig 6 the chemical analysis made by FOI, of the content in commercial TNT of different origin, clearly shows that there is no DNT in the product made by producer number 2. Seeing this, it is easy to understand the danger of only training a MDD on 2,4-DNT.

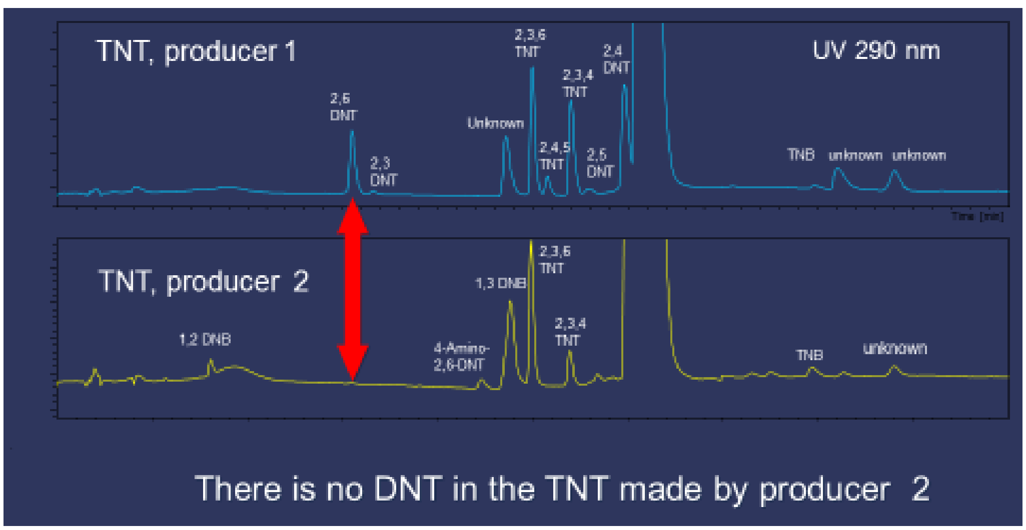


Fig 7. The difference in the content of commercial TNT manufactured by two different producers.

Another example of why it is important that the dog respond to the explosive itself, is shown in Fig. 8. It is a chemical analysis of an air sample taken above an AP mine, buried in sand at 10 cm depth, that reveals a content of only 2,4,6-TNT without any other ERCs present.

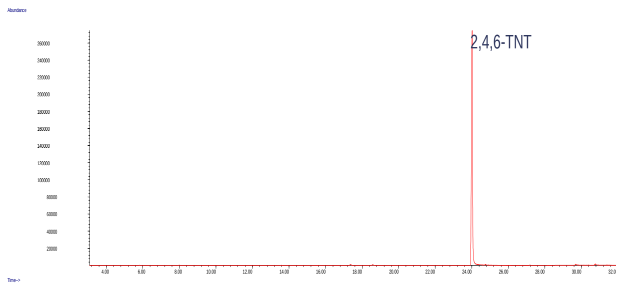


Fig 8. The ERCs in the air above an AP mine, buried in sand at 10 cm depth.

The chromatogram in Fig. 8 is also displayed in Fig. 44a, illustrating that even the depth at where the landmine is placed, affects the explosives related odour signature.

The odour signature of commercial TNT, the core component of many landmines vary:

- …over time (many of the contaminants are volatile)
- …depending on the manufacturer and type
- …depending on buried depth, soil type, climate, time
- …due to the degradation process in soil

The common denominator in all TNT based explosive is the actual explosive 2,4,6-TNT. All other components are either by-products or impurities from the manufacturing or degradation products due to ageing. In the training procedure of the MDD, it is therefore important to include and teach it to detect the 2,4,6-TNT, se Fig 9.

		
Piece of military grade TNT	Flaked commercial TNT	Purified TNT

Fig 9. Different types of TNT

In the case no access for purified TNT can be obtained, the addition of flaked vented TNT to the TNT water solution is an alternative. Vented TNT is produced by crushing a solid piece of TNT and leave it in a dark shaded place (no UV light) so that all volatile components can evaporate from the TNT.

The purified TNT crystals are not easy to handle. They adsorb to container walls, getting static (charged) and it is not easy to avoid contamination issues if one is not attentive to this risk. To avoid this problem, the crystals were solved in water. This method of using water as a solvent of target related material for MDD training, originated from the GICHD sponsored OSP project. Though having that in common, the OSP project idea was to find a water solved mix mimicking the complete odour signature of a landmine, instead of only focusing on the explosive, see section 13,4. The 2,4,6-TNT water is put out on the soil surface, by using a syringe. This makes it possible to control the presentation of the TNT water, getting it close to the soil surface but without any surface disturbance, see Fig 10.

Fig 10. Illustration of the process behind the DBOX tool, the TNT water, from left to right.

The 2,4,6-TNT water tool of the complementary training method is the outcome of the sampling and chemical analysis, in the search of a way to improve MDD performance. By also training the dog on pure 2,4,6-TNT, the dog will have the ability to detect TNT targets with less content of the volatile by-products, like vented flaked TNT.

The procedure of the training method with TNT water, releases the TNT into the ground, where it starts to degrade, mimicking the release from a local buried landmine. The fast and easy way to prepare a training area abroad, facilitates the calibration of the MDD when deployed in another country. In essence, it is possible to make a highly controlled vapour image for MDD training.

5. OBJECTIVE

This complementary training method aims to improve the quality of MDD performance and is a tool to ensure that the dogs recognise the odour from the actual explosive which in this case is 2,4,6-TNT. In addition the MDD shall be trained on commercial pieces or flaked TNT, preferable using a water solution of it as well, also described in this report (see section 8.3.2, 12.1, 13.3, 13.4.1). For QA and additional training, the need for training on real targets remains. Practise have shown, that the extra training aid of purified TNT (chemically by recrystallization or aired/vented) water, is worth the effort and give measurable improvement of the detection capability, see section 10 and the MDC example in 11.2.1. It also seem to make the transition from the training aid, to the finding of real buried landmines smoother for the dog, and faster. A possible explanation for this could be that the solved TNT soaks into the ground, and then degrades in the same way as TNT leaking out of buried landmines.

It is a mature method, currently in use by the SAF. There is no commercial product or patent connected to the complementary training method, but when used a courtesy to DBOX, FOI, SAFDTC and GICHD is appropriate.

5.1 ADVATAGES OF THE 2,4,6-TNT WATER

The 2,4,6-TNT is the least common denominator of trotyl containing landmines, which represent the most common type of mine threatening civilians today. The search dog is a very useful mine detector, as long as it is properly trained. It is already mentioned that landmines represent a very variable target, when referring to its odour signature. The one component always present close to a TNT charged landmine, is its explosive part – the 2,4,6-TNT. The TNT related by-products and degradation products vary over time, manufacturer, climate and soil type or depth buried, and are therefore less reliable for detection purposes.

The TNT water is not an explosive and so low in TNT concentration that it becomes safe to handle. It is to be considered as contaminated water. This is a huge benefit, compared to training a dog on a piece of commercial TNT, which is very toxic. The solid TNT can harm both dogs, humans and the environment, if not carefully handled. Staff at the SAFDTC have reported about a MDD in training, accidently biting a piece of commercial TNT. The dog was paralysed due to this incident and had to be put down. This can never happen, when using TNT water for training.

The benefits of this method will be of significant importance to humanitarian demining operations and organizations with limited access to landmines for training of mine detection dogs. It is a useful training aid for operational work in different countries since it is easy and fast to set up new training areas wherever you go.

Access to anti-personnel (AP) landmines is strictly regulated by the Ottawa treaty, officially known as the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction. The treaty aims at eliminating AP-mines around the world and it became a binding international law in 1999. This method using the 2,4,6-TNT water solution, will make it possibly to quickly set up a training area for the MDD, in a foreign country. After the TNT water has soaked into the ground and the water has dried (evaporated), it is OK to start the training.

The TNT will be available to the dog and it will instantly start to degrade, in the same way as TNT that has been leaking out from locally buried landmines. This will make the dog adapted to the odour signature of the explosive, developed due to local soil and climate. This calibrates the dog to the local conditions of the operational area. For MDDs in the Swedish Armed Forces this used to be a problem, as described in section 4. Normally a training area with real buried mines, takes at least three months to settle. Time is needed for the visual cues of digging to disappear, where the TNT water gives no surface disturbance. It also takes time for the TNT to leak or permeate out from the buried mines. At first there might be TNT contamination from the outside of the mine casing available, but after this has disappeared it takes time before the TNT from the inside of the mine to be available for the dog to detect.

Another aspect is the difficult security situation related to a training with real landmines. They are always subjected to the risk of illicit use, since they are very portable, insensitive when the detonation device is removed, but still containing explosives. This means that a training area for MDDs always need to be fenced, with security alarms and heavily guarded. These necessary actions are expensive. In countries with many conflicts and political instabilities it may be impossible to set up or keep training areas with real landmines. This situation proved to be truth for the training area of the Afghanistan Mine Action Center (MAC) in Kabul. It was an area prepared for MDD training and IMAS certification, with over 600 buried landmines, situated 20 kilometers outside Kabul. Increased instability and conflicts in the country, resulting in a couple of incidents at the training site, eventually made it impossible to keep. All the landmines there had to be removed (oral reference by Conny Åkerblom, working for GICHD at that time).

The very low concentration in the 2,4,6-TNT water solution is also mimicking the usually low concentration of TNT, in the gas phase (air) above a landmine. This correlation has been shown in the sampling and analyses of both soil and gas phase (air), above buried landmines in different types of soil, performed by FOI over the years and presented in section 13.1 and 13.2. As always variation is crucial in dog training (see section 12.1) and it is easy to vary the concentration of TNT in the water solution, up to the saturated solution with a concentration of approximately 20-100 µg TNT/ml water, depending on the room temperature. The explosives concentration available for detection close to landmines, ranges from true trace detection of picogram (10^{-12}g), up to occasionally slightly overwhelming high concentrations (relatively speaking, to a sensitive dog nose) of explosives close to certain anti-personnel (AP) landmines, such as the PMN mine type (see Fig 39).

5.2 SUMMARY OF THE ADVATAGES OF THE 2,4,6-TNT WATER

- Pure 2,4,6-TNT (trotyl) is *always present* near a TNT landmine – and therefore a proper training aid.
- The 2,4,6 -TNT water is not regarded as an explosive, it is contaminated water.
- Less toxic to the dog, humans and environment.
- No need for guards or fences, no security risk.
- Easy to prepare a MDD training area – instantly available to the dog. A training area with buried landmines needs about 3 months to settle.
- No surface disturbance.
- Getting low and variable concentrations of 2,4,6-TNT is easy, mimicking the release from a landmine.

- Useful training aid for operational work in different countries. The 2,4,6-TNT soaks into the soil and degrades in the same way as TNT released from local buried landmines.
- Makes it possible to train MDDs, even without access to real landmines.
- It is an easy and cheap method to use.

5.3 LIMITATIONS OF THE TNT WATER TRAINING TOOL

In this section the technical and environmental constraints of usage will be described, see also section 12.1. There is a need for some materials and equipment to prepare and store the TNT water and depositing it on the ground (see Annex 1). In sun and hot, dry conditions the TNT will start to degrade quite rapidly. After distribution of the TNT water, the water needs to evaporate from the soil surface before the dog can start the training. If not, the dog will learn to search for spots of water – a mistake made that does not need to be repeated.

The MDD as a tool cannot be expected to find landmines if the ground temperature is too low for releasing any TNT molecules or particles. When that happens is up to debate, but to be on the safe side a rule of thumb, could be below 5 degrees Celsius (approximately). Different soil types and climate, type of mine and buried depth will affect the detection premises. Sand storms, rough terrain and heavy rainfall makes it hard if not impossible to use a MDD. The rain will push the TNT down deeper into the ground, but sometime after the raining has stopped the process is reversed and detection conditions will be very good.

Another limitation is the TNT water being invisible, after being poured out – which will force the trainer to keep good lane records, see Annex 4. On the other hand it is a benefit, since the dog does not get any visual ques from it either. The dog's performance is also dependant on physical and psychological issues. The MDD performance also depends on the dog handler and trainer, where one problem is that handlers do not always trust their dog. Not trusting them when indicating properly, nor when showing increased interest. More is presented in the next section on ethics.

The limits of the MDD team as a mine detector, can often be solved by using another sensor or tool, well described in the DBOX project. There is also the possibility of integration with those other tools, using them side by side.

6. ETHICS

This complementary training method, is a tool for training of dogs to get high quality MDDs. When using dogs to perform work, it is absolutely necessary to consider the welfare of the dog. The usage of this complementary training method stipulates that it should not be practised by any dog organisation, without first having appropriate routines for the welfare of the dogs. However, since FOI does not have specific expertise in this area, only a general description of the importance of ethical treatment of MDDs is outlined. It is recommended that operators seeking to use this tool, apply to the appropriate national authorities, for specific protocols on ethical treatment of working dogs.

It is a responsibility of every one using dogs for work, to do this in an ethically appropriate way. One can never put aside that a dog is a living creature, and it needs to be treated accordingly. The advantage mentioned in previous section, by using the considerably less toxic TNT water for training, is a huge benefit from an ethical point of view. When following the instructions for preparation and presentation of the TNT water, it will be safe to use for both dog handler, dog and the environment.

For detection purposes, the dogs' natural instincts with its search drive and stamina, is working in favour of the mine detection services. One does not need to be a dog expert to appreciate and notice the obvious joy expressed, by a well-trained search dog when performing its task. The connection with the dog handler, building mutual trust, is also necessary to get a god detection team, see Fig.11.

Fig 11. Playing, strengthening the dogs kong (reward) interest and exercise, is part of the preparations.

It is important to give the dog the best possible working conditions and preparations for the task. Then the best detection capabilities will follow. To perform well, the dog needs enough water, food, rest, a clean bill of health, exercise and regularly veterinary controls and caretaking with good kennelling facilities. In Fig 12, a MDD in Afghanistan, is protected from the sun by an umbrella when waiting for its turn to work.

Fig 12. A mine detection dog, protected from the sun.

A dog in poor physical condition or if being ill, cannot be expected to detect landmines. In fact there are some conditions that may have a negative influence on the dog's olfactory capability or even stop it from being able to sense any odours at all. A sick dog is no better suited for working than a sick dog handler. Therefor it is necessary to give the dog a physical check-up before and after, each day of working. The detection capability also needs to be confirmed before the dog starts a day of work – exactly in the same way that an instrument needs calibration and testing before put to use. Each dog organisation, if professional, has standard operational procedures (SOP), to cover the welfare of the dog and also good practise for how to perform and prepare the dog of the search task.

7. PURIFIED TNT

The need and benefits of adding purified TNT as an extra training aid of a MDD, is not obvious for everybody, it is still something up for debate. Initially it means extra work for the trainer, but it pays off in the long run. Hopefully this report will strengthen this statement.

7.1 WHY PURIFY THE TNT?

The reason for purifying the TNT is due to the fact that different manufacturers provides a TNT product that contains different impurities to various concentrations and the impurities are usually more volatile than TNT.

If the dog learns to recognise pure 2,4,6-TNT from the start, the olfactory capability and chance to discriminate the variation of impurities present could enhance the detection capability. The key component that is always there, if the mine contains trotyl, is the 2,4,6-molecule presented in Fig.13.

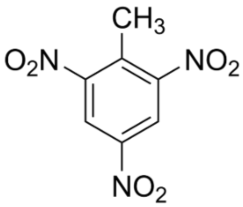


Fig 13. The 2,4,6-TNT molecule

Another way of showing the difference in training the dog on regular TNT compared to purified TNT is presented in Fig. 14. The purified TNT does not leave the dog any option on which part/compound in the odour signature mix it is supposed to respond to.

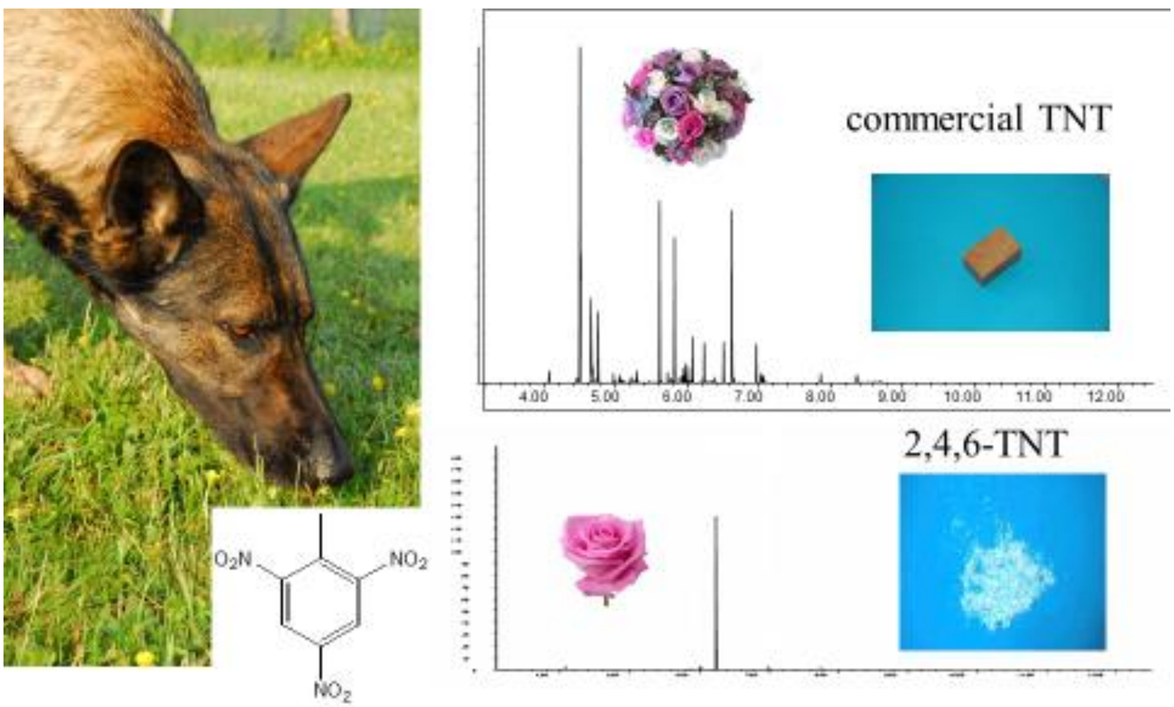


Fig 14. The difference in odour signature when comparing the gas phase above purified and unpurified TNT. Pure TNT is the lowest common denominator of all TNT landmines, and the dangerous (explosive) part.

If a dog is trained on commercial, or military garde TNT, it will get exposed to the more complex odour signature showed in the picture above (the bouqet). This odour signature will also vary over time and depend on the manufacturing process.

7.1.1 PURIFICATION BY AIRING

Crush a piece of TNT or use flaked TNT. The smaller the pieces, the faster the release of the by-products will be and less impurities will remain. Be sure to keep it away from sun light as well as artificial light (lamp light). All types of UV radiation degrades the TNT. Keep it clean during the airing, not directly on the soil, to avoid biodegradation of TNT, induced by the soil bacteria. The longer you leave the commercial TNT out in the open, the better result in terms of pure 2,4,6-TNT you will get. An effective evaporation of impurities will be achieved.

This method of training the dog on mainly 2,4,6-TNT, achieved by airing of commercially available TNT, has successfully been used by the Mine Detection Centre (MDC) in Afghanistan. It has significantly improved the quality and success of their MDD teams deployed in mine clearance, see section 11.2.1.

7.1.2 PURIFICATION OF TNT IN THE LABORATORY

The procedure below describes the purification of military grade TNT into pure 2,4,6-TNT. Most mono- and dinitrotoluenes are removed by a reaction between the military grade TNT in organic solution and sodium bisulfite in aqueous solution. Any remaining contaminant less volatile than 2,4,6-TNT was efficiently removed by repeated recrystallisation from ethanol.

TNT (10 g, NST11 military grade) was dissolved in ethyl acetate (200 ml). This solution was washed with an aqueous sodium bisulfite[13] solution ($NaHSO_3$, 3×100 ml, 5 g per 100 ml solution) in a separatory funnel[14]. The organic phase was dried with magnesium sulfate and concentrated *in vacuo* into an off-white solid.

This residue was recrystallized three times from the minimum amount of ethanol. The ethanol solutions should be heated with a water or oil bath – not directly on a hot plate – to prevent ignition of any spillage. The 2,4,6-TNT precipitated upon cooling.

The crystals were filtered off and dried at 40 °C overnight. It is important to use an oven that is not contaminated with other TNT isomers or by-products from the production. The mother liquors from the latter crystallisations were evaporated into dryness and saved to be mixed with the crude product after the evaporation of the ethyl acetate in the next batch. This procedure resulted in 6 g of fine, needle-shaped crystals.

Any equipment used in the purification – glassware, spatulas etc. – was washed with acetone, which was disposed of according to local routines.

GC-MS analysis (not shown here) indicated that the obtained 2,4,6-TNT is very pure. The only contaminant was an isomer of TNT that is less volatile than 2,4,6-TNT and in such low amount that it was difficult to distinguish from the background noise of the instrument (<1 pg[15]/injection of 1 µl[16]) [10]. Thus, this was not considered as an issue.

[13] If sodium bisulfite is not available, sodium sulfite can be used. Then the pH must be adjusted with acid, for instance one equivalent of hydrochloric acid.
[14] The used aqueous solutions should be sent for appropriate disposal for environmental reasons and not be poured down the drain, as they contain the substances that caused pink water pollution in old-fashioned TNT production.
[15] pg or picogram, is equivalent to 10^{-12}g
[16] µl or microliter, is equivalent to 10^{-6}g

NOTE: The cooling process should be fast, in order to get small, fine, needle shaped crystals of 2,4,6-TNT. Remove the beaker from the oil or water bath, to let it cool down. The smaller crystals have a bigger surface area, which benefits the vaporisation and thus increase the access of the odour when presented to a dog. This is especially important during the imprinting of the dog, on the 2,4,6-TNT target odour.

8. HOW TO USE THE TNT WATER FOR DOG TRAINING

In this section the way of how to use the TNT water for training will be described. A shorter version, but also containing some extra pictures for illustration, will be found in the Annex.

Prior knowledge needed

- Do the basic training according to your normal training procedures.
- The dog has to have a good search system, covering lanes or boxes, with the alertness, focus, intensity, slow enough tempo, endurance and keeping the nose close to the ground – to be able to detect buried landmines.
- It is beneficial if the dog recognises the vapour of commercial (unpurified) TNT and is able to alert or indicate the presence of it, in boxes or lanes. This will make it easier to imprint the purified TNT odour.

8.1 IMPRINTING OF PURIFIED TNT

The dog must be taught a search system before it can proceed to imprinting and other search training, in an effective way. The purified TNT is presented to the dog by evenly distributing the TNT in the container, so that there is much TNT in the vapour phase available for the dog. The container must be closed in a way that contact with the TNT in solid phase is avoided. It should be remembered that TNT is very toxic for dogs. In addition, it can take several exposures before the dog shows a reaction.

Fig 15 a. Dog serching on the carousel

15 b. purified TNT spread out in the container

8.2 PRESENTATION OF THE TNT WATER

When you expose the dog to the TNT water solution the first time, the spot should be large (10-100 ml) and the solution should be warm, see annex 1. Be sure that the water has evaporated before you begin the search, see Fig. 16. If the water has not evaporated, there is a risk that the dog will respond to water spots as well.

Fig 16. Put out the TNT water and let it dry and then let the dog search for the TNT.

<u>Imprinting procedure for TNT water</u>

You can use the TNT water indoors in a sandbox/lane or outdoors in different types of terrain. Load the box/lane by pouring out the start solution, the one with highest concentration, on the ground by taking about 100 ml and spread it out over a circle of 1dm in diameter. Do three circles in the lane to increase the dog’s possibility to find the spot. Pour it out near the ground and not on top of the vegetation, see Fig. 17.

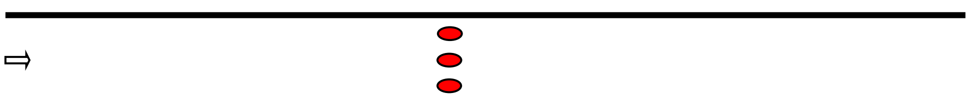


Fig 17. Pour out the TNT water, in different type of terrains, with a syringe. Make sure that it doesn’t lie on top of the grass.

Load with TNT water and other backgrounds/neutrals in lanes.

Amber jar with distractors/backgrounds and TNT water in different concentrations.

Let the solution dry for at least 30-60 minutes to let the water evaporate or soak into the soil. Start the dog search, and if the dog shows some interest in the TNT spot, you shall encourage the dog. Continue the search on the empty lane/box.

If the dog does not show any interest, you can increase the TNT water volume (effectively distributing a larger amount of TNT). Another option is to keep the TNT water warm, dissolving a larger amount of TNT in the water (higher concentration). The amount of TNT in a warmer solution (e.g. 60-80 °C) can be increased up to about ten times. The dogs need some time in order to recognise the vapour of the TNT solution. This time varies, depending on the individual dog and its prior training. An estimate of about 10-15 repetitions would probably work for many dogs.

If it is difficult for the dog to understand what it is supposed to find, it is a good idea to present a training lane prepared with unpurified TNT solved in water. When the dogs respond to the unpurified TNT spot, then go back to the area prepared with the purified TNT solved in water. When the dog is being good at detecting the TNT, and able to discriminate it from background/neutral targets (being other sources of odour that has no relation to the target and should be ignored – the vegetation type of the training area needs to be changed, se Fig. 18.

Fig 18. Search in a box in an open forest

Lane search on grass

When the dog indicates/alert for the TNT water, you decrease the concentration by distributing smaller volumes of it or use a more dilute solution of the TNT water. As described in section 12.1, the variation is important. The different conditions of the training areas will affect the odour signature.

Experience together with sampling and analysis, has shown that the TNT stays for longer time in a forest, compared to an open grass area or sandy soil [9]. The organic content in certain soils and in a moss, seems to have a great ability to adsorb and keep the TNT for longer time. Some options for variation of the terrain is illustrated in Fig. 19. It is also possible to train the dog indoors, to extend the training season for colder climates, if there is access to proper facilities. Since the TNT water is very low in concentration and not considered as an explosive, nor toxic – this opens up for new training opportunities even using more public areas.

Parameters for effective training:

- Increase the time before you let the dog search the prepared area, up to 24 hours.
- You can vary the spot size and spot shape with the water solution.
- Compose your own odours by adding different backgrounds (neutrals) to the solution.
- Make TNT hotspots (high in concentration) in a TNT contaminated area[17].
- Vary the type of soil surface and type of vegetation.

Fig 19 The water solution enables searching in different types of terrain, indoors and outdoors.

When using any training aid, that is not the actual target (a landmine), it adds to the complexity; most notably, it is important to use matched blanks[18] or background samples/neutrals, as part of the training regime. This is important, whereas to ensure that the dog is indeed detecting odours associated with the intended target material, and not some other odour.

The complementary training method presented in this report, use hot (heated) tap water as a solvent for the purified TNT. This tap water is an example of an added odour signature, which the MDD must not learn to focus on. Therefor it is necessary to *let the*

[17] The purpose is to mimic a more heavily TNT contaminated area than usual, in example mimicking the odor signatur of a PMN mine (see Fig. 39)
[18] Matched blank is referring to a sample/object containing **all** the components of the training aid, except **without** the components identical with the real target. A matched blank for TNT water, is the water (without the explosive component, the TNT).

water evaporate, from the 2,4,6-TNT water spot, *before letting the dog search* the area. To confirm that the dog ignores the water, of the TNT water training aid – present also tap water without any added TNT – in the same way as the TNT water, in the search lane.

You can add background/neutral samples for discrimination control, by putting out water samples with just water or other substances dissolved in water, see Fig. 20.

Fig 20. Neutrals or background samples of in example lemon juice or urine dissolved in water

If you use a sand lane or box for training, you can add TNT contaminated sand in distinct spots, thus creating a training area, see next section. Add and remove the TNT sand, varying the positioning in the lane. For indoor training, the contaminated spot will last for over three month.

When you use TNT water outdoors, for training, the ground will remain contaminated for up to two months (but depending on the climate), this being valid for northern Europe. Avoid to train on the same lane for up to three months to be sure no residues of the TNT are remaining. The same degradation process will take place with the TNT water, as in the TNT leakage from a buried landmine.

8.3 OTHER ALTERNATIVES

Here other alternatives of using the TNT water are presented, also in section 11.2.1.

8.3.1 SAND CONTAMINATED WITH TNT WATER FOR INDOOR USE

In order to make a controlled contamination of sand, TNT dissolved in water is distributed in the sand and the water is left to evaporate. This procedure makes it sure that the odour signature is close to the real world conditions (with no added tap water).

If the contaminated sand is left outdoors, the wind and weather will break down the components in the same way, as the TNT released from mines, leaking out in the surrounding soil.

About 30% to 50% of the TNT in the TNT water used, is lost during the preparation of the contaminated sand. The exact amount depends on several parameters, such as how long the drying process was and the surrounding temperature of the environment. Some of the TNT evaporates along with the water, and some of the molecules can be adsorbed to the interiors of a sample tray. If the sample is put it in a jar, the TNT vapours will adsorb to the inside walls of the jar as well, in various extent. The TNT concentration of contaminated sand also depends on the size of the grains of the sand. Smaller sand particles will make up a larger available surface area for the TNT to adsorb onto. Therefore it is advised to use a specific particle sized sand throughout a typical training, e.g. 0.1-0.5 mm particle size.

The shelf life for TNT contaminated sand shows from the experience of practical work and also to some extent on stability studies, that it can be stored for at least a month, as long as it is kept under dry and dark conditions. For longer storage times use aluminium bags and seal them tightly. For a shorter storage time (less than a week) amber (dark) glass jars kept cold and dry are recommended.

8.3.2 USING COMMERCIAL NON-PURIFIED TNT IN A WATER SOLUTION

When preparing TNT water, there is a choice between using the commercial TNT as it is, or purify it by airing/ventilating it, crushing it into fine particles for a faster release and let it be for at least one week. There is no right or wrong here. The variation in training aids will benefit the detection dog, as long as the MDD is also trained on the pure 2,4,6-TNT compound as well, see section 4 and 7.1.

The simplest way of preparing a TNT solution in the field, is to boil some water and pour it over a piece of commercial TNT in a jar. Remove the TNT piece after 24 hour and decant the solution in order to achieve separation from small particles. The concentration of the prepared solution is in the region of 40-80 µg/ml.

Different kind of non-purified TNT gives different components in the solution, depending on what the original TNT contained and it is also influenced on the shape and size of the TNT used; flakes, particles, pieces. This was studied in a GICHD funded project called the Odour Signature Project (OSP) performed at FOI in Sweden.

If you leave the TNT in the water solution you will see an increase of DNT and also other components over time and the solution will also turn yellow after some time and this colour change is easily observed with the eye and it is recommended to discard this solution and prepare a fresh one. The TNT water is stabile in room temperature 20-30°C for at least 1 month, as long as it is kept in a dark jar, avoiding sunlight and lamplight.

9. PREPARING AND STORING OF TNT WATER

The procedure to prepare the solution is described below. The solution will turn yellow with time, when the degradation process starts, and if you expose it to sunlight, the solution will turn red (sometimes referred to as pink water). Measure the pH of the water, to make sure it is in the neutral range, between pH 6-8. A lower or higher pH-value will give stability problems, where chemical reactions of the TNT over time will result in other complex substances.

To get higher concentration of TNT in the solution you can keep it warm (60-80°C) over night and use it while it is still warm. The warm solution can be up to 10 times higher in concentration (up to 600 µg/ml), in comparison with a room temperature solution.
The solution is stabile in room temperature 20-30°C, for at least one month, as long as it is kept in a dark jar, protecting the solution from sunlight and artificial (lamp) light.

9.1 PREPARATION OF TNT SOLUTION

Day 1

- TNT should always be handled with gloves or tools and protective clothing. TNT is toxic and it is important with a high level of hygiene; clean your hands with both soap and warm water in order to wash off any possible TNT.
- Prepare the TNT target liquid using water from the tap. Check the pH value with a pH indicating paper. Drop some water on the pH indicating paper and watch for the colour change. The pH shall be around 7 (neutral), if it is too low or too high it will degrade the TNT solution over time.
- Measure the temperature conditions in the room. The solvability of TNT depends on the used water temperature.
- Take some small amount of purified TNT (or non-purified), and put it in the amber glass jar. TNT crystals or small pieces gives higher concentration.
- Heat the water to around 80°C (avoid boiling water), and pour it into the amber glass jar, until half of the jar is filled with water. Put the lid on and gently swirl the jar.
- Let the jar stand in room temperature for 24 hour, however in order to get higher concentrations, keep it warm, about 60°C over the mentioned 24 h. This has proven to be a method that works. Remember to rotate the jar a couple of times during the 24 hour.

Fig. 21, shows the equipment needed. For a full illustration of the preparation, in pictures see annex 1.

Fig 21. Equipment needed, tap water and a piece of regular TNT or purified TNT, aired (flaked)/crystals).

Day 2

- Remove the piece of TNT from the glass jar after 24 hours by decanting, by slowly pour the solution into a new amber jar, leaving small parts and the TNT piece in the old jar. When the TNT is left in the solution for longer, the impurities will increase in the target liquid over time.

The prepared solution now contains about 20 -100 µg TNT/ml water depending on the room temperature. The solution is stable in the temperature interval of 20-30°C for 1 month, stored in the amber glass jar. Label the jar with content and date of preparation.

NOTE: It is important to prepare and store the TNT solution in brown (amber) glass jars. This is to prevent light from breaking down the TNT. The solution will turn red (called pink water) if exposed to UV-radiation (sunlight, lamp light) se Fig 22.

Fig 22. Do not use UV-light exposed (pink), store TNT water in labelled and amber jars.

The light will destroy the TNT solution over time. Old solution will turn yellow.

9.2 DILUTE THE SOLUTION

A start solution (with highest possible TNT concentration) diluted 1:10 means the mixture contains 1 part TNT start solution and 9 parts of water. Use warm water for better solvability.

Dilute 1:10 take 180ml water and 20ml TNT start (saturated) solution
Dilute 1:100 take 198ml water and 2ml TNT start (saturated) solution
Dilute 1:1000 take 180 ml of water and 20 ml of the 1:100 TNT (previous) solution

The start concentration is around 20-100 µg TNT/ml. To get the same concentration as above the buried mine, the concentration needed is about 0,1µgTNT/ml. So dilute the solution up to 1000 times.

9.3 CLEANING OF EQUIPMENT TO AVOID CROSS-CONTAMINATION

This method describes how to clean equipment (glass and metal) that has been contaminated with TNT solution, in order to minimise cross-contamination.
You need hot water and a capped bottle with acetone (acetone bath) and thick gloves. Reserve a special room with good ventilation, or a place outdoor where all cleaning is performed. Make sure you never prepare any samples in this cleaning place/room.

- Always use gloves for protection when acetone and explosives are handled.
- Remove all visible dirt, explosives etc. from the equipment and clean everything with hot water.
- Put the equipment in the acetone bath and soak it for at least half an hour. If you are indoors, make sure the lid is on, or you will have acetone steam released into the whole room.
- Take up the equipment and wash it in hot water
- Let the equipment dry and put it back in the user box/preparation room.

Use the acetone in the bath until its yellow, then discard the acetone by incineration or other ways for destruction.

An alternative for cleaning by soaking the equipment, is to carefully clean with acetone using an acetone soaked rag/paper followed by wiping clean the equipment. Throw the rag after cleaning.

9.4 HOW LONG WILL THE TNT CONTAMINATED SAND LAST OUTDOORS?

In order to understand how long the TNT sand is useful for dog training, FOI made some stability studies. Samples were taken from the prepared spots in order to see how and if, the concentration changed over time. Temperature and humidity (RH) were logged during the experiments. The test dates for the experiments were between June 6th to August 20th, in 2007. Samples were also taken in the edge of the box in order to see how much the spot was spread out. The samples were taken on the surface and 2 cm down in the soil, where the spot was distributed.

The stability of TNT over time in the ground depends on many things like temperature, soil conditions, humidity etc. The bacteria in the soil will also break down the TNT. In Figure 5, annex 3, the loss of TNT concentration over time is illustrated. It is quite interesting that regardless of the starting TNT concentration, analysed after the preparation of the sand, the concentration of the TNT after one month are equally low for all three of the sand batches.

10. PROOF OF CONCEPT BY SAFDTC

In this section the FOI and SAFDTC research and results will be presented in summary.

10.1 RESULTS AT SAFDTC- 2007-2012 [5],[7],[8],[9]

The project started together with SAFDTC 2007 and ended 2012. The purpose of the research was to investigate the possibilities to increase the efficiency of mine detection dog (MDD) training and the quality of MDDs and was based upon the theory and findings presented in section 4. The most common explosive in mines and in MDD training is military grade TNT (MTG TNT).

The project objective was to investigate if dogs trained on pure 2,4,6-TNT were able to detect military grade TNT, without prior training. Another task was to see if these dogs showed an interest in landmines. If the project was successful it would open the possibilities to make the training more efficient.

The proof of concept of the complementary training method is based upon FOI research and validated by the SAFDTC MDD teams. It is illustrated in pictures presented in Fig. 23. The number of research MDD teams might not seem impressive, in a statistical evaluation aspect, but this type of resources are costly. Having dedicated fresh[19] dogs and staff reserved for all the work that needs to be done.

[19] A fresh dog refers to a dog that has no prior experience or education as a search dogs.

Fig 23. This picture illustrate the whole research period of the complementary training method

- Siw and Jörgen (SAFDTC) started in February 2008 with Bossa and Baxa
- Siw and Anni (ING 2), Bossa and Baxa at NPA GTC[20] in Bosnia, May-June 2009
- Per Lindgren (SAFDTC) with Derby, Dwight, Duni and Daim, in 2010
- Per Dimsjö (Amf 1) and Duni, in 2011

When working together with the SAF there is often a rotation of staff, with possible disruption of ideas but also feeding the project with new fresh perspectives. In this case, the proof of concept grew stronger, when different trainers with different backgrounds participated over the years, all with good results. Some of them had no prior experiences of mine detection dogs.

There was also a reference group at Göta Engineers, ING 2, with Anni, Michelle, Helén, and Annika, and the dogs Acca and Basse, see the picture in the upper right corner of Fig. 23. The reference dogs were only trained on military grade (MTG) TNT and had never been trained on purified TNT. External advisors for these projects were, Conny Åkerblom and Bertil Ljungqvist, at the time being GICHD consultants.

The purified TNT water, described in this report, was used for the training of the six dogs. First they learned a search system, indicating and discrimination at the carousel and in lane search. To do this, a Kong (red rubber toy) was used as training aid. When the dog could find the Kong, cut in smaller and smaller pieces, it was trained to find the pure TNT, see Fig. 24.

[20] NPA GTC is the Norwegian Peoples Aid in Bosnia

Fig 24. Training to search, at the carousel and in lane search, using small pieces of the rubber kong.

A test was performed to see if the dogs showed an interest for a water solution with military grade (MTG) TNT and mines in a lane. One of the two dogs showed an interest for both water solutions with MTG TNT and mines and the other showed an interest for the MTG TNT water, but not for the mines. A similar test was performed using the carousel with TNT contaminated sand, with MTG TNT and with pieces of mine shells. Both dogs indicated for all the targets. These results show that dogs trained on purified TNT can recognize the smell of TNT in a new odour signature.

The first part of the project ended by sending the dogs to Norwegian Peoples Aid Global Training Center (NPA) in Bosnia 2009, with Siw Rüdén who had been training the dogs from the beginning and Anni Båth. They spent five weeks there, training on TNT water detection and discrimination, using a variety of background samples. At the end of this period, the dogs were tested.

10.1.1 Results from the testing of Bossa and Baxa, in Bosnia

The tests were set up as blind tests, where the dog handlers did not know the position of the targets, beforehand. Blind tests were used for all tests performed during the whole research period. Both dogs indicated or showed interest in mines and water solution of different types of military grade TNT.

10.1.2 Results from the training and testing of Derby, Dwight, Duni and Daim

From April until October year 2010, four new dogs were trained at SAFDTC, by Per Lindgren. The result of the training was that the dogs could find and indicate purified TNT crystals and water solutions of purified TNT positioned on the ground. The spots from the water solutions were dried up to 4 hours before the search.

When tested, one of the dogs spontaneously[21] indicated for one mine, and the other three dogs showed an increased activity, like stop and sniffing a bit extra or lie down by the mines, at several occasions.

[21] Spontaneously meaning that the dog was only trained on TNT water, was searching a lane with a buried landmine (blind test) when it chose to indicate the mine, without prior training or reinforcement by any type.

In the autumn the TNT concentrations in the air above the TNT water spots, were at the same TNT concentration levels measured in air over buried mines. The dogs seldom or never, reacted/indicated at backgrounds as objects, other solutions or different changes or disturbances of the ground. The method was perceived as easier for teaching the dog to search on the ground and getting it to find and indicate buried mines.

In summary;

- After seven months of training all the dogs had fulfilled all the practises planned and trained to an authentication in a mine lane placed on the SAFDTC training area.
- Search in short and long leash along a rope on the ground up to 10 meters.
- Search four boxes of 8x8 meters in a row without resting.
- In its search system, find and indicate a water solution of 2,4,6 TNT or military grade TNT, after waiting up to four hours after the positioning on the ground.
- This training method led to that the dogs could find and indicate crystals and water solutions of purified TNT, positioned on the ground. The spots from the TNT water were dried up to 4 hours before the search.
- The concentration of the water solutions of TNT used was between 1-100 ng/ml[22] and the TNT water volume used on the ground ranged between 2–20ml.
- The dogs seldom or never, reacted/marked at backgrounds as objects, other solutions or different changes in the ground.
- At the verification (blind) test, one of the dogs spontaneously indicated one mine, three of the dogs, at several occasions, showed an increased interest like stopping, sniffing a bit extra, or lie down, over the buried mines.

10.1.3 Results from continued testing and training of Duni

In 2011 FOI wanted to try to include a validation of a research dog, according to an accreditation standard. The previous four dogs were however no longer stationed at SAFDTC. Upon a request from FOI, SAFDTC managed to get one of the dogs back, Duni, trained April-November in 2010 by Per Lindgren. There were no DTC staff available, so Per Dimsjö, from an amphibious battalion, Amf 1, came to help out. He had never before trained a MDD, and he started the training with Duni in March and outdoors in April 2011.

He used the TNT water for training and then continued the training over buried mines. The dog showed interest, but did not indicate any of the mines. To help the dog, the TNT water was used for reinforcement. A few drops of TNT water was placed on the ground above 10 buried landmines. Duni now indicated six of them and showed interest for the other four, without an indication. The training continued on buried mines, of four types. Using the TNT water for reinforcement for a couple of days.

[22] ng/ml is equivalent to (10^{-9})g/mL

After that training on buried mines, without any added reinforcement was performed in May 27th to June 15th in 2012. During this period Duni searched over 52 mines in total and indicated 46 of them (88 %). A test ”Explosive Detection Dog Accreditation Sudan” Operations SOP 1.2, was performed in June 21, 2012. Pictures from the test are showed in Fig. 25.

Fig 25. Duni and Per Dimsjö, training and tested in wood and meadow terrain.

For the accreditation test, four boxes with seven buried landmines was used.
The results of the first accreditation test was:

- Duni indicated 11 times. The indication closest to a mine was 1.25 m away from the landmine.
- SOP: Indication must be within 1 m from the mine.

After the test: Air samples were taken from three locations where Duni indicated and samples above three of the mines. They all contained TNT ranging from 1-3 picogram TNT (10^{-12}g)TNT/liter of air. The days before the test, we had 30 mm of rain.

After their summer holiday, Per and Duni trained for one week, beginning the 23rd of August. Then a new test was performed:

- In the 2 boxes in forest terrain (soil with moss, high in organic content) Duni alerted all 3 mines within 1 m and 2 false indications (50% allowed).
- I the 2 boxes on the meadow, the alerts were 1.3 m from one mine and more than 2 m from the other mine.

Results improved by 50%, but still no certificate. At the test in September, the concentration above the mines ranged between 100-3000 pg TNT/l of air, where Duni indicated. The concentration of TNT was significantly higher in September compared to June. This is in accordance with our experience. Background concentrations (in soil far away from nearest landmine) in the boxes ranged from 1-600 pg TNT/l air.

10.2 Final remarks on the SAFDTC proof of concept

Bossa and Baxa became operational in a humanitarian demining environment, stationed in Afghanistan in the proud and gentle care of Zainuddin Shamsuddin, head of the dog trainers at the MDC in Kabul, Afghanistan.

The research and work presented in section 10 resulted in new SAF guidelines for education and training of mine detection dogs.

The latest of the dogs trained at SAFDTC to become a MDD, was FM (SAF) Faxo, in 2012. The training begun with 2,4,6-TNT, but when the dog did not respond to the odour the training aid was shifted to military grade TNT. The training continued outside on the ground with MTG TNT water. Then it was replaced with 2,4,6 TNT water and now the dog started to respond to, and indicate for the purified TNT. The training was completed at the training area with buried landmines. Faxo there chose to indicate the first buried landmine (laying at a shallow depth) it was encountering when searching in a lane. It was a proper indication, sitting down (oral reference by Martin Johnson, SAFDTC).

11. PROOF OF CONCEPT BY OTHER ORGANISATIONS

The use of TNT water for dog training, when access to training areas of buried landmines are limited, is not a new concept. Alan Sims from the DBOX end user group, kindly brought attention to the fact that Karenswood Ltd had been using this tool already in the late 1980´s. Alan has also submitted the text in 11.1.

11.1 KARENSWOOD Ltd

Although Karenswood[23] (International) Ltd, had conducted many research and development projects relating to a variety of other substances and for different purposes it was the hydrocarbons project that spawned the idea of contaminated water solution (primarily relating to regulated narcotics substances).

It was during the late 1980s and early 1990s that movement of cattle throughout the UK was prohibited and human access to agricultural land severely restricted. BSE, commonly known as mad cow disease, is a transmissible, neurodegenerative disease affecting cattle. When BSE was first diagnosed in cattle in 1986 it was a novel disease and risk assessors did not possess adequate scientific knowledge about its epidemiology or pathology to confidently evaluate what sort of risk it posed to animal or human health. These restrictions prevented Karenswood (International) Ltd from accessing its established Land-mine training sites. Further, and for the same reasons, Karenswood was not able to construct new training areas for land-mine detection. This was a serious blow to the organisation's humanitarian and commercial interests. Something had to be done - and quickly. TNT contaminated water allowed the company to create training sites on areas of private land and also on land to which the public had access (text kindly submitted by Alan Sims, Karenswood Ltd.).

11.2 MDC IN KABUL, SUPPORTED BY GICHD

The Mine Detection Centre (MDC) in Kabul, is another example of an organisation using TNT water for training of MDDs. With the support from Conny Åkerblom and Bertil Ljungqvist, they have found a way of using the method, preventing them from being hindered by the acute security problems in their country.

[23] Karenswood (International) Ltd is the oldest organisation of its kind in the world and this year (2016) the company celebrated its 63 rd year. It was in the early 1960s that Karenswood first trained dogs as hydrocarbons detectors, and it was at the beginning of the 1980s that Karenswood conducted a research and development project designed to evaluate the competency of the trained dog to locate oil leaks in underground high voltage electricity cables.

11.2.1 THE USE OF TNT WATER IN SOIL PUCKS AND SOIL PELLETS

The FOI degradation studies described earlier, shows that the 2,4,6-TNT concentration in contaminated sand, quickly drops down to a very low level. Usually there are no detectable concentrations left in the sand, after 40 days (see Figure 5, in annex 3). The TNT in the purified TNT-water, soaked into the ground, also disappears rather fast, compared to the slow and continues TNT release from a buried mine. It seems that the weather and temperature is crucial for how long time it remains in the air phase above the place it was poured out.

GICHD, (Conny Åkerblom, project manager and Bertil Ljungqvist as technical advisor) has developed a new way of training the MDDs, after inventing a new way of presenting the purified TNTwater. They did it together with the Mine Detection Centre (MDC) in Kabul, Afghanistan. The goal was to find a way for keeping the TNT concentration in the training area for a longer period.

Local soil was contaminated/spiked by a water solution of TNT, purified by airing. Thereafter the TNT contaminated soil was pressed in a machine, under heavy pressure into hard soil pucks. The analysis of the 2,4,6-TNT content was done by FOI, in early 2010. The levels of explosives in the pucks varied with the number of times the soil was contaminated and the TNT concentrations of the water. The soil pucks, pellets and tool for manufacturing them, are shown in Fig. 26.

Fig 26 Soil puck and pellets, containing purified TNT water and local soil, produced under high pressure

The puck was put back in the training area, buried and slowly releasing TNT, mimicking the explosive leakage from a buried trotyl containing landmine, see Fig 27. The soil pucks was also broken in smaller pieces, for hides or to vary the concentration of buried TNT. Smaller pellets of local soil and purified TNT water was also developed and used, for variation and convenient handling. The pucks and pellets were stored outside, in the shadow. Stores with different manufacturing date of pucks and pellets, and containing higher and lower concentrations of TNT, was kept – to get variation in the odour released and in the MDD training.

Fig 27 Soil is removed, the puck is produced and the puck is placed back where the soil was taken.

Pucks and pellets were also contaminated with only water, to be used as neutrals or backgrounds. In this way the dog can be taught to discriminate/ignore the pucks and pellets without any TNT in them. This is a way to make sure that the dog does not search for the soil puck/pellet with water – only searching and indicating for the 2,4,6-TNT content. For variation in training, pucks of different soil types was produced, see Fig 28.

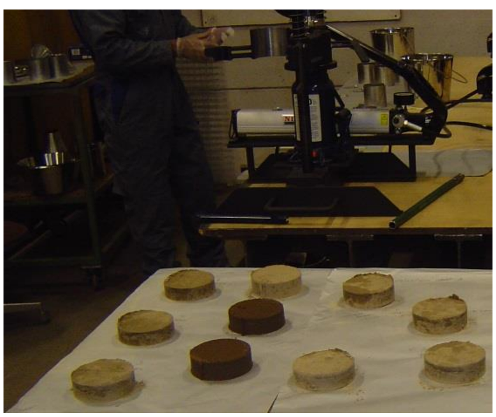


Fig 28a. Pucks of different soil types.

Fig 28b. Tools for producing the soil pellets.

Maybe this method of using purified TNT in their training targets is especially important in a country so heavily contaminated of commercial TNT as Afghanistan. The improved detection quality was clearly demonstrated when revisiting supposedly cleared areas, finding and clearing many remaining buried landmines (oral reference from Bertil Ljungqvist). This improved way of training and resulting detection performance may have saved a lot of civilian's lives.

12. WHY THIS TRAINING METHOD IS COMPLEMENTARY

There will always be a need for *variation* in the education and training of the MDD, to teach the dog to *generalise* and indicate as many types of landmines as possible. For that reason it is good to also use TNT water, made out of commercial flaked TNT or from a piece removed from a landmine, to train the MDD on. The access to real targets, which in this context are real buried landmines, will always be necessary from time to time – to confirm that the training of the detection dog is working. There will still be a need for IMAS[24] certification for quality assurance (QA) of operational MDD teams.

12.1 VARIATION, GENERALISATION AND REAL TARGETS TRAINING

The Fig. 29 is a picture from a study illustrating why variation in training of Explosive Detection Dogs, EDDs, is so important, for the dogs ability to generalise [4]. This is of course also valid for a Mine Detection Dog. In the study there were six dogs, only trained on military flaked TNT. The six dogs showed a detection rate, correlated to the trained target, of nearly 100 %. When the same six dogs were tested on TNT of different origin; Canadian TNT, Chinese TNT, ¼ lb Demoblock, Landmine Block, ¼ lb Demoblock Pellets, the detection rate was very low. The response of the dogs "Alerts to Probes", in red displays the probability of responding to the other types of TNT, in Fig.29.

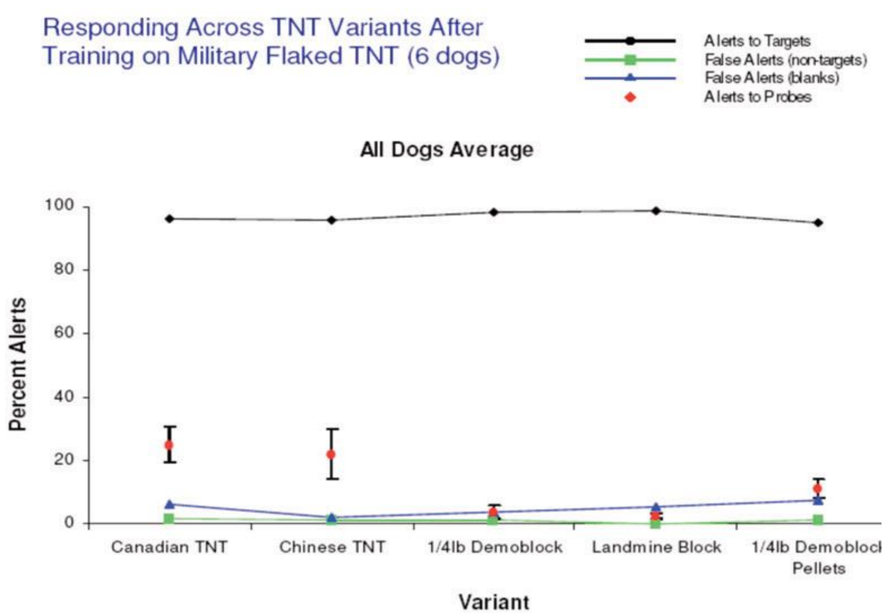


Fig 29. This Fig illustrates the danger of only training an EDD on one single target.

This clearly demonstrates the danger of only using one single target (type of landmine) or training aid (TNT of the same type and origin) and expecting the dog to be able to generalise and detect also the types of TNT or landmines it has not been training on.

[24] International Mine Action Standards

A Mine Detection Dog only trained on 2,4,6-TNT crystals should probably be equally bad. When presenting it solved in water and soaked into the soil, before training the dog is better. The degradation of TNT starts when released into the soil, and the degradation products of TNT mimicking the process around a buried landmine, will give a broader spectra of compounds presented to the dog. Regardless of this fact, the TNT water solution is not meant to be the only tool for training of the dog. This is why it is called a complementary training aid, since there have been misunderstandings that this tool equals training without using real targets, landmines.

Worth noting though is that using the TNT water in training seems to make the transition from detecting TNT, transported with water, to finding buried landmines easier and faster. The SAFDTC staff reports that it was sometimes difficult to teach the dog to shift from detecting buried mines, when being trained on soil surface contaminated with a piece of TNT.

13. BACKGROUND STUDIES

13.1 MIGRATION OF TNT IN DIFFERENTSOILS, [1],[1]

Over the years FOI have performed extensive research efforts studying the leakage of TNT from different landmines, in a large variety of soils and storage conditions. In order to use biological sensors for the detection of mines, in this case dogs, there must be chemical compounds available in the vapour phase that the dog can detect. In this section some selected results are presented, to exemplify some of the findings and conclusions.

FOI have analysed soil samples from different parts of the world, and from different types of mines, to study the gas phase above a landmine and its chemical signature. Parameters of influence for the vapour image are related to soil conditions, the shell of the mine as well as the surrounding environment and climate.

One observation made, is that a dense material, like clay or laterite seems to retain more of the various components than other coarser material, like sand. Another observation in the many experiments conducted within this project, was that during the winter the leakage of the explosive substance from the mine appears to stop. Also, in springtime the levels are considerably lower than during the autumn. Furthermore, heavy rainfall depletes the soil of explosive substances, and it can take many weeks before the explosive and related substances are present in detectable levels at the ground surface.

In Figure 30, results from the concentration of TNT in the soil for spring and autumn conditions in Sweden are shown.

TNT and ERCs in clay from FOI test site, expressed in concentration of ng/g in dry soil

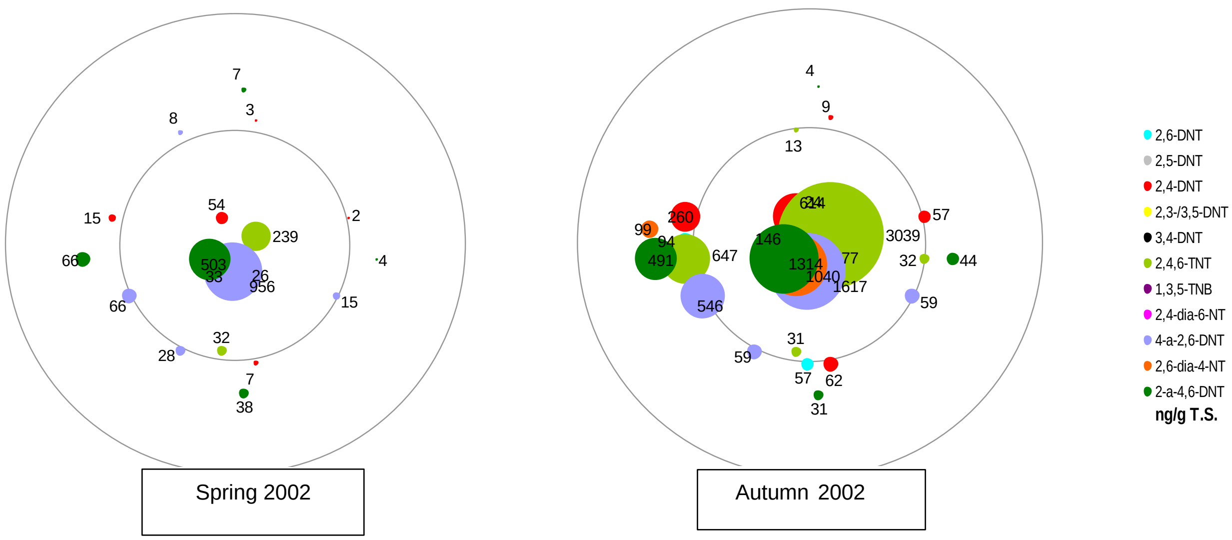


Fig 30. During the autumn the concentrations over the mine is higher than in the spring. The size of the color dots relates to the concentration. Bigger dots means higher concentration.

When mines are buried in the soil a complicated process starts. TNT and its explosive related substances (ERCs) transfers to the soil through leakage or diffusion through the material of the casing. Diffusion takes place at different speeds depending on the casing material. If the casing is made of rubber, the molecules diffuse about 30 times faster than through, for example, hard PVC plastic. The temperatures in the ground affect the diffusion, which is five times faster in water than in air.

If the casing is made of metal, there is no diffusion through it. The leakage occurs instead through joints, cracks and voids in the casing. If the casing is painted with a paint containing polymers, the color is probably contaminated with explosive substances from storage, transport and handling. This contamination will disappear after some time because it is not replenished by diffusion of explosive through the metal.
Chemical molecules from buried mines distributes themselves between the soil particles, the water in the soil and air above of the soil. Soil moisture is very important for this complex process. It has been observed that dry soil absorbs more explosive related compounds, ERCs, than moist soil. When the soil becomes damp by dew or rain, it will release the molecules from the soil particles. The heat from the sun will start evaporating the rainwater and the dew, giving a dog optimal detection conditions. The released molecules, will be carried with the moisture to the soil surface by evaporation. The TNT and ERCs found in the object's immediate vicinity must come up to the surface and into the air layer, closest to the ground surface, to become available for an air sampler or a dog. One can also speculate that small particles with adsorbed compounds on the

surface, can be sampled in the dog's nose, where the moisture releases the molecules to the olfactory receptors.

Several processes contribute to the transport, diffusion and convection. Diffusion is the movement caused by differences in concentrations between different sites and depths in the soil and in the air and water phase in the soil. Both the air and water contain molecules of TNT and ERCs. Convection is when rain has brought water down into the soil or when the water evaporates from the soil surface. Movement in the soil caused by winds and atmospheric pressure allowing the air phase to move up and down in the boundary layer between the ground and the air. If the soil temperature is higher than air temperature the boundary layer becomes unstable and molecules are diluted. If the temperature of the ground is lower than in the air, the molecules are drawn into the boundary layer.

13.2 THE DEGRADATION PROCESS

FOI test field consisting seven boxes with seven different soil types to conduct migration studies of TNT that leaks out from a buried mine, TRPM 10. Soil samples from various soils are collected and analysed by using the method that is designed for the extraction of the soil sample. Analysis was done with GC and the results have been verified by LC-MS.

There are different types of processes degrading the TNT. These are biological (in soil), chemical or UV-radiation degradation processes, see Fig 31.

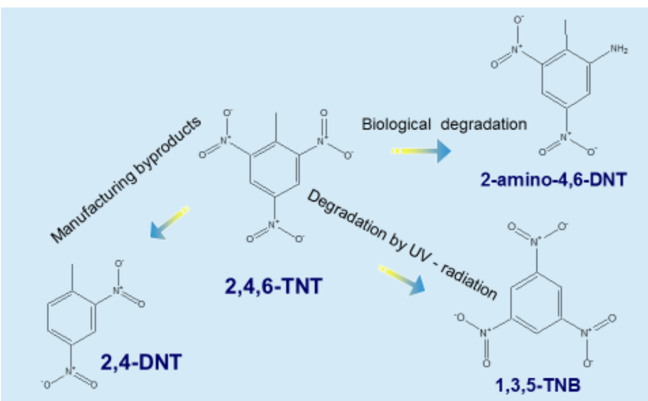


Fig 31. TNT and examples of its ERCs, explosives related compounds

Analyses performed on soil samples taken after a year indicates TNT, 2.4-DNT and amino-compounds in all soil types. The amino compounds, 4a-2.6-DNT and 2a-4.6-DNT are produced by biodegradation of TNT in the soil. These compounds are water-soluble and can be carried away by rain and melt water. The analysis of soil samples taken after a year showed that the concentrations of TNT were highest in clay and magnetite. The following years, the concentration decreased in all samples. The amino compounds, 4a-2.6-DNT and 2a-4.6-DNT were found in all soil types. In laterite the 2.6-dia-4-NT were detected in higher concentrations than in other soils. After the winter period, however, the levels of all the compounds sunk.

The conclusion so far is that TNT is converted to amino-compounds and flushed away by rain and melt water. Later testing found levels of explosive substances sporadically over and around the mines. There were always higher concentrations in autumn than in the springtime. The overall trend is that TNT and ERCs are detected in highest levels just above the mine. Next to the mine is the presence of TNT-related compounds significantly lower.

In clay, the detected concentrations of TNT and related compounds are much higher than in other soils (up to a factor of 10 higher levels). It is reasonable to assume that the surface area of clay is very high. This should mean that the clay can adsorb larger quantities of TNT and related compounds (per gram) than other soil types. Other soils will rapidly be saturated with TNT and related compounds. The non-adsorbed molecules will sublimate into gas phase during the warm period of the year.

In FOI´s test field, buried mines (without the ignition device, but sealed) have been studied. Soil samples around and downhill from the mines has been taken and analysed with respect to TNT and related compounds. The compounds in Figure 32 are marked by color codes and the numbers indicate the concentration of that compound, in ng/g dry soil. The colored areas do not specify the exact position where the compounds are detected but rather the area where it was detected, relative to the mine.

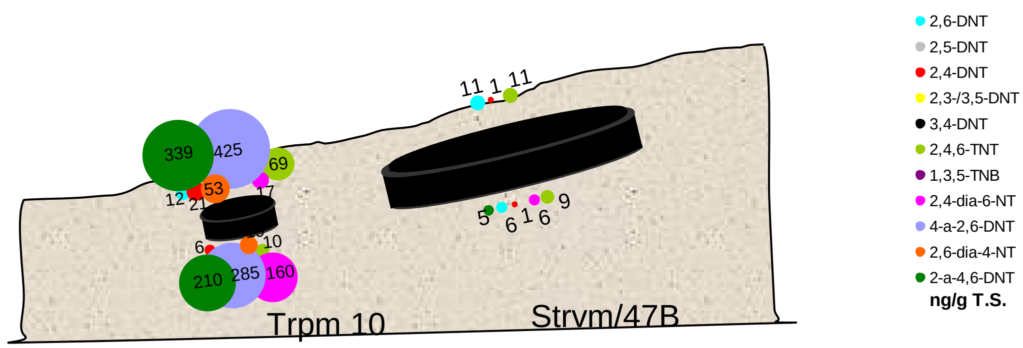


Fig 32. The concentration around mines with different type of mine casings

The Trpm 10 (anti-personnel mine, AP) contains 110 g of TNT and the Strvm/47B (anti-tank mine, AT) contains 5,5 kg of TNT. The amount of explosives in the mines does not correlate to the amount of explosives leaking out to the surrounding soil.

From a MDD perspective it is much more difficult to detect the AT mine, even though it contains several kilos of TNT. It is easier for the dog to detect the AP mine, compared to the AT mine. The explanation is revealed in Figure 32, where the leakage from a small AP mine generated significantly higher levels of TNT, 2,4-DNT, as well as the biological degradation products (the amino compounds). The shell of the Trpm 10 is made of plastic and the mine shell of the anti-tank mine is made of metal. The described patterns of migrant associations from these mines, clearly shows the benefits of combining different detection techniques, in this case a mine detection dog and a metal detector or ground penetrating radar (GPR).

The odour from the mines are influenced by the soil, climate, buried depth, time factor, manufacturer and type of mine etc. Thus, the vapour image that the dog percept will vary accordingly. Sampling above a mines and over a above buried mine is shown in Fig. 33.

Fig 33. Air samples over different types of mines shows different explosive related signatures

The air sampling verify that there is something to detect for the dog. A filter on top of the cone collect explosives and ERCs and small particles. The filter is then analysed at the laboratory with a GC-MS. The GC-MS presents a chromatogram with the different substances, see Fig. 34. The two chromatograms below show different amounts in concentration and different odour composition over the two buried mines.

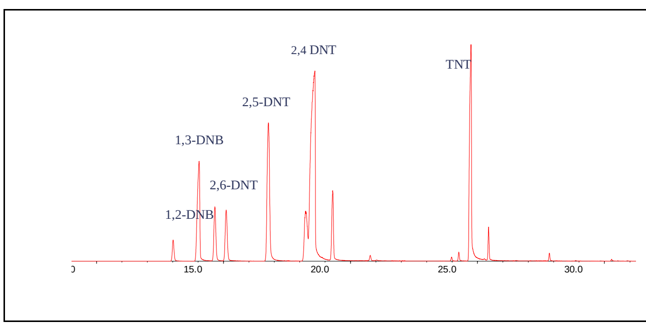


Fig 34a. Signature of TMA 3 mine

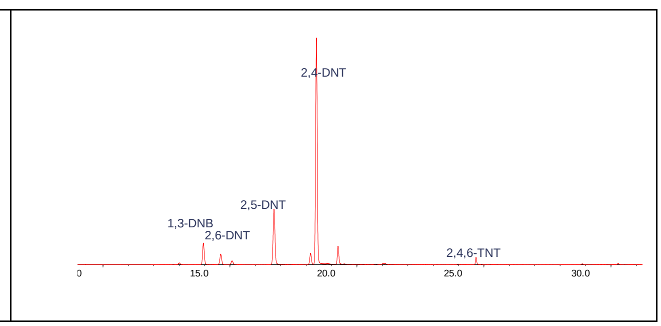


Fig 34b. Signature of TMA 4 mine

13.3 RESULTS FROM FORMER OSP PROJECTS SPONSORD BY GICHD 2006-2008

Here the results from the OSP project, together with GICHD are summarised. The objective of this project, was to try to produce a water solution that contained all ingredients found in a mine, mimicking the complete odour signature of it, for MDD training.

13.3.1 METHOD FOR PREPARATION OF THE TNT WATER SOLUTION

Aqueous TNT mixtures are made in various concentration ranges, depending on how much TNT is dissolved into the water. This depends on the water quality parameters, such as acidity, time, temperature and agitation (stirring) etc. All parameters mentioned will probably affect the composition of the TNT/water mixture as well, as well as its stability. Normally, TNT is dissolved into hot water, because this improves the solubility of the TNT, resulting in higher TNT-concentrations. The TNT/water solution must not be exposed to light, so light-proof plastic bags or jars will have to be used for storing TNT solutions or TNT-spiked samples of sand. The concentration of the solution varies between 50-100µg/ml water. The solution is stabile up to 4 weeks in room temperature, as long it doesn't turn yellow.

13.3.2 AGING STUDY OF SAND CONTAMINATED BY TNT WATER

500g spiked sand were prepared. All samples are dried in room temperature (22°C) in a dark room. The sand is stored in dark glass jars with lid in 3 different temperatures and the temperature is logged during the storage stability test. The sand grain size is <0.5mm. The sand is analyzed after 0, 1, 10, 30 and 90 days of storage.

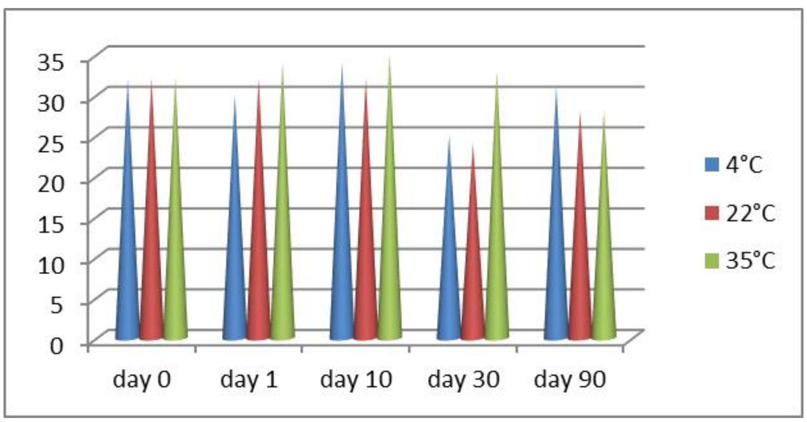


Fig 35. Storage of contaminated sand in different temperatures.

All TNT concentrations of in Fig 15 are in ng (10^{-9}g)/g dry sand and the average concentration of three samples. The concentration corresponds to the height of the peaks in the Fig 35.

13.3.1 THE USE OF A DUMMY DISK TO MIMIC A MINE

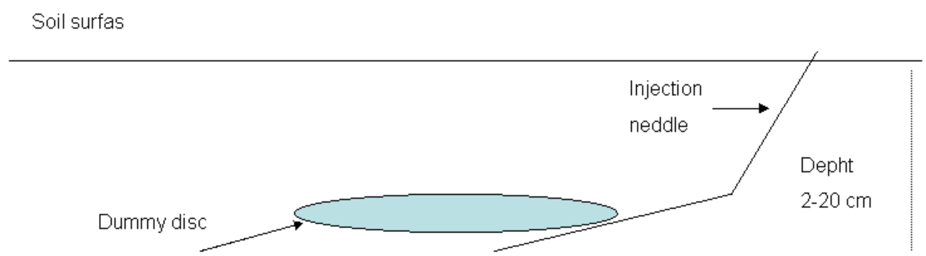


Fig 36. Dummy disc preparation

The disc shall be buried at a depth of 2-20 cm. The disc can be of rubber, plastic, metal and shall have a diameter of 5-15cm. The solution is then injected under the dummy.

During the summer 2006 FOI buried a couple of dummy disc and injected TNT water solution under the disc. The soil over and around the disc were sampled over time to see the migration of the TNT. The depth of the disc was between 2-20 cm and samples were taken during two weeks.

The purpose was to see if we could use the buried disc with TNT solution instead of real mines. We got the same pattern of TNT around the disc as the one we have seen around real mines. The TNT quickly disappeared to nearly undetectable concentrations and it was no differences between injected high concentrations and lower ones.

13.3.2 WATERBASED EXTRACTION OF MINE CASES

Pieces of plastic mine cases from three different mines has been used as starting materials: PMA-1A, PMA-2 and TMRP-6. In an attempt to maximise the concentration of dissolved case material, four different conditions have been examined; the samples have been boiled, subjected to microwave treatment, stored in water solutions 25°C and at 75°C. Approximately 1.5 g of plastic material has been used at each experiment. The mine case materials were washed in water before the experiments.

The results showing the extracted compounds are different depending on extraction method and mine shell composition, example is presented in the chromatograms shown in the table below. The mine shell is stored in 75° water for two weeks.

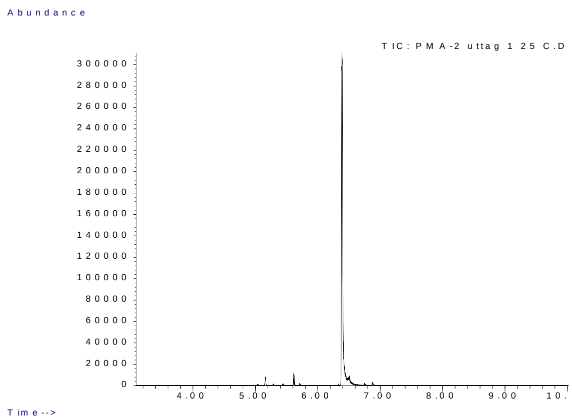


Fig 37 a PMA-1A

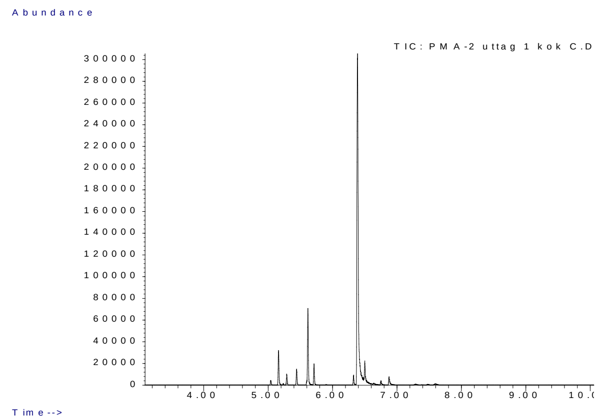


Fig 37 b TMRP-6

13.3.3 EXPLOSIVE COMPOSITION OF LANDMINES

The explosives from 15 different mines were dissolved in methanol and added to SPE columns in order to facilitate the transportation to FOI. The explosives delivered by the GICHD to FOI have been analysed by LC-MS. The results showing the bulk explosive components are presented in Table 1 for all of the analysed samples.

Table 1. Different mine types and its contents

Marking	Country of origin	Explosives
P3-MK1	Pakistan	TNT
No-4	Israel?	TNT, RDX
P4	Pakistan	Tetryl
P2-MK3	Pakistan	TNT
US Claymore	Egypt (USA?)	TNT, RDX
YM-11		RDX
YM-3		TNT, RDX, some HMX
TM-57	Azerbaijan	TNT, RDX, some HMX
YM-18		RDX, trace of pentyl
PMN	Azerbaijan	TNT
TC-6	Italy	TNT, RDX
TC-2.4		TNT, RDX
TM-62-P3		TNT, RDX
Type 72	China	TNT, trace of RDX
PMN 2	Tjetjenia	TNT, RDX

13.4 GICHD AND THE MINE DETECTION CENTRE IN KABUL

13.4.1 RESULTS FROM DOG SEARCH AND SOIL SAMPLING IN AFGHANISTAN

The samples were taken after the dog had search an area, trying to sample the spot where the dog had indicated. These were hits, where the dog found the mine and on false indications and missed mines. Background samples were also taken at the site. The soil samples taken for analyses were the topsoil on the surface. An example of the result of finds, misses and false indication is presented in the map of the box.

Fig 38. Soil samples taken by FOI, at MDD training and IMAS certification test site, 20 km from Kabul, Afghanistan

In Fig 39 and 40 the results of some of the soil sampling and analysis are displayed. The sampling was done immediately after the dogs had finished the search. There is a great source of error in this procedure, since the location of the dogs indications could not be marked inside the box, just using points of reference marked outside the boxes.

The soil samples taken over the false indications were all containing TNT with concentrations in the same levels as were found in the tests background (background sample contains 0.5-3ng/g soil). Generally all samples contained low levels of TNT and only three samples had high concentrations of TNT and related compounds.

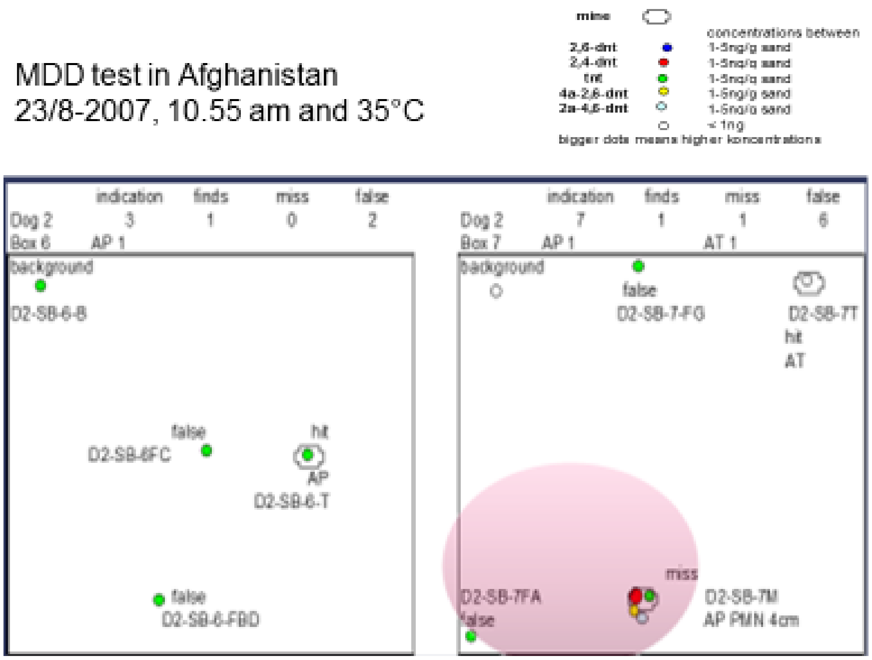


Fig 39. Dog search In Afghanistan 23/8-2007, 10.55 am and 35°C

The testing was an IMAS accreditation test and therefore the sampling could only be done, after the test was finished.

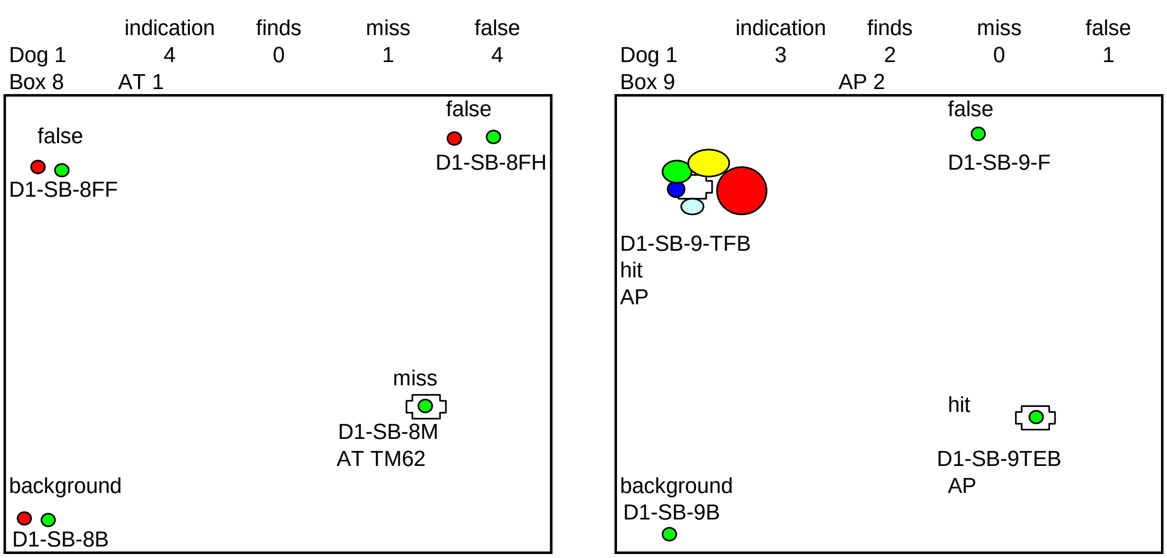


Fig 40. Dog search In Afghanistan 23/8-2007, 10.55 am and 35°C

It is common knowledge that in Afghanistan, a soil sample often contains grains of TNT. This was also verified when a soil sample taken from a plant pot, outside of a hotel, was analysed and revealed a content of TNT. We cannot exclude the possibility that there were TNT available for the dog that was not collected in the sample. That dogs finds and indicate for mines where we don't find detectable levels suggest that the dogs put more things into odour picture than only the explosive substance.

We know today that the available levels in the air phase of a soil sample over a mine do not contain the same components as the soil sample. The more volatile substances are present in higher concentrations in the air phase than in the soil phase. In Figure 41 this is demonstrated, where two graphs are presented that shows an example of how the concentration of TNT in soil samples and in collected air samples differs.

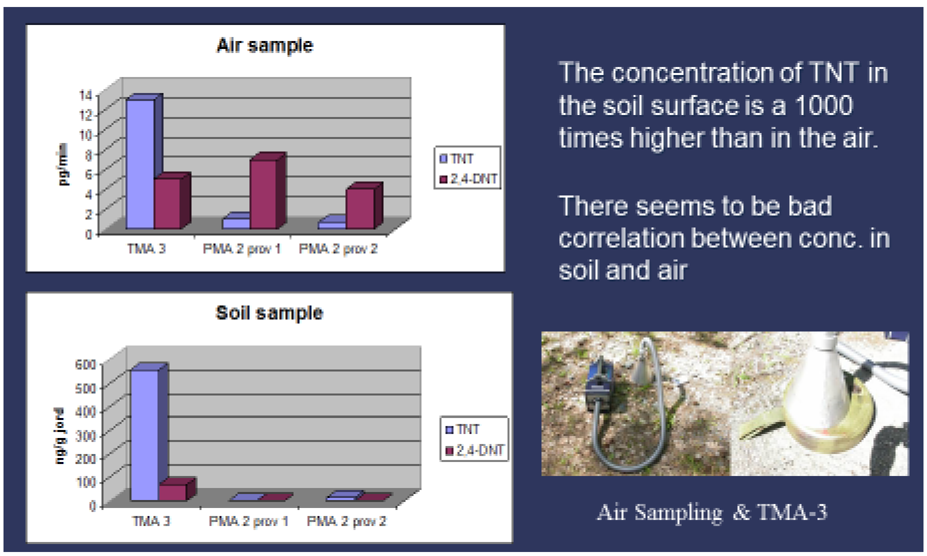


Fig 41. Dog search In Afghanistan 23/8-2007, 10.55 am and 35°C

14. VERIFICATION OF THE TNT WATER METHOD

When a dog was indicating the presence of a target, FOI wanted to verify the presence or absence of TNT and related compounds, at that spot. To verify the dog's indications when testing them (see also section 10), air samples and soil sample were taken after various searches, to see what was in the air and soil. The air sample were taken with C18 filters attached to an air pump and air was sucked through a filter, see Fig. 42. The filter was extracted with acetonitrile and analysed on GC-MS. The results, a chromatogram, showed the components that were present in the sample. All soil samples were extracted an analysed according to methods described in articles, see references [3],[10].

Fig 42. Air samples are collected by using a funnel, a filter and an air pump.

14.1 CHEMICAL ODOUR SIGNATURES FROM LANDMINES

Many conclusions have been drawn based on the dog's behaviour, combined with the chemical analysis. Below there are examples of analyses, in table 2.

Table 2. Air samples above a buried mine

Sample date	**Mine type**	**ngTNT (10^{-9}g)/sample**	**pgTNT (10^{-12}g)/litre air**
6th of August	TRPM 10	13	15
6th of August	TRPM 49 B	22	26
14th of September	TRPM 10	10	12
4th of October	TRPM 10	8	10
4th of October	PMA 2	2	2

Despite the fact that the concentrations in the air over the mines were so low, the dogs could detect them and showed increased interest by staying, or scratching the soil. Note that for a fully trained MDD, *scratching is NOT an acceptable behavior encountering explosives or mines*, an indication *shall always be passive,* for safety reasons.

Regardless of the sensor that is beeing used for detection, here being MDDs, the fundamentals of all detection is to know, what is there to detect. To gain more knowledge about the explosives and ERCs to be found, near buried landmines, FOI prepared a reseacrh area of buried landmines. It contained different types of mines, buried in different type of soils, at different depth – for comparison of the degradation process. The research area was kept and studied for more than 10 years. The example presented here, show analysed samples taken over a AP mine, LI 11, in boxes of clay and sand, see Fig.43 and 44. The boxes were next to each other and the mines were layed at the same depth. The mines had been buried in the soil for eight years. The shallow mines, placed at 2 cm had higher concentrations of the volatile by-products. Specially in the clay, where the TNT concentration showed a reversed relationship to DNT, when comparing the deep and shallow mine. The bigger surface area of clay, with higher adsorption capacity, showed more explosive related compounds (ERCs) in the air, compared to the sand. The clay aslo generated aminocompounds, being degradation products of TNT. Over the deep mine in the sand, the only compound present, was a very high concentration of TNT. The air sampling was done at the same time.

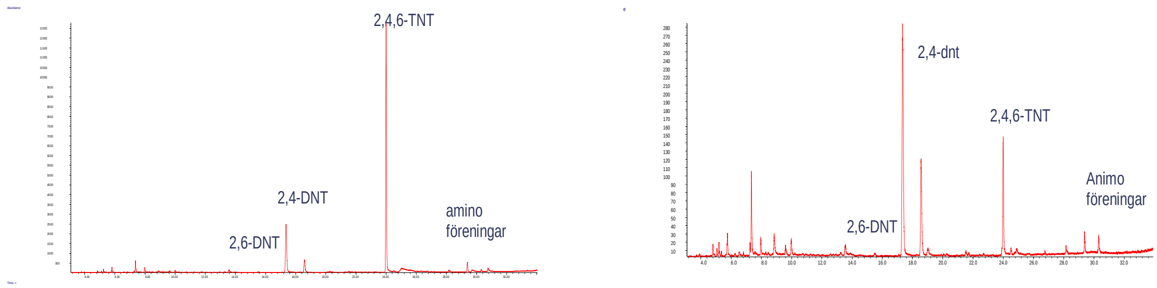


Fig. 43 a) Deep (10 cm), in clay *b) Shallow (2cm), in clay*

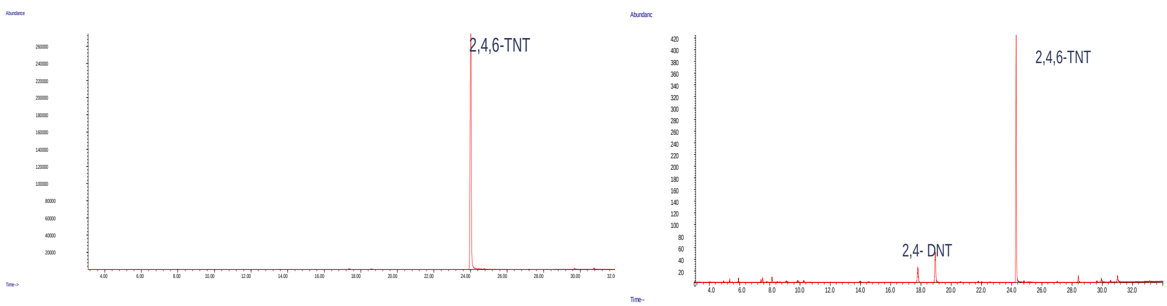


Fig. 44 a) Deep (10 cm), in sand b) *Shallow (2cm), in sand*

Examples of chemical analyses of air samples taken directly above different types of landmines, as shown in Fig. 45, are presented in the following pages, see Fig 46-48. Each peak height corresponds to the relative concentration of each compound.

Fig 45 TMA 3 TMA5 TRP 10

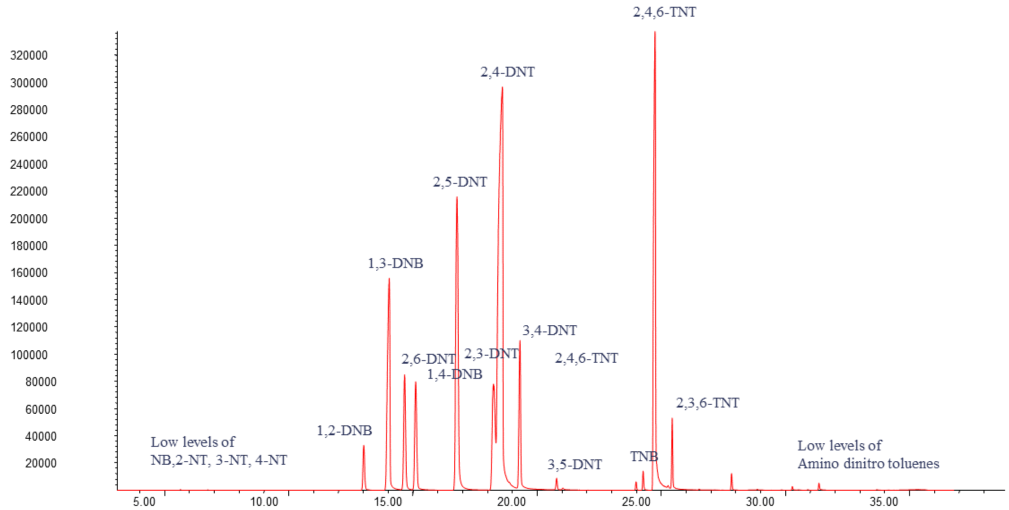


Fig 46. TMA 3, explosives and related compounds, in analysed air sample.

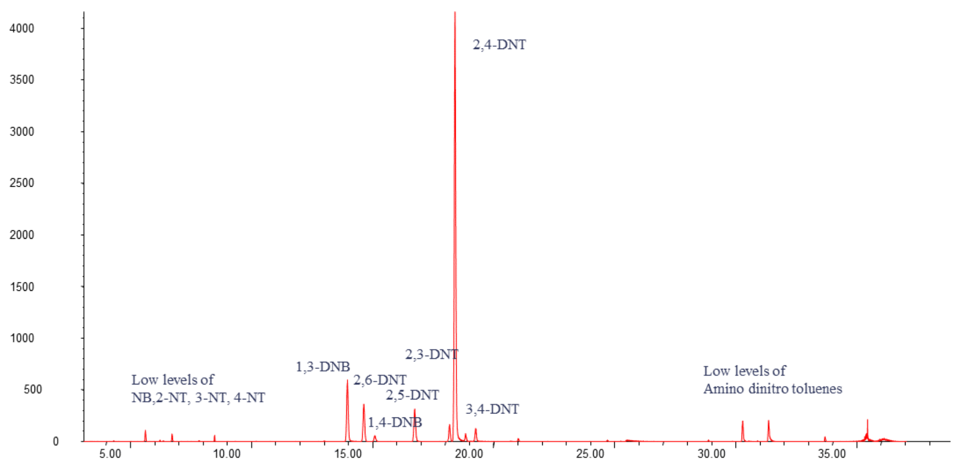


Fig 47. TMA 5, explosives and related compounds, in analysed air sample.

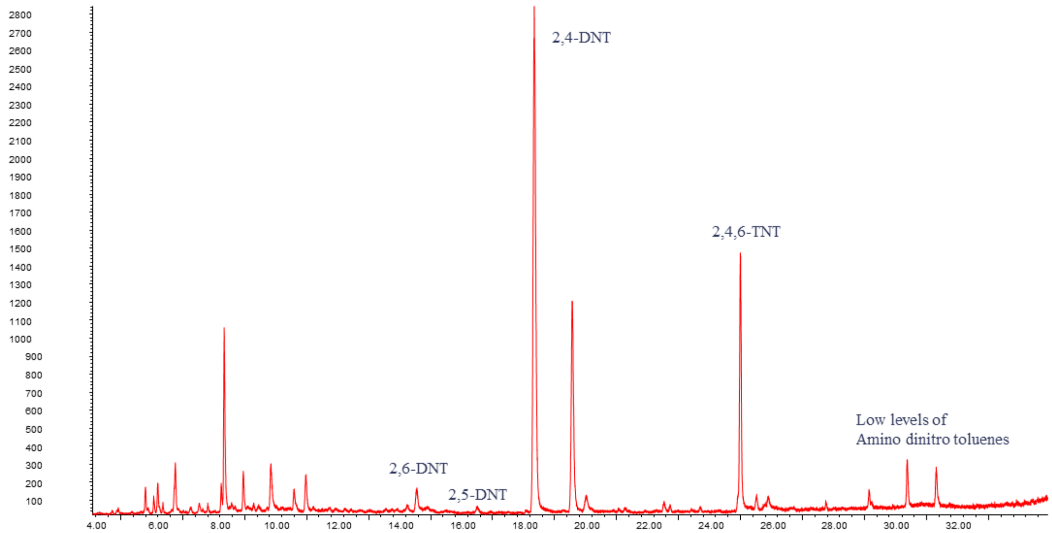


Fig 48. Trm 10, Swedish AP mine, explosives and related compounds, in analysed air sample.

The results show that several different explosive related substances are available for the dogs and that vapour signature varies, depending on the type of mine, depth and type of soil. The least common denominator, always present, seems to be the explosive itself, the 2,4,6-TNT.

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Photo: Erik Mattisson, SAF

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SRSA Swedish Rescue Services Agency

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ANNEX 1 PROTOCOL ON PREPARATION OF TNT WATER

Equipment needed for preparation of the TNT water, see Fig.1.

Fig.1 The equipment needed. To prepare purified TNT water, use 2,4,6-TNT crystals or aired/vented TNT.

→ DAY 1

Take out all equipment that needed, see Fig.1
Use protective clothes and chemically resistant gloves, TNT is toxic!
Measure the pH of the water, should be pH 6-8.
Put the TNT in the amber jar,
Heat water to nearly boiling temperature
Pour the hot water over the TNT in the amber jar
Put the lid on the amber jar and rotate it gently
Leave the jar in the room for 24 hour and gently rotate it a couple of times during the 24 hour

See Fig. 2 for illustration of the preparation.

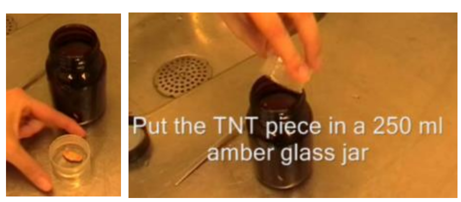
		
Test, use pH-paper for measuring the pH of the tap water. It should be between pH 6-8.	A 250 ml amber jar for preparation and storage of TNT solution, no UV-exposure allowed. A piece of regular or purified (aired or crystals) TNT	A stove or hot plate, for boiling of the water

Fig.2 Day 1 of the TNT water preparation process.

Continue to next page, for the rest of the preparation process in day 1, in Fig 3.

	
Pour the hot water over the TNT in the glass jar.	Put the lid on, an rotate/shake the jar gently a couple of times during 24 hours.

Fig.3 The last steps in day 1 of the TNT water preparation process.

→ DAY 2

Slowly pour the solution over to a new amber jar, leaving the unsolved TNT residues in the first jar. Label the jar with TNT type (crystals, vented flakes or unpurified TNT), concentration (start TNT water or saturated TNT water) and date for preparation. The concentration usually ranges between 20-100 µg TNT/ml water.

Dilute the prepared, saturated TNT water in 1:10, 1:100, 1:1000 etc. The 1:1000 solution should

For imprinting/learning the dog to detect the TNT in the TNT water,
use a high concentration, and pour out a larger volume (i.e.10-100 ml):

- Keep the saturated TNT warm (60-80°C) over night and use it while it is still warm. Then it can be up to 10 times higher in concentration (up to 600 TNT µg/ml), in comparison with a room temperature solution. Let the soil surface dry, before presenting it to the dog! Otherwise the result can be a water search dog.

- When the dog can find the TNT soaked into the ground, start using diluted TNT water. The 1:1000 dilution of the TNT water will mimic the concentration of TNT in the air above a buried mine – around 20-100 ng TNT/ml and put out.

The solution is stabile in room temperature 20-30°C, for at least 1 month, as long as it is kept in a dark jar, protecting the solution from sunlight and artificial (lamp) light.

ANNEX 2 PROTOCOL ON HOW TO USE THE TNT WATER

Dilute the solution:

A ”start solution” (with highest possible TNT concentration) diluted 1:10 means the mixture contains 1 part TNT start solution and 9 parts of water. Use warm water for better solvability.

- Dilute 1:10 take 180ml water and 20ml start solution
- Dilute 1:100 take 198ml water and 2ml start solution

The start concentration is around 20-100 µg/ml. To get the same concentration as above the mine you need a concentration around 0,1µg/ml. So dilute the solution up to 1000 times. Use 2-10 ml for regular training. During the FOI research, 5 ml was the most common volume.

Get variation in training by changing:

- The spot size and shape (cross, circle, line etc.), see Figure 1.
- The concentration (by using different concentrations and volumes)
- The time elapsed before dog search the set up training area
- Put a hotspot (high in TNT concentration), in a big spot of lower TNT concentrations
- Mix background/neutrals and TNT solution in the same spot, for a mixed odour.

Different types of loading spots in the lane is shown in Fig. 1.

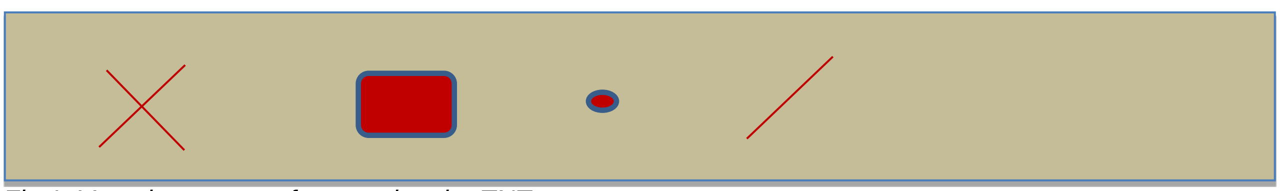


Fig 1. Vary the pattern of presenting the TNT water.

Vary the training by preparing training areas in different types of terrain, see Fig.2.

Fig 2. Vary the type of soil surface/terrain for the training of the dog.

2.1 BACKROUNDS OR NEUTRALS FOR DISCRIMINATION/STIMULI CONTROL

As important is exposing the MDD to a lot of background samples or neutrals. This is to make sure that the dog is only searching the area and detecting the explosive itself (the target) and not just any anomaly, in the hope of being rewarded. Use solvable backgrounds like water, urine, coffee or other solvents to create background smells. Put metal, plastic and rubber in water and let it soak for some days to make backgrounds of solids. Dilute or mix the solvents to create different concentrations or mixes of odours.

You can put out solids directly on the ground to make sure the dog have absolute stimuli control and don´t indicate/alert on rubbish or things on the ground. This includes odours soaked into the ground, being water solutions of any item except explosives or explosive related items, explained earlier in this section.

Fig. 3. Use background/neutrals, both water solvable ones (to the left) as well as solids (to the right).

When you load the water solutions on the ground, make sure you put it directly on the ground/soil surface and not on top of the grass. The dog need to learn to always keep the nose very close to the ground, to be successful. Otherwise it will not be able to do the trace detection related to finding buried mines. Let the solutions evaporate for at least 30 minutes before the search with the dog, so the dog don´t alert on water spots.

ANNEX 3 PROTOCOL ON PREPARING TNT CONTAMINATED SAND/SOIL

Take sand from the search lane and contaminate it with the TNT water solution. The equipment needed is presented in Fig. 1.

Fig. 1 Equipment needed to prepare TNT contaminated sand

Put the sand out in a tray of tin foil. Smaller sand particles will make up a larger available surface for the TNT to adsorb onto. It is advisable to use a specific sand throughout a typical training e.g. 0.1-0.5 mm particle size.

Pour the TNT water over the sand, mix it well and let the water evaporate, and dry overnight, see Fig. 2.

Fig. 2 Pour out the TNT water, and stir until all of the sand is moist.

Take the dried sand and use a funnel to put the contaminated sand in an amber jar for storage. Label the jar with content and date of preparation, see Fig. 3.

Fig 3. When the contaminated sand is dry, put the TNT sand in an amber glass jar and put the lid on.

The contaminated sand can be stored for at least a month, as long as it is kept under dry and dark conditions. For longer storage times, use aluminium bags and seal them tightly. For a shorter storage time (less than a week) amber (dark) glass jars kept cold and dry are recommended. Lay out the TNT contaminated sand in the lane, using in example a large spoon. To prevent the dog from starting the first part of the search, in a tempo that is too high – put the TNT sand in the beginning of the lane a couple of times, see Fig. 4.

Fig 4. Preparation of an indoor training area, with TNT contaminated sand spots.

Remember to vary the loading position, utilizing the whole length of the lane. After the search, remove the contaminated sand and rake the lane, before preparing new spots. The TNT contaminated (spiked) sand can also be used outdoors, see Fig. 5. Note that it the TNT seems to disappear after 40 days, regardless of the starting TNT concentration.

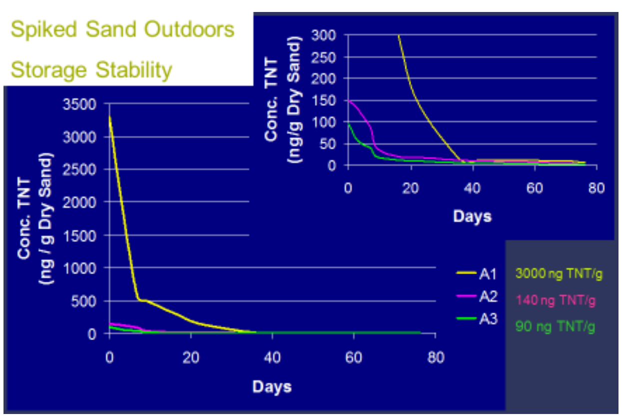
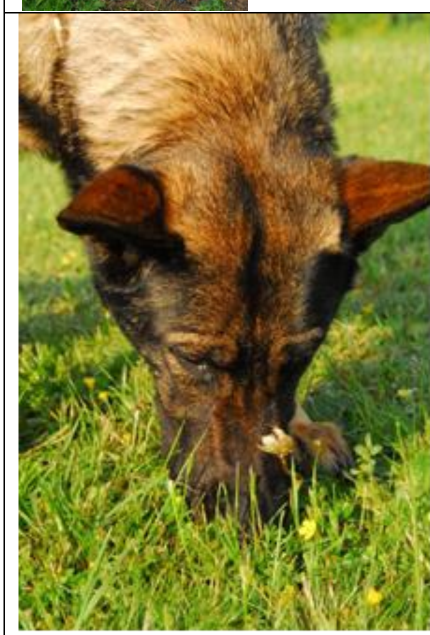


Fig 5. Preparation of an indoor training area, with TNT contaminated sand spots.

ANNEX 4 THINGS TO REMEMBER

- Stand and walk in the lane/next to the lane, if you do that when you load, so that the dog doesn’t take that as a clue for the TNT odour.
- Put out water background and let them evaporate in the same way as the TNT solution to ensure that the dog don´t search for water spots.
- Keep lane records over your training fields to ensure where the loading points are and that you have correct documentation.



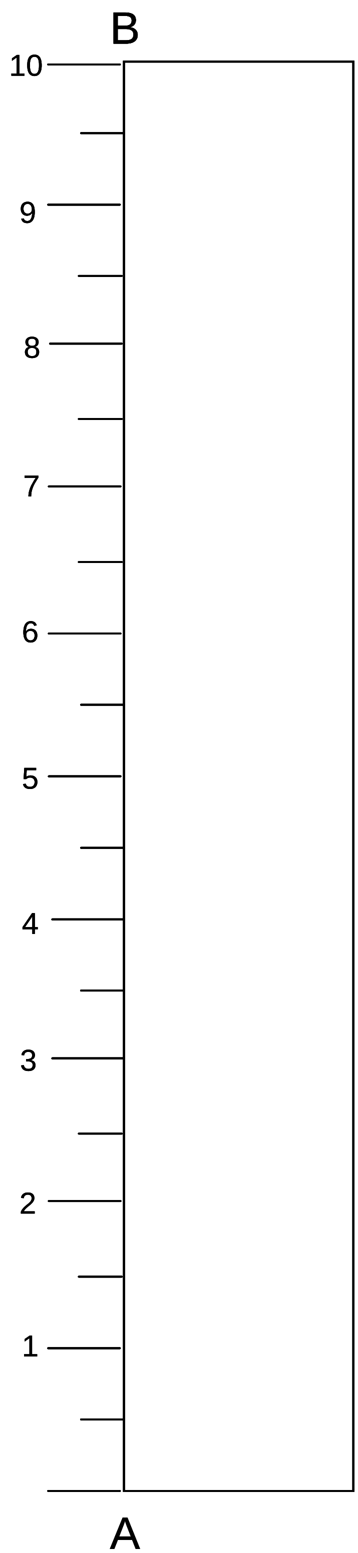
- It is important that the dog search with his nose pressed to the ground and in a moderate speed.
- Load the solution directly on the ground, not on top of the grass/vegetation.
- Search on different type of soil surfaces, since different surfaces provide different odour signatures or bouquets.
- Vary the 2,4,6-TNTwater spot size and shape.
- The TNT-water released, initiate the same degradation process as the TNT leakage from a buried landmine.

 	• An old TNT spot have a different odour signature compared to a new one. • It takes up to 90 days, depending on the weather/climate and soil conditions before the TNT is completely decomposed and no traces can be detected.
   	• Don’t use old yellow or pink TNT solution. • Store the solution in amber glass jars to protect it from sunlight. Label with content and date of preparation. • Use purified TNT (crystals or weathered/aired TNT) water, as well as unpurified TNT water (of different manufacturers/origin). • Variation is important, to teach the dog the ability to generalize.

Another important thing to remember, is to prepare lane records when setting up training areas. On the next page an example of a lane record protocol is presented. For how long the TNT remains present in the soil, at a former training site, depends on the climate and soil type. Generally speaking, the degradation process is faster in warm and humid climate. For Swedish conditions though, FOI recommend a period of three month, before the former training area can be considered free of TNT (at least not detectable with chemical analysis, but to be sure – check it also with a fully trained MDD.).

It is important to know where the TNT spot is, to know if the dogs indication is a true or false one. Use a measuring tape, on one side of the lane – for reference.

LANE RECORD……………….



Date of contamination:…………………………

Name:……………………………………………

Contamination sample 1……………………….

2………………………

3………………………

4………………………

Measurement sample: 1………………………

2………………………

3………………………

4……………………….

Date of action in lane: First……………………..

Last……………………..

Lane re-contaminated:…………………………