Detection of explosive as an indicator of landmines – BIOSENS project methodology and field tests in South East Europe

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ABSTRACT

The IST-2000-25348-BIOSENS project carried out a number of studies to assess the use of explosive detection technology for humanitarian demining. This paper presents sampling / collection technology developed, test methodology and results including comparisons with dogs and soil sampling. Findings are presented in terms of the detection of explosive from mines in the environment and demining.

Keywords: Vapor trace explosive detection, demining, biosensor, environment effects

1. INTRODUCTION

A system consisting of a sample collection unit and analysis unit for the detection of explosive has been developed. The analysis unit principle is antigen and antibody weight loss technology with a Quartz Crystal Microbalance. It detects a number of explosives and/or their by-products simultaneously and may be used stably in the field. Studies in the project included the use of the biosensor system, the use of the biosensor collection unit with a Gas Chromatograph (GC) system, soil sampling and comparisons with Mine Detection Dogs (MDDs). The technology and initial findings up to December 2003 have been presented previously[1,2]. Here we present results from methodology studies (MS) 1-13 (2002-2004) carried out with the biosensor sampling / collection systems and a GC system, soil sampling results and comparisons with MDDs.

2. TEST FIELD

The test field used for the MS is 17.9 Ha and in Croatia. It is representative for mined areas in the Balkans covered with grass, similar to pasture-ground, with variable incidences of stones (mainly lime stone) on and below the surface. Soil samples taken and analyzed by the Swedish Defence Research Agency (FOI) before the testfield was prepared, showed no presence of explosives or explosive related substances. The majority of the MS tests were undertaken in 16 boxes of 10x10 meters. The shortest distance between the boxes was 25 meters and only one object was placed in each box. Thus, the large test field contained initially only 16 mines: 6 TMA5s, 6 PMA1s and 4 PMA2s with modified fuses. Boxes were planned based on known conditions of gas dispersion and dilution in air. During the course of the project further mines were added to the testfield. No mine was however ever closer than 75m from the boxes described above.

3. METHOD

3.1. Test Equipment

The methodology studies and field tests were carried out in parallel to the development of the system itself

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due to the relatively short duration of the project. Following the fast development of a sampling system and the provision of a testfield, it was possible to start tests with a sampling system and a GC system early in the project as illustrated in Fig. 1. A single use sample collection filter bridges the two systems. The developed filter is based on a filter matrix used for the removal of fine particles from air and as such it works very well for the collection purpose. An additional coating also enhances the uptake of vapor.

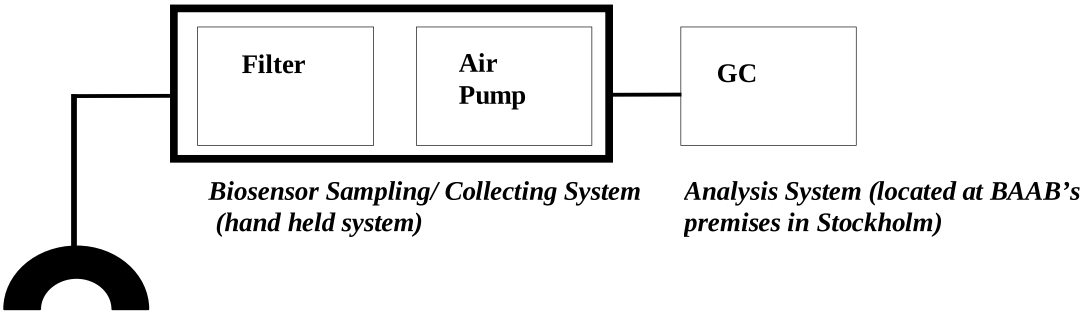

Fig. 1 Test Equipment, BCS 1 or 2 and GC

MS1-11 were carried out with the first Biosensor Sampling/Collector system (BCS 1) (cone) see Fig. 2 and MS12-13 were carried out with the second Biosensor Sampling/Collector system (BCS 2) (sweeping) see Fig. 3.

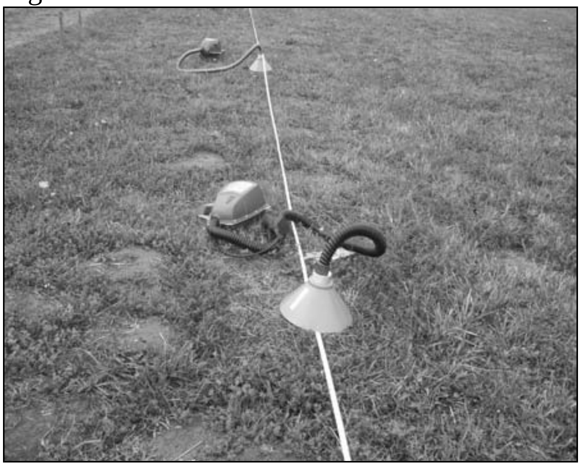

Fig. 2 BCS

Fig. 3 BCS

BCS 1 consists of a mouth-piece (plastic cone) connected to the filter holder. The end piece of the BCS 2 consists of a long (140 cm) plastic rod-like tube ending with the collector nozzle. The nozzle consists of a filter holder of aluminum on to which flexible plastic feelers are attached on its outer perimeter (Fig. 4).

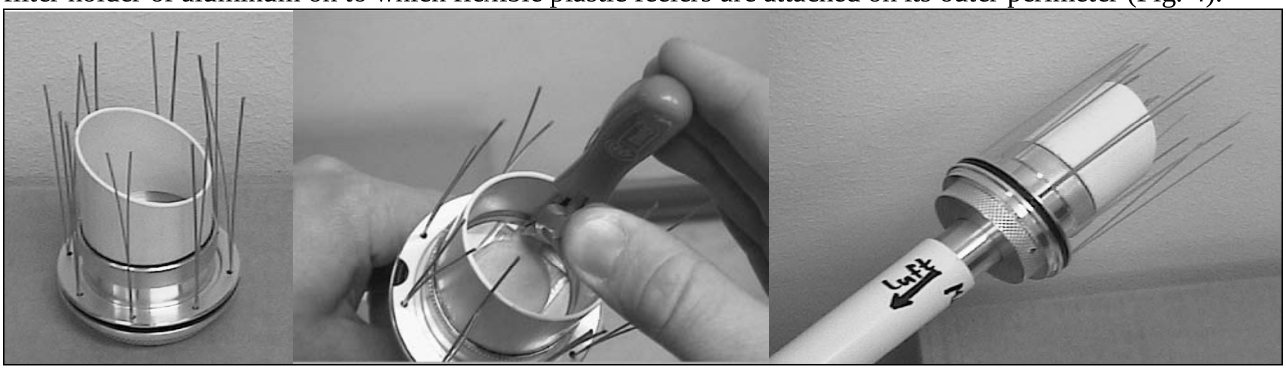

Fig. 4 End piece of the sweeping collector

The feelers were designed for mobilizing the fine particles on the ground surface for more efficient collection on the filter. The distance from the filter to the ground surface is ca. 10 cm. The width of the nozzle is only ca. 5 cm allowing the operator to get close to the ground surface efficiently even on a rough surface (this is important to ensure maximum uptake of small particles). The air pump is enclosed in rugged housing and can be hand held, or carried on the back. An easily replaceable battery pack is enclosed in the housing. The air pump and battery capacity allows continuous use for 2-3 hours. Replacing the battery is a fast operation taking only seconds to complete. The charging process takes only 1-2 hours. The pump is connected to the sample collector via a light weight flexible tubing. This set-up of equipment enabled the following performance to be achieved: Air flow 1-2 litres/second, Sampling times 60-600 seconds (for the major parts of the samples 360 seconds, 6 minutes), Limit of Detection (LOD) 0.1 ng TNT for MS01-07 and LOD 0.05 ng TNT for MS08-13. BCS 1 was used for stationary sampling only and BCS 2 carried out continuous sweeping sampling at 1sqm / min.

3.2. Test procedures

During the field tests the mouth-piece or nozzle and the filter holder were cleaned with ethanol (70%) and a filter was inserted before each collection. For the tests with BCS 1 the widest part of the cone (21 cm in diameter) was placed on the ground surface to be tested. For the tests with BCS 2 the rod with nozzle was moved close to the ground in a sweeping fashion while the operator walked along a designated line. Once the collection was finished (3-6 minutes) the collection equipment was carried to the automobile where the filter was removed and stored either in a small glass vial with screw cap or put in a sealable plastic bag. The samples were stored cool (<4 degrees) and dark until analysis. After cleaning and insertion of a new filter, the next collection was started. A number of control filters were also taken as presented in Tab. 1. The numbers and types of different controls evolved during the project in order to provide a better understanding of where collected TNT/DNT originated. Modified cleaning procedures were also introduced during the tests to reduce the risk of contamination.

Control filter, SE	Blank filters left in Sweden, added to the filters from the test period before analysis
Control filter, CRO	Blank filters not used in the testfield but nevertheless prepared and sent for analysis
Reference test	Samples taken over a known source of TNT
Fresh air samples	Sampling while the cone is directed upward to the sky
Between boxes	Sampling on the ground in-between boxes
Environment tests	Sampling at areas not considered to have explosive present e.g. hotel
Test of personnel	Sampling on personnel clothing and in test vehicles

Tab. 1 Control and other filters

All filters sent for analysis were marked with an individual number. The key to the numbers were submitted to BAAB after SRSA had received the final test results. Filters were extracted with tert-Butylmethylether (LiChrosolv, Merck, Germany). Hexachlorobensen was included as internal standard substance in the extraction solvent to verify GC performance. For GC analysis of extracted filters, a HP 6890 Series GC system was used with an accompanying µ-ECD detector. The separation column was either an Agilent HP-1 (25 meter) or a Varian VF-5MS (30 meter). Quantification of sample peaks were made by comparing to known standard explosives in solution. Normally 2,4,6-TNT and 2,4-DNT were quantified. In some tests tetryl, 4-amino-2,6-DNT and 2-amino-4,6-DNT were also quantified. Detection limit on filter is 0.05-0.1 ng for TNT and DNT and 0.5 ng for tetryl, 4-amino-2,6-DNT and 2-amino-4,6-DNT.

3.3. MS1-10

The methodology studies study started in 2002 when the test field was chosen after evaluation. A time chart is presented in Tab. 2 illustrating when the MS took place. The tests were undertaken with the BCS 1 and the GC system described in 3.1 and the procedures described in 3.2 in the 16 boxes described in 2. Tests were carried out during all seasons of the year.

MS01	MS02				MS03		MS04			MS05		MS06	MS07				MS08	MS09	MS10
A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**

Tab. 2 Time chart of methodology tests

3.4. MS11-13

The studies were carried out in February, April and June 2004. In MS11 BCS 1 was used for collection of samples both inside and outside the test field. The sampling was performed in points forming a line at a distance of 100 [m] south-east of the test field border. Inside the test field the traditional sampling in boxes as for MS01 to MS10 was performed. The weather conditions during this test were cold and extraordinarily wet.

For MS12 the BSC 2 was used and sampling was performed in test lines outside the south east border of the minefield at distances of 6, 12, 25, 50 and 100 meters and in lines inside the test field. The test procedures were planned for more than one direction but bad weather prevented this. We were interested to see if we could identify a distance at which we would first detect explosives or at least a pattern of increased hits or quantities of collected explosives.

MS13 was also performed using the BSC2. During this period the vegetation was unusually high compared to the previous period (MS12) as well with normal conditions for June: hot and dry.

3.5. Soil samples

Soil samples were taken from MS02 onwards and analyzed by FOI. The goal of soil sampling was to learn more about how the concentration of TNT/DNT levels in the ground around mines progress. Soil samples (ca 40 g) were collected from the surface to a few centimeters below it. During MS13 soil samples from outside the testfield were also taken.

3.6. Comparisons with MDDs

During the course of the project a number of studies were organized to try to learn more about how MDDs work and to compare results with our sampling and analysis methods.

3.6.1. MDDs at test site in Croatia

During the course of MS08 two Norwegian People's Aid (NPA) MDDs with handlers were tested to see whether they could pinpoint the 16 planted test mines. The dogs searched the boxed areas before and after the sampling of air took place.

3.6.2. Samplings with MDDs in Bosnina-Herzegovina at NPA test facilities

In-door tests were performed in a facility located in an isolated shed with soil temperature control. In the shed (inner area 10x5m) there were 8 parallel lines prepared. In these lines different types of mines representative for the Bosnia-Herzegovia area were planted. The mines were planted at soil depths of ca. 15-20 cm. The air temperature inside the shed was 41-48 degrees C. 24 air and 13 soil samples were taken. The ground was water-soaked in large quantities shortly before testing.

Out-door tests were also performed at a MDD training facility. 31 samples were collected in total: 1 Sample of fresh air, outdoors; 3 wipe samples from the MDD fur, paws and nose; 7 air samples in boxes above mines marked by the MDDs, 20 soil samples above mines and in 'safe lines'. By 'safe line' we mean an area considered as clear from a mine as the MDDs mark no spots.

4. RESULTS

4.1. MS1-10

In Tab. 3 the yield, meaning the number of positive results from filters sampled directly above planted test mines in ratio to the number of total samples taken above test mines, is presented for each MS. The amount of explosive on positive filters was typically between 0.05-0.3 ng.

Methodology Study no.	MS01	MS02	MS03	MS04	MS05	MS06	MS07	MS08	MS09	MS10
Positive response/ Samples in total above mines	8/16	1/16	Disc.*	3/16	8/32	4/26	5/23	7/27	3/48	1/16
Yield [%]	50	6	-	18	25	15	22	26	6	6

*Discarded due to expected contamination of the samples but see comment below.

Tab. 3 Yield of positive results when sampling above the planted test mines

In Tab. 4 the results from different controls are presented.

Methodology Study no.	MS01	MS02	MS03	MS04	MS05	MS06	MS07	MS08	MS09	MS10
Control filter, SE	-	-	1/5*	-	0/10	0/10	0/10	0/10	0/10	0/9
Control filter, CRO	-	-	7/12*	0/19	2/10	1/10	0/10	0/10	0/10	0/10
Reference test	6/6	4/4	8/8*	8/8	8/8	8/8	8/8	8/8	8/8	8/8
Fresh air samples	-	-	-*	-	9/45	3/30	2/32	2/22	0/21	0/15
Between boxes	-	-	-*	-	-	-	1/27	5/23	1/25	2/45
Environment tests	0/16	0/4	-*	1/4	3/4	0/4	0/4	-	-	-
Test of personnel	1/2	3/23	-*	13/15	11/27	5/13	8/19	1/6	1/3	2/5

Tab. 4 Results from different controls

In Fig. 5 and Fig. 6 the levels of TNT and respectively DNT measured in the soil samples around the planted mines are shown.

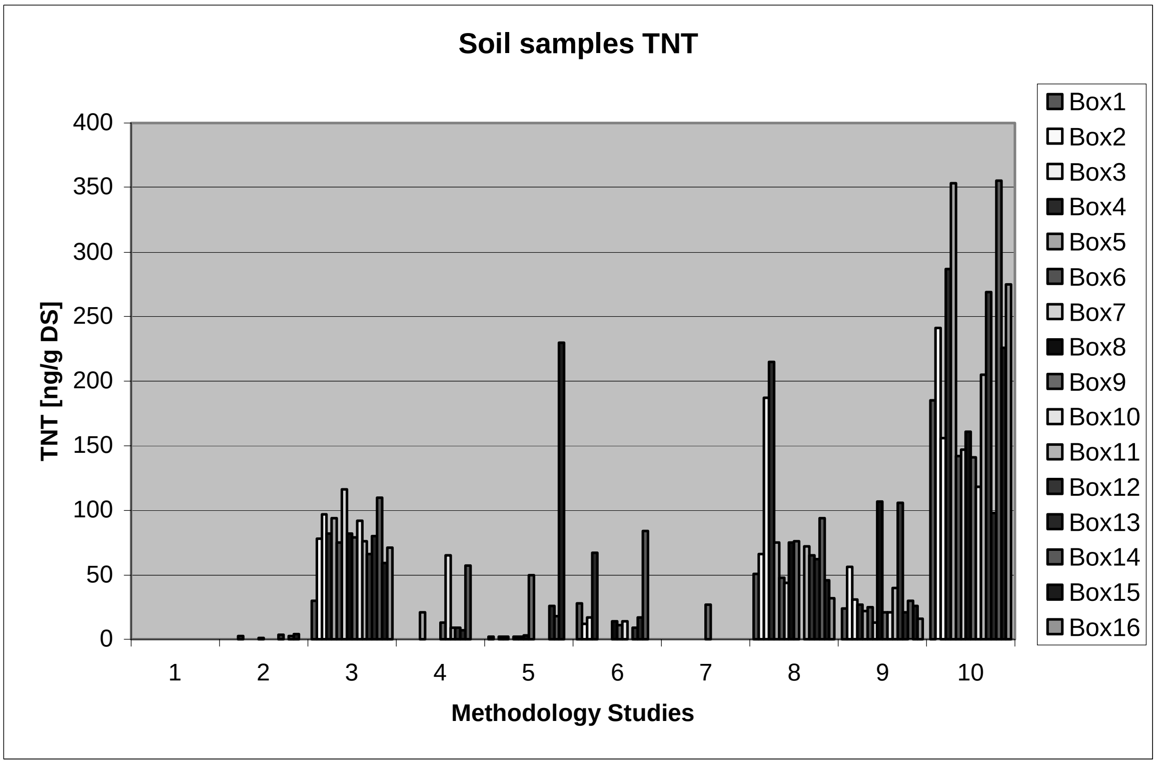

Fig. 5 Levels of TNT found in soil sampled around planted mines

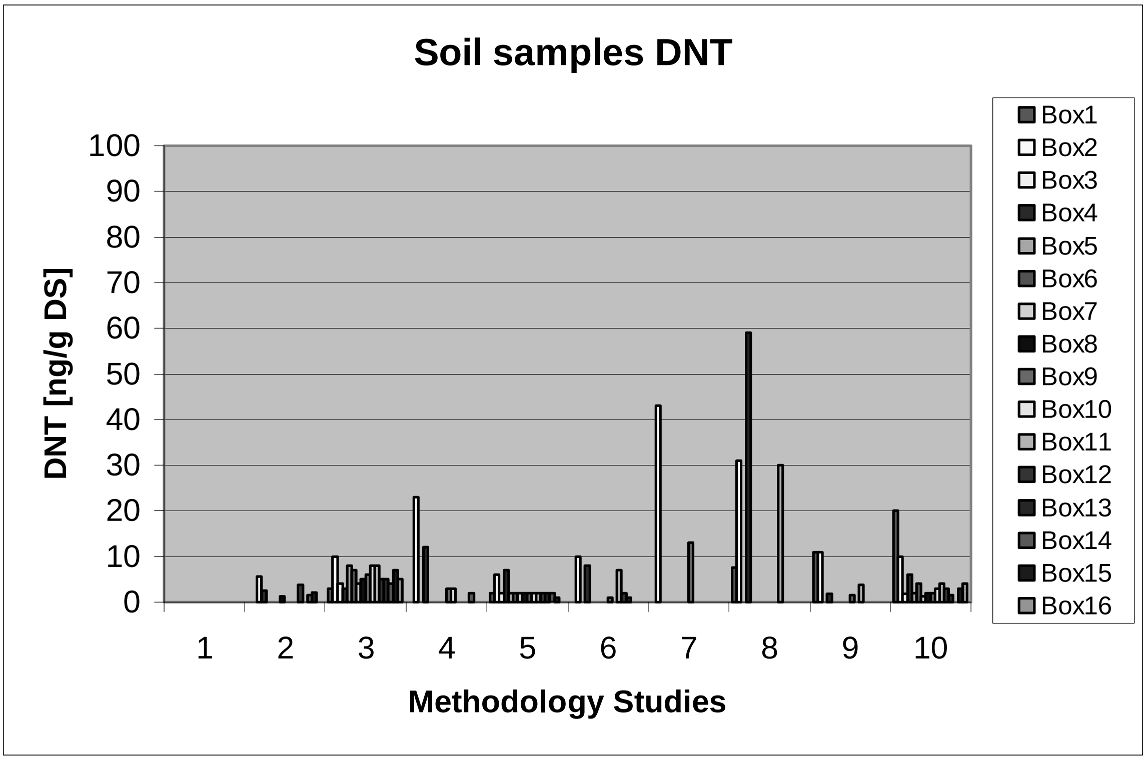

Fig. 6 Levels of DNT found in soil sampled around planted mines

In what follows we seek to highlight the more interesting results which lead us to the discussion and conclusions. Tab. 3 shows the results for air samples collected above planted test mines. In general we find that the percentage of boxes containing TNT or DNT is around 20% for most of the studies except for MS1-2 and MS9-10. No individual boxes were found to have a higher incidence of hits than the average (data not shown). Tab. 4 shows the results of control samples related to air sampling. For the filters left in Sweden as controls, no explosives could be detected. When collecting air samples at other positions than above planted mines we also recorded a number filters with explosives, this included between boxes and in samples taken with the sampler pointed to the sky. Fig. 5 shows there is a trend of increasing levels of TNT. During MS03 and MS08-10 TNT was found around all planted mines. Fig. 6 shows the levels of DNT were in the order of 10 times lower than for TNT. The high levels of TNT and DNT in MS03 should also be noted.

4.2. MS 11-13

In MS11 with BCS 1 the presence of TNT/DNT was found in **1** box of **19** in total. The results from sampling in points at a distance of 100 [m] south-east of the test field border were **no** positive sample for TNT/DNT of **7** samples in total.

For MS12 Tab. 5 presents the finding of explosives at different distances outside the south-east border with the use of the BCS 2 .

Line id*	Number of samples in total	Number of samples positive TNT/DNT	Yield TNT	Yield DNT
L 100 m	9N	6N	6N	4N
L 50 m	3N	2N	1N	1N
L 25 m	3N	1N		1N
L 12 m	2N	2N	1N	2N
L 6 m	2N	2N	1N	2N

Tab. 5 MS12. Sampling in test lines outside the test field with BCS 2

The presence of TNT and DNT at the 100 meters distance is quite interesting. The yield for TNT was 6 samples positive of 9 in total (66,7 %). The yield for DNT was 4 samples positive of 9 in total (44,4%).
The other lines also showed some positive results. The yield for all samples collected with the new BCS was for TNT, 9 samples positive of 19 in total (47,4 %) and for DNT, 10 samples of 19 in total (52,6 %).

17 samples were also collected in test lines inside the minefield. The yield for TNT was 13 of 17 in total (76,4%) and for DNT 14 of 17 in total (82,3%). Taken together 15 samples of 17 in total (88%) contained explosive (either TNT or DNT or both).

The results of air sampling in MS13 are summarized in Tab. 6. Some soil samples taken outside the testfield were also positive.

Location of sampling	Yield /number of samples TNT/DNT	Percentage
Inside test field	**5/17**	29%
South-East	**1/24** (1/15 at 100 [m])	4%
North-East	**5/17** (3/8 at 100 [m], 2/9 at 25 [m])	29%
South-West	0/21	0%
North-West	1/9 (1/9 at 25 [m])	11%

Tab. 6 Results from MS13

4.3. Comparisons with MDDs

4.3.1. MDDs at test site in Croatia

The dogs successfully pinpointed all the 16 planted test mines on two days without any false alarms despite severe weather conditions (rain).

4.3.2. Samplings with MDDs in Bosnia-Herzegovina at NPA test facilities

Tab. 7 shows the results of the analysed air samples from the special test-shed. The levels of TNT/DNT concentration in the indoor air samples were almost comparable despite the type of mine the air sample was sampled above and 2 of the 4 outdoor samples were positive for TNT/DNT. The 22 positives were all in the range 0.1 – 0.9 ng TNT. The median was 0.15 ng.

Sample type	Number of samples	TNT	DNT
Air sample: indoor test lines	19	19	0
Air sample: indoor 1.5 m above sand	1	1	0
Air sample: outdoor 1.5 m above ground	4	2	0

Tab. 7 Results from air samples collected in in-door dog-test shed

Tab. 8 shows the results of the analysed soil samples from the special test-shed.

Soil Collection	No. of samples	No. of samples containing detectable levels of TNT/DNT
Close to planted mine	9	7
Between planted mine	4	1

Tab. 8 Results from soil samples collected in in-door dog-test shed

Tab. 9 shows the results of samples analysed from the outdoor MDD test-facility.

Sample type	Number of samples	Positive for TNT	Positive for DNT
Fresh air	1	0	0
Wipe from MDD fur, paws and nose	3	3	0
Air samples above mines marked by MDDs	7	1	0
Soil samples from above planted mines and also in “safe lines”	20	20	0

Tab. 9 Results from samples taken at NPA outdoor MDD training facility

It is worth noting that all the wipes of the MDDs were positive for TNT, only one of the samples above a mine marked by a MDD was positive for TNT but that all soil samples were positive for TNT above mines and also in “safe lines”

5. DISCUSSION OF RESULTS

5.1. MS1-10

In commencing MS01-10 we aimed to learn sufficient about the movement of explosive to establish a method to identify a way to detect every individual mine. Following this we had the objective to develop a methodology for the marking of hazardous areas without the requirement to detect every individual mine i.e. area reduction.

Following the above aim and objective, the BCS 1 system and was designed predominantly with a view for vapor collection of TNT/DNT as the concentration of TNT/DNT in gas phase can be expected to be in general highest above the planted mine and more diluted far from the mine. The sampling methodology was also developed to be performed directly above the planted test mines. The results highlighted however that the BCS 1 and sampling methodology combined with a GC for analysis with a detection level of 50-100 pg would not be able to detect individual mines. By methodology study MS07 we were also confident that the lack of positive findings could not be explained in terms of the lag phase of the mines. The lack of positive findings seemed to be caused by not being able to collect a sufficient amount of explosive in the form of either vapor or contaminated particle. Faced with this knowledge the partners sought to target the collection of particles as a reservoir of explosive molecules and hoped still to be able to develop a methodology for area reduction. This led on to the BCS 2 and the MS11-13 studies.

A number of individual points are however also worth noting from the MS1-10 studies. High findings of explosives were found in the air samples on the day after planting this was somewhat surprising as it is generally accepted that it may take up to 6 months before the levels of concentrations of substances emanating from mines reach levels that may be detected by dogs. There is however no guarantee that the positive TNT/DNT results originated from leakage from the planted mines. It is more likely that explosive dust on the mines' casing spread during the plantation itself. This hypothesis is strengthened if we consider the low yield from MS02.

The finding of explosives in almost all samples as well as most control samples collected in MS03 made us initially treat this series of data with extreme caution as we could not be sure from where the explosive originated. In hindsight, there are however reasons to believe a disturbance from an outer source during MS03 since following MS studies have neither reached the same high yield in fresh air samples nor the levels of TNT/DNT sampled in the filters. The soil samples collected also showed a notably higher frequency of positive samples. Later on in the project it came to our knowledge that demining actions were performed in an area not more than 20 km away from the test field. During these demining actions anti-tank mines were destroyed. According to the Swedish Meteorological and Hydrological Institute (SMHI)[3] small particles less then 10 µm can easily be transported over a distance of more then 300 km. Our initial assessment of MS03 did however lead us to even stricter procedures for cleaning, test, storage, transportation and laboratory procedures.

The following studies MS04-06 indicated that if contamination had been an issue in MS03 then modified procedures had been effective. However, the frequency of findings in air samples above mines was also low between 15-25%. In contrast to this there were a rather high (1-2ng) and unexpected number of findings of explosives on personnel’s clothing, over 50%. Some of the tests of the clothing were performed on clean clothes of personnel upon arrival at Zadar before having entered the test field. The source of this contamination is unknown but could have been from the air intake in the car taking in explosive contaminated dust from the roads. In addition, during the sampling of 'fresh air' in the test field and at the hotel during MS05, 9 of 45 samples were positive for TNT/DNT although chronologically separated. This indicated that TNT/DNT was present in the test field area however it was not possible to know from which source the TNT/DNT originated and that it could be present in areas not expected.

During MS07 the previous procedures were complemented with air sampling above the soil between the planted test mines. This was in order to study if there were any correlation between the high levels of TNT/DNT in the previous samplings of fresh air to the deposit of TNT/DNT spots inside the test field but not above mines. We considered that if an outer source had contaminated the field there would be a period of time when there would be positive responses all over the test field as a background level. We also thought that it could be possible to find higher levels of TNT/DNT above planted mines since they continue to leak

TNT/DNT compared to the levels found as a background. During MS07 we also carried out sampling early in the mornings and late in the afternoons to avoid influence of small local wind turbulences caused by the sunlight. It is known that a temperature difference of only 0,1 degree Celsius between soil temperature and temperature in the air 2 m above the ground is sufficient to start a small upwind strong enough to bring small particles less then 10 µm in turbulence. The yield of MS07 was 5 of 23 (22%) in total positive when sampling above the planted test mines and only 1 positive of in total 27 when sampling between boxes, providing a ratio of 5:1. For MS08 SRSA tried to repeat the same test procedure as for MS07 in order to achieve more results, however the weather conditions did not permit sampling without wind even in the mornings and late afternoons. The result showed a ratio between sampling above mines and between mines to 1:1 (7/27 above mines and 5/23 between mines).

The results from MS07 and MS08 indicate the importance of wind influence in the detection of particles contaminated by mines and indeed the detection of mines based on the detection of particles. Even local wind turbulence can lift the upper particle layer of the soil surface above a mine and transport it one or several meters away from the mine. This can result in a positive false alarm when sampling above the redeposit of contaminated particles and a negative false alarm when sampling above the mine. The local wind turbulence makes it difficult to predict where the mine is located after having a positive sample.

In MS09 and MS10 the main objective was to compare sampling times since theory says that small particles collected almost immediately could lose TNT/DNT from the surfaces of the particles with continued sampling of air. The results from MS09 and MS10 gave however no indication if 1 minute was preferable to 6 minutes due to a small number of positive results. The longer time 6 minutes is the time which was chosen for sampling throughout the whole of the methodology study.

5.2. MS12-13

The results from MS12 indicated deposits of TNT and DNT at different distances in the south east direction from the test field border up to 100 meters. These deposits could have originated from mines present in the minefield. However, the deposits could have also originated from an outer source. These results support the discussion of the local wind turbulence' effect on dispersion of contaminated particles. The BCS 2 unit also seemed to have a better design for the collection of particles. Only one direction (south east) was sampled during MS12. This limit of information did not permit us to draw any theories as to whether these deposits originated from mines present in the minefield or from an outer source which had contaminated the whole area.

The low number of positive results in MS13 may be due to high vegetation. High vegetation in itself prevents the wind turbulence to disperse the particles. However the vegetation is also likely to absorb the TNT/DNT[1]. In hindsight, the vegetation should have been cut or at least partly to allow for a comparison. On the north side it must be noted that two additional factors must be considered with the results. First the collections were taken at 100 and 25m north east of the whole test area (and not just the test field used for the methodology studies). This was because of other test mines planted in the field. Second, according to the test personnel the vegetation was shorter on the north-east side of the test field. The results from the methodology studies MS12-13 do however suggest that with a collection system designed for the collection of particles it seems possible to confidently collect explosives in mine fields to detect the presence of mines.

[1] This has been confirmed by GICHD and it is also an end user experience that dogs can have problems in higher vegetation.

5.3. MS1-13, Soil samples

In the soil samples taken close to the planted mines presence of TNT was more frequent and in higher levels of concentration than DNT. This may be explained by DNT's characteristics regarding vapor pressure. DNT is much more easily transformed into vapor phase than TNT and thereby is also more easily influenced by local wind turbulence. TNT on the other hand sticks to surfaces and therefore accumulates on particles in some conditions. Other tests (not described above) where air samples were taken in pits which had contained mines showed positive results while sampling right above visible mines gave negative results. One explanation could be that the small amount of explosive that continuously leaked from mines was too small to be detected by the present method of analysis (GC). However, the soil located next to the mines seemed to function as a reservoir i.e. the soil accumulated the continuous leakage of TNT/DNT from the mine. This would also be an explanation for the generally increasing levels of TNT in our testfield. The levels of concentration in soil were relatively high during good conditions, not too wet or hot, and quite similar between the different types of mines in the minefield. Bad weather conditions gave poorer results over all the different mine types in the test field. NPA also demonstrated that the soaking of the ground in its test shed was relatively successful in removing build-ups of TNT in non-mine locations. Air samples taken above planted test mines from Methodology Study MS09-10 gave extremely few positive results of TNT/DNT despite quite high levels of TNT in soil samples taken above the planted test mines. This can be explained by sampling procedures not working in a sufficient way or the presence of TNT/DNT contaminated particles on the top surface being very limited. Some of the soil samples taken outside the testfield in MS13 were positive for TNT/DNT. It is however not possible to draw conclusions from this result as it is not certain that this area was free from explosive before the testfield was established.

5.4. Comparison with MDDs

The fact that the MDD were able to pinpoint all the planted mines in our test field despite rain indicates the dogs' sensitivities for TNT/DNT detection or other mine marker substances to be extremely high. The dogs may not require TNT/DNT to be accumulated on the soil top surfaces for their detection. It could also be sufficient for the dogs to smell the continuous leakage of TNT/DNT vapor emanating from just below the air-surface interface above the planted mines. The results from the studies at the MDD training facilities also indicate that if the dogs only use TNT/DNT as a marker for detection of mines then they must work with extremely small gradients of TNT/DNT for pinpointing of planted mines. Unfortunately it was not possible to verify this as the BCS systems work with 1 m^3 of air compared to a dogs single sniff of a few cm^3. On the other hand the studies, could also indicate that the dogs use one or several other substance/substances than TNT/DNT (or in combination with TNT/DNT) as a marker for their assessment of the smelling patterns originating from mines. This concept is supported by the fact that the dogs did not mark other TNT/DNT deposits at none mine locations in either our test field or their training facilities although we collected explosive at non-mine locations. In addition, we note the contamination of the dogs themselves with explosives and an overall contaminated background irrespective of position and height when sampling in the training shed. According to NPA, a well trained dog has no problems in pinpointing the planted mines in their test facility. A more extensive study of substances emanating from mines including casings, paint etc could show more appropriate markers for detection.

6. CONCLUSIONS

At the beginning of the project, it was felt that if a sensor were able to detect picogram quantities of explosives in mine fields then it would be possible to detect mines. Our results suggests that the detection problem is not as simple as this. Key findings which we have been able to confirm are that 1) Explosive vapor/particles would seem to be spread out in test and minefields; 2) It is not always possible to detect explosive vapor/particles directly above mines (with LOD of 50pg); 3) It is possible to detect explosive vapor/particles between mines; 4) Areas that can be positive during one sampling must not necessarily be positive during another suggesting that explosive contamination changes with environmental conditions; 5) Dogs are able to pin-point mines; 6) There is still a great deal to be learned about the spread of explosive contamination from mines.

Findings which we feel need to be particularly considered in further work targeted towards vapor / trace detection for demining are that: 1) Concentrations of explosive detected may not necessarily be higher close to mines; 2) Explosive may be detected (which we believe emanated from mines in our testfield) over 11m away from individual mines. In our results explosive was detected over 100m away from the area containing mines; 3) It is possible to detect explosive vapor/particles in expected “clean areas” in mine affected countries (in our example at the hotel); 4) Dogs are able to pin-point mines even if there is a high amount of background explosive contamination.

This leads to a number of conclusions and hypotheses the most important of which are that: 1) Dogs are using a combination of molecules and perhaps ratios to pin-point mines which probably include explosives and their by-products but may well also include for example plastic and rubber (NPA reports that on occasions dogs have marked false alarms at rubber tyres); 2) Although it is difficult to draw a distinction between systems that rely purely on vapor for detection of explosives and those which rely on particles as well, operational procedures for demining are potentially very different depending on the type of sample collected; 3) A system which is even more sensitive (and real-time) able to detect continuous leakage of the low flow of TNT/DNT (as oppose to a temporary deposit) could offer improvements in terms of detection but that it is perhaps also necessary to look for other substances; 4) Saturated sampling of suspect areas which relies purely on the detection of explosive by a technology as a marker of mines could by a method to reduce suspect areas if no explosive is found but operational procedures require development, it may be for example necessary to carry out sampling on a number of occasions.

7. DISCLAIMER AND ACKNOWLEDGEMENTS

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