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Abstract <p>There is reason to ask whether it is beneficial to decontaminate vehicles, in view of the great effort applied. If the level of contamination is low before the decontamination process, then the cost is not motivated, even if the decontamination is shown to be effective in relative terms.</p> <p>The report describes two trials at the National NBC Defence School in Umeå and one trial at the French test site in Bourges.</p> <p>The aim is to investigate how vehicles are contaminated and at which ground deposition levels troublesome levels of contamination will arise. In the trials, a non-radioactive agent substituting real radioactivity was used.</p> <p>The trials in Sweden so far have used the All-Terrain Carrier 206, during both winter and summer conditions. The vehicles were driven a specific distance along a road on which a known amount of the test substance had been dispersed. Samples were taken on pre-determined areas on one side of the vehicles to measure the amount of test substance. Later, the vehicles continued along a "clean" road where additional samples were taken, but on the other side of the vehicles. The largest amount of test substance was collected on the tracks and on the back of the vehicle. The tracks and mud-flaps were effectively decontaminated when the vehicles were driven along a clean road, while most of the contamination remained on the backside.</p> <p>The purpose of the trials in France was to compare the results from our non-radioactive and their radioactive method, based on the radioactive La-140. Due to ground conditions, the level of contamination on the vehicles was much less than in the trials in Umeå, but in spite of that an effect of decontamination could be measured.</p>		
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Sammanfattning <p>Det finns anledning att ställa frågan vilken nytta en sanering av fordon gör i relation till den stora insatsen. Om kontamineringsnivån på fordonen innan sanering är låg är kostnaden inte motiverad för en sanering, även om saneringen i relativa termer är effektiv.</p> <p>I rapporten beskrivs två försök som har gjorts vid Totalförsvarets Skyddskola och ett vid en fransk provanläggning i Bourges.</p> <p>Syftet med försöken är att undersöka hur fordon kontamineras och vid vilka markbeläggningsnivåer besvärande kontamineringsnivåer på fordon kan förväntas uppstå. Vid försöken har ett similiämne använts i stället för radioaktivitet.</p> <p>Försöken i Sverige har hittills genomförts med det svenska försvarets bandvagn 206 under vinter- och sommarförhållanden och gick till så att fordonen kördes en bestämd sträcka utefter en belagd väg. Prover togs därefter på förutbestämda platser på fordonets ena sida för analys med avseende på mängd similiämne. Därefter fortsatte fordonen längs en obelagd vägsträcka och nya prover togs, men nu på fordonets andra sida. Den största mängden similiämne har i försöken ansamlats på banden och bak på vagnen, och kontamineringsnivån blev högre på vintern än på sommaren. Band och stänkskydd sanerades effektivt vid körning utefter en obelagd väg, medan det mesta av kontamineringen fanns kvar på fordonens baksida.</p> <p>Avsikten med försöket i Frankrike var att jämföra resultat från vår icke-radioaktiva metod med den franska, baserad på det radioaktiva ämnet La-140. På grund av markförhållanden blev kontamineringen på fordonet mycket lägre än i Umeå, men trots det kunde saneringseffekter uppmätas.</p> <p>Rapporten förekommer även i en svensk version.</p>		
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Content

1 Summary	2
2 Background and purpose	3
3 Introduction	3
4 The tests at the National NBC Protection School	4
4.1 Test arrangements	4
4.2 Test conditions	5
4.3 Taking samples	6
4.4 Results	8
5 The trial at DEP in France	9
5.1 Arrangements	9
5.2 Test conditions	11
5.3 Sample taking and results	11
6 Discussion	14
7 Coming activity	15
8 References	15
Non-radioactive test substances	Appendix 1
Arrangement for the measuring of La-140	Appendix 2
Result from automated measure of gamma dose-rate	Appendix 3
Results from samples along the track	Appendix 4
Transfer from the ground to test areas on the vehicles	Appendix 5

1 Summary

To set up a temporary decontamination site and to decontaminate a number of vehicles which have driven through a fall-out field is a large and time-consuming task. There is reason to ask if the benefit is large enough to motivate the effort. If the contamination of the vehicles is low, the decontamination effort may not be motivated, even if the decontamination in relative terms is effective.

The purpose of this work is to start investigating how vehicles are contaminated and at which ground deposition of radioactivity troublesome contamination levels on vehicles can be expected.

It is for several reasons difficult to perform large-scale field trials with "real" radioactivity. In the tests, in co-operation with the National NBC Protection School in Umeå, Sweden, a non-radioactive agent therefore was used; fluorescent Rhodamine carried on small particles of silica gel, substituting the radioactive deposition. At the tests, measurements were made on the amount of a specific ground deposition that is transferred to selected areas on the vehicle and the amount that disappears when the vehicle is driven in a clean area. The resulting contamination is a combination of these two processes and the trials are aimed to give values to parameters in a future model to make contamination prognosis.

The trials in Sweden have so far been performed with All-Terrain Carrier 206 during summer and winter conditions. The vehicles were driven 1000 meters on a part of a road on which the coloured silica gel had been spread. Samples were taken on selected areas on one side of the vehicles and after that the vehicles continued 1400 meters along a clean part of the road. Samples on the vehicles opposite side then were taken. After that all the samples were transported to the laboratory for analyses of the amount of Rhodamine, which is proportional to the amount of silica gel.

The largest amount of silica gel was found on the tracks and on the rear part of the vehicles, and the contamination level was higher in winter than in summer.

Within the framework of a MoU between France and Sweden a French - Swedish common trial was performed at the French testing site DEP in Bourges in April 1997. The purpose was to see, by parallel tests, if the same contamination and decontamination effects could be measured by the French radioactive and the Swedish non-radioactive method. In that case it would be possible to exchange future results. At the site it is possible to perform contamination and decontamination tests on military vehicles with ^{140}La carried on sand of variable grain size. At the site there is a 100×100 meter large area covered with grass, surrounded by 5 meter high banks. Here the radioactive test-substance is dispersed and different tests can be performed, for example to drive vehicles to get them contaminated. Close to the area there is a concrete pavement tile to which the vehicles are driven afterwards. The resulting contamination is measured, the vehicle is decontaminated and the contamination level is measured again.

The vehicle used in the tests in April 1997 was AMX-10, a tracked vehicle for troop transport. The condition of the soil (wet clay) gave such a low level of contamination that the amount of coloured silica-particles was impossible to measure. Comparisons between the two methods were therefore not possible to do, but based upon the radioactive contamination the trial gave results regarding contamination and self-decontamination. In addition the tests gave valuable

experience to the Swedish participants of how it is to work in a radioactive environment and how one secure a good control in the test conditions.

2 Background and purpose

To set up a temporary decontamination site and to decontaminate a number of vehicles which have driven through a fall-out field is a large and time-consuming task. There is reason to ask if the benefit is large enough to motivate the effort. If the contamination of the vehicles is low, the decontamination effort may not be motivated, even if the decontamination in relative terms is effective.

The purpose of the trials was to start investigating how vehicles are contaminated and at which deposition levels of radioactivity troublesome contamination levels on vehicles can be expected. The results are expected to enhance the base of knowledge when operations in fall-out fields are performed and when new regulations of protection are made.

3 Introduction

It was for several reasons difficult to perform large-scale field trials with "real" radioactivity in Sweden. In the tests, in co-operation with the National NBC Protection School in Umeå, a non-radioactive agent therefore was used, substituting the radioactive deposition. After some pilot tests close to the National NBC Protection School in Umeå, two tests were performed during 1996, with the fluorescent RhodamineB (RhB) carried on small particles of silica gel as the test substance. The size of the particles ranged between 60 - 200 μm . In the case of a near-surface nuclear weapon detonation a large fraction of the deposition will be ground material, which holds a lot of silica, so by that respect silica particles are suitable as test substance. Particles from a surface burst will start to fall from a height of about 2 kilometres if the yield is a few kilotons and about 20 kilometres for a weapon in the megaton range. In both cases particles greater than 30 μm will reach the ground within a few to 20 hours. Following a surface burst, 25 – 30 percent of the total activity can be on these large particles. Due to the fact that short time has elapsed since the burst, both the radioactive decay and the range of the area will be small. This means that these large particles will give the highest deposition and corresponding doses.

Vehicles driven in fall-out areas will be contaminated by processes where radioactive substances on particles in the ground material are transferred to the vehicle. In our trials a test substance substituted the radioactivity, but the interesting process (the transfer of particles from the ground) is the same. Test results, based on deposition expressed as the amount of test substance per unit area (mg/m^2), can then directly be transformed into real situations with contamination expressed as radioactivity per unit area (Bq/m^2).

In April 1997 a common test was performed together with French researchers from Delegation Generale pour l'Armament (DGA) at its testing site Centre de Décontamination et d'Etudes de Protection Nucléaire (DEP) in Bourges. The test particles at that occasion were silica particles as before, but this time coloured with methylene blue. At the test silica particles of the same size marked with the radioactive nuclide ^{140}La were also used.

The amount of silica particles in the samples taken is determined by analysing the amount of Rhodamine or methylene blue in the samples.

4 The tests at the National NBC Protection School

4.1 Test arrangements

The device for dispersion of test substance consists of a 2,5-m long stainless steel pipe (\varnothing 25 mm) with 5-mm holes drilled each 50-mm. Four plastic cans were symmetrically connected to the pipe from above. The plastic cans contained the test substance and the pipe was driven to oscillate laterally by pressurised air. At dispersion the drilled holes were directed downwards and the oscillating made the test substance to be spread within 2,7 m width.

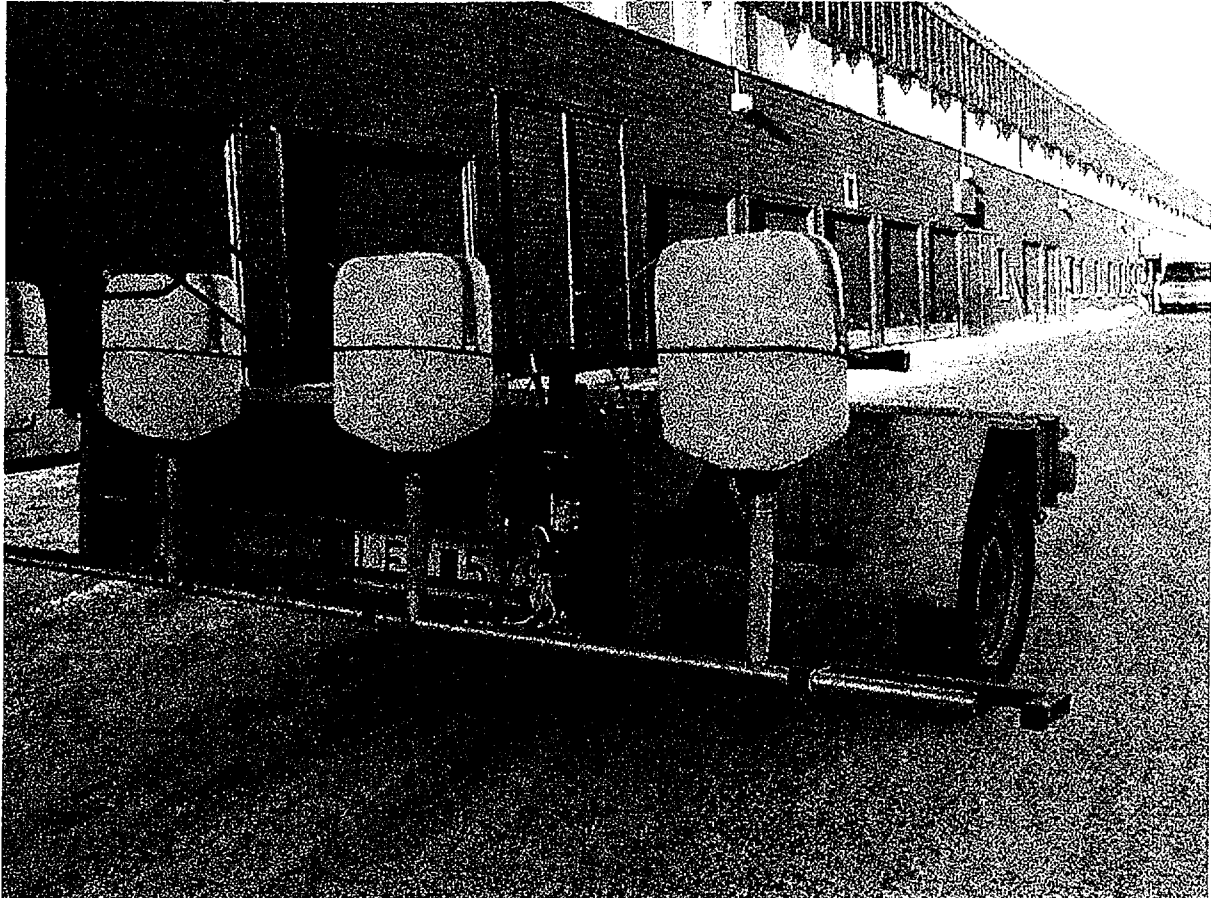


Figure 1 The dispersion device

The dispersion device hanged on the back of a trailer to a private car and the test substance were dispersed on a 1000 meter long part of a gravel road close to the National NBC protection school in Umeå. The car drove three times along the selected part of the road and the plastic cans were exchanged before each run. A small side shift each time made the covered width to be 3 meter.

Vehicles contaminated in the tests were All-Terrain Carrier 206, which have a width of 1.8 meter. Two vehicles were used, driving at a speed of 30 - 40 km/h in the middle of the road and separated approximately by 50 meters, very well corresponding to normal marching. The vehicles stopped immediately before the end of the covered part of the road and the sample taking started at once. Samples were taken on the traction vehicle's left side (driver's side) and on the trailer's right side.

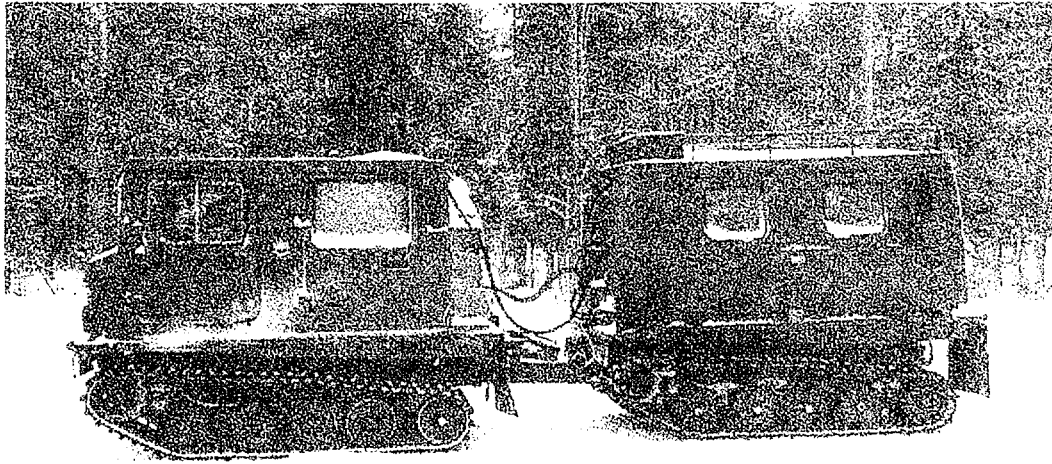


Figure 2 All-Terrain Carrier 206

When the sample taking were terminated the vehicles were driven 1400 meters along an uncontaminated road and then stopped for another sample taking. This time the samples were taken on the traction vehicles right side and on the trailers left side. The purpose was to see what decontaminating effect driving in an uncontaminated area gives.

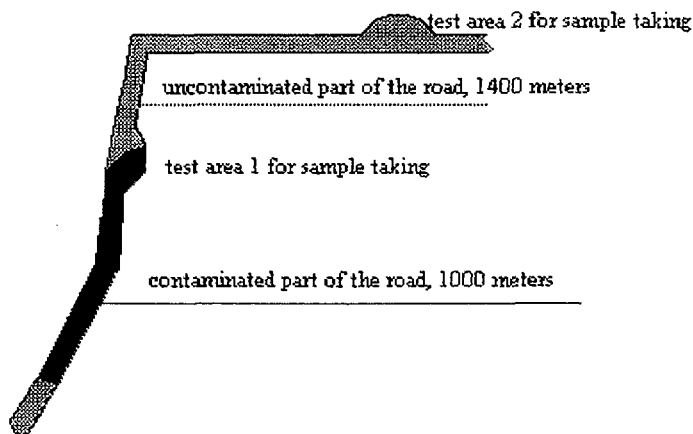


Figure 3 The test road with places for sample taking

4.2 Test conditions

Two tests were performed during 1996. The test conditions were selected to represent two extremes regarding contamination. The first test was performed during winter condition with the test substance on newly fallen wet snow and the second test in summer time after a long dry period, making the road dry and dusty.

4.2.1 The first test, winter

The road was frozen with a few centimetres of rugged hard snow, covered with a thin layer of newly fallen wet snow. The test was made between 09:00 and 12:00. The temperature was

- 1° C, it was overcast, no wind and a very slight snowfall. The night before the test the temperature was between -3 and - 5° C. The dispersed amount of silica was 17.4 kg.

Taking the samples, with two teams, took about one hour each time.

4.2.2 The second test, summer

The road was very dry and dusty. The tests were performed between 10:00 and 13:00. The temperature was + 25°C, it was sunny and no wind. The dispersed amount of silica was 22 kg.

4.3 Taking samples

Sampling was made by flushing the selected areas on the vehicle with de-ionised water and collecting the flush water into small cans. Equipment for the sample taking was specially made aluminium plates, designed to secure that all flush water was collected. For the tracks and mudflaps the water was flushed down to a wide plastic box, wide enough to collect all the water.

When possible, accumulated snow was collected. Where the samples were taken and their sample codes are shown in Figure 4a and 4b.

The sample taking was performed in the same way on both vehicles. Samples from the first vehicle are marked with "A" after the number and from the second vehicle with "B".

Fabrication of the test substance and the evaluation process is described in Appendix 1.

←← driving direction

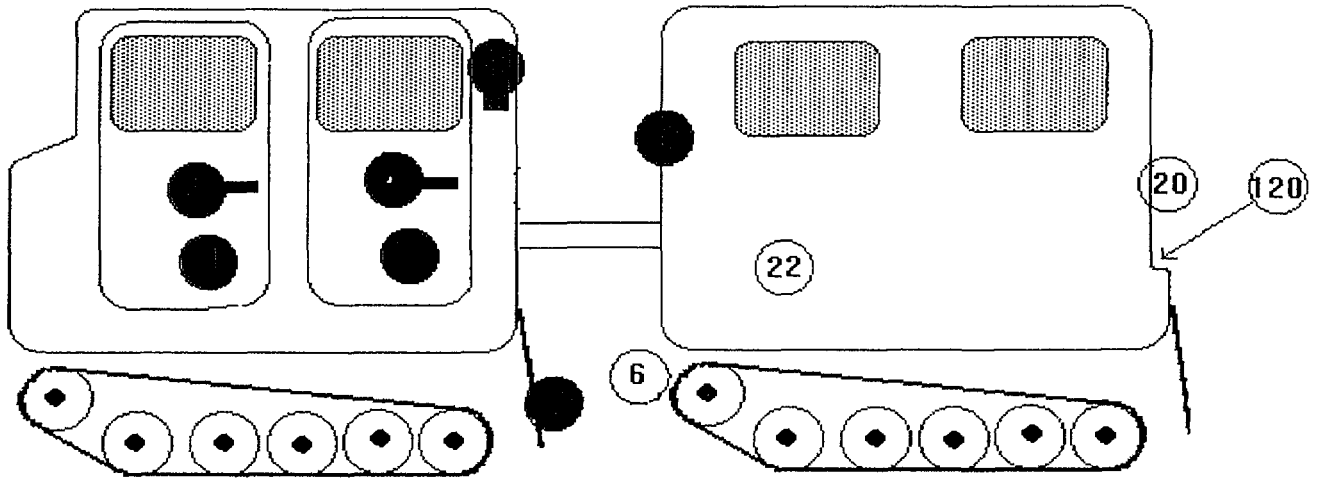


Figure 4a Where samples were taken on the vehicle's left side (driver's side)

driving direction ⇒⇒

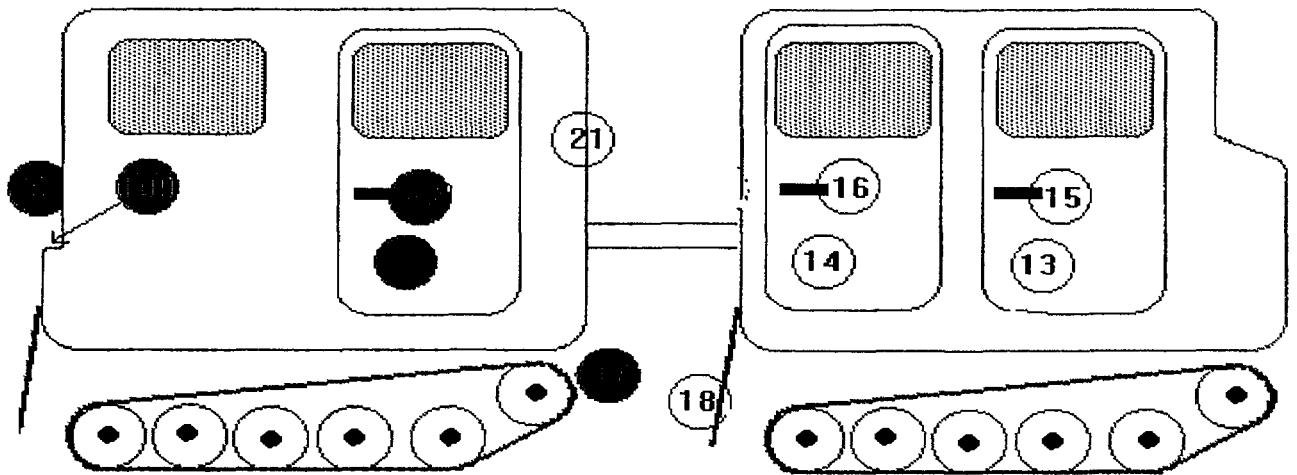


Figure 4b Where samples were taken on the vehicle's right side

After the first (contaminated) part of the test road the following samples were taken (marked with blue colour ●): 1, 2, 3, 4, 5, 7, 9 (back on the right side), 10 (corner on the left side), 11, 12, 17 and 109.

After the second (clean) part of the test road the following samples were taken (marked with yellow colour ○): 6, 13, 14, 15, 16, 18, 20 (back on the left side), 21 (corner on the right side), 22 and 120.

4.4 Results

The amounts of Rhodamine-coloured silica measured in samples from the selected objects are shown in Table 1 (the detection limit is 0,1 mg)

Table 1 Measured amounts of silica in samples

object	object size (m×m)	after ● part 1		after ○ part 2		after ● part 1		after ○ part 2	
		winter				summer			
		sample	silica (mg)	sample	silica (mg)	sample	silica (mg)	sample	silica (mg)
door	0,35×0,35	1A	11	13A	0.3	1A	0.4	13A	0.21
		1B	4.2	13B	<0.1	1B	0.4	13B	0.19
door	0,35×0,35	2A	5.5	14A	0.5	2A	0.3	14A	0.2
		2B	3.8	14B	<0.1	2B	0.3	14B	0.2
handle	0,12×0,18	3A	11	15A	<0.1	3A	0.4	15A	0.2
		3B	3.4	15B	<0.1	3B	0.8	15B	0.2
handle	0,12×0,18	4A	7.7	16A	1.4	4A	0.9	16A	0.2
		4B	3.1	16B	0.9	4B	0.7	16B	0.2
air inlet	0,33×0,14	5A	1.9			5A	0.3		
		5B	<0.1			5B	0.3		
mudflap	0,65×0,33	7A	110	18A	3.4	7A	2.4	18A	0.4
		7B	49	18B	1.7	7B	2.0	18B	0.3
back, trailer	0,50×0,50	9A	410	20A	210	9A	2.7	20A	3.0
		9B	560	20B	190	9B	0.8	20B	2.7
front, trailer	0,43×0,38	10A	6.8	21A	7.8	10A	0.3	21A	0.3
		10B	6.0	21B	14	10B	0.2	21B	0.2
door, trailer (se note 1)	0,35×0,35	11A	<0.1	22A	0.3	11A	0.3	22A	missing
		11B	<0.1	22B	<0.1	11B	<0.1	22B	missing
handle, trailer	0,12×0,18	12A	2.0			12A	2.5		
		12B	0.2			12B	0.9		
tracks	0,65×0,30	17A	15	6A	0.9	17A	0.7	6A	0.4
		17B	680	6B	<0.1	17B	0.7	6B	0.4
Back edge, trailer	0,10×0,60	109A	500	120A	410	109A	210	120A	190
		109B	320	120B	290	109B	140	120B	60

note 1: There is a door only at one side of the trailer. The sample after part 2 therefor is taken at the corresponding area on the trailer, see figure 4a and 4b. Test area 22 has the size 0.50×0.55 (m×m)

As can be seen from the test conditions the amount of dispersed Rhodamine-coloured silica per m² was larger at the summer test. The relation between the amounts in the summer test to the

winter test is $22/17.4 = 1.26$, by which the values for the winter test in the table should be multiplied to be comparable to the summer values.

Tracks, mudflaps, the back side of the trailer and the back edge of the trailer are the objects where most silica has been accumulated, both in the summer and winter tests. Of these objects the tracks and mudflaps were effectively decontaminated when driving the uncontaminated part of the road. The back side and the back edge of the trailer, on the contrary, were much less decontaminated. This holds both for the summer and winter tests.

The handles on the traction's doors were heavily contaminated. Regarding the decontamination effect the outcome from the winter test is a bit hard to interpret, while for the summer test the amount was reduced to one third.

The residual amounts of silica after part 2 of the test road in relation to the amounts after part 1 have been calculated, when possible, see Table 2

Table 2 Residual amounts of silica after part 2

Object	sample codes	residual amount of silica, % (winter)	residual amount of silica, % (summer)
door	1A,B - 13A,B	1	51
door	2A,B - 14A,B	5	65
handle	4A,B - 16A,B	21	31
mudflap	7A,B - 18A,B	3	17
back, trailer	9A,B - 20A,B	41	--
tracks	17A,B - 6A,B	< 1	58
back edge, trailer	109A,B - 120A,B	85	71

A comparison between the results from the winter and summer tests (table 1 and 2) shows that the winter test gave 9 times higher contamination, but a more effective self-decontamination.

5 The trial at DEP in France

Within the framework of a Memorandum of Understanding (MoU) between Sweden and France, plans were initiated during 1996 to make a common Swedish-French trial at the French testing site DEP in Bourges. At that site there are, among other facilities, possibilities to perform trials concerning contamination and decontamination of military vehicles. The activity is based on the radioactive nuclide ^{140}La , carried on sand of variable grain size. At the site there is a 100×100 meters large field, overgrown with grass. The ground material is clay. In this area the radioactive test substance is spread and different tests can be performed, for example to drive vehicles along a path to get them contaminated. In connection to the field there is a concrete-covered area to which the vehicles are driven afterwards. The resulting contamination is measured, the vehicles are decontaminated and the contamination is measured again.

5.1 Arrangements

The purpose was, by parallel trials, to see if the French radioactive and our non-radioactive method could detect the same contamination and decontamination effects. If so, this should make it possible to exchange future results.

Before the trials we changed from Rhodamine to Methylene blue, in order to get a more stable test substance, and the reason was that we were not sure to have as good control on the trial conditions as we have at home. This should counterbalance the drawback of a slightly lower detectability. The equipment for dispersion of the test substance that we had used in the trials at the National NBC-protection school was transported to DEP and mounted on a special vehicle for dispersion.

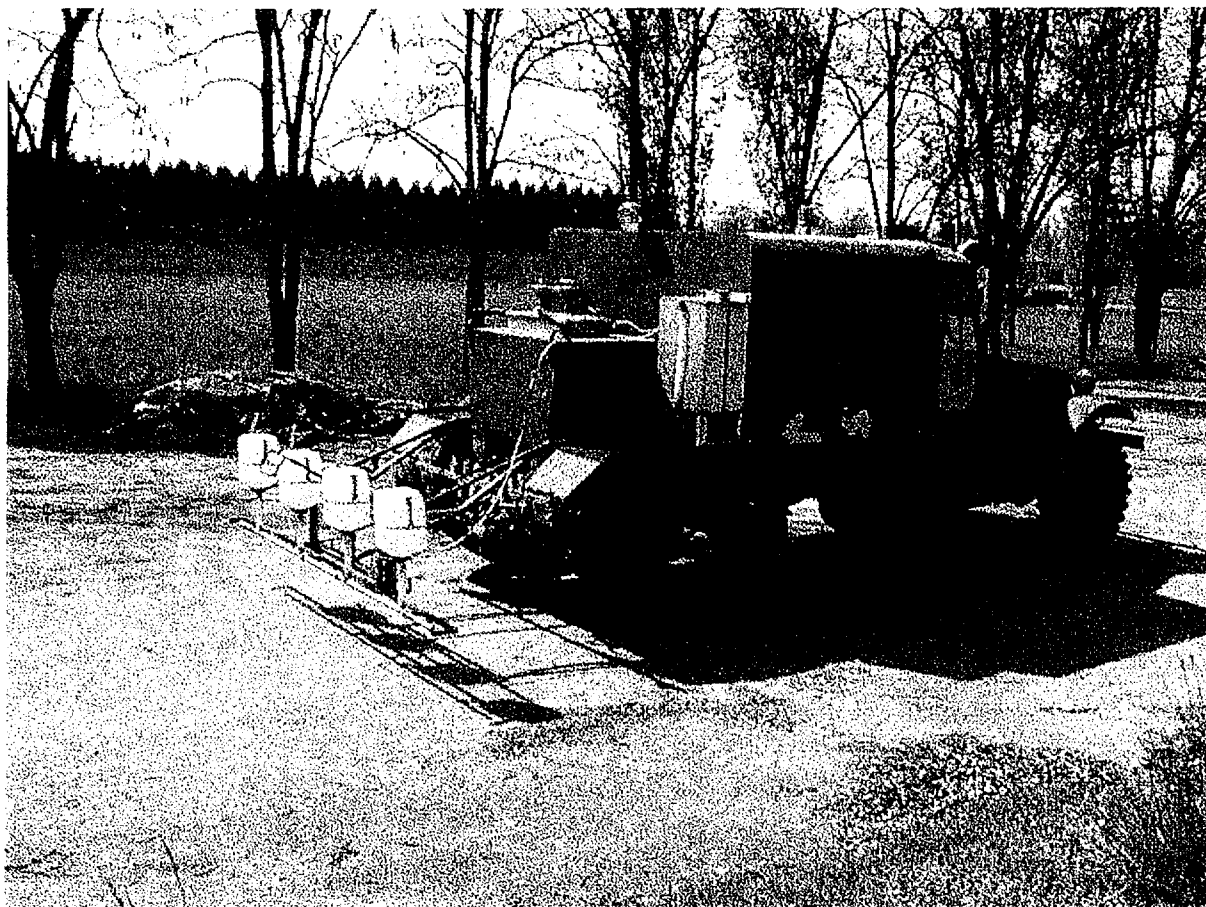


Figure 5 FOAs equipment mounted on DEPs vehicle for dispersion

This time our test samples would contain the radioactive nuclide ^{140}La together with the Methylene blue and we wanted to measure this content. There were two reasons: Firstly we needed to know the content to be able to decide when the samples could be sent to Umeå with respect to transport regulations for radioactive goods. Secondly we were interested to know the relation between our non-radioactive and the French radioactive test substance. During the preparation for the trial we therefor built a special detector arrangement to be able to measure the content of ^{140}La in samples.

The date for the trial was set to April 9, 1997. To get a wet track with an effective contamination the test area was sprinkled with water continuously several weeks before the trial. This sprinkling showed later on having been too heavy.

The vehicle chosen for the trial was AMX-10, a track vehicle for troop transporting. During preparation a number of test areas were selected on which samples were to be taken. The day before the trial these areas were marked on the vehicle. The selected areas and their codes are

shown in figure 6. In the codes 'B' stands for 'Before', that is before driving in the uncontaminated area and 'A' stands for 'After'. According to the plan the vehicle should drive three laps along a quadratic track with dimensions 80 × 80 meters, and after that the contamination should be measured and samples were to be taken on areas marked with 'B'. After that the vehicle should drive 1 kilometre in an uncontaminated area, the measurements should be repeated and we should take samples on areas marked with 'A'. The speed should in both cases be 30 km/h.

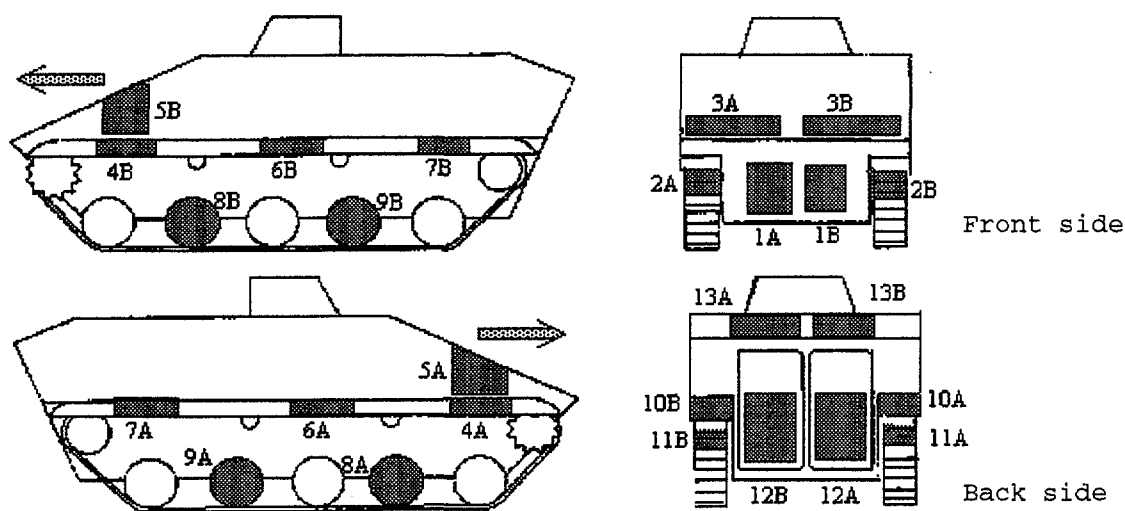


Figure 6 Test areas on AMX-10

In addition to taking samples to detect coloured or radioactive particles, the vehicle also should be measured regarding the gamma radiation level from ^{140}La . The measurement should be performed both with hand-held dose-rate meters at the selected areas and as an automated measurement with 50 detectors in a measuring ramp. For this trial the sand normally used as carrier of ^{140}La , had been substituted by silica particles with the same grain size as the Swedish test substance.

5.2 Test conditions

The contaminated track was on very wet clay soil, partly covered with grass. The trial was done between 05:00 – 12:00 (am). The temperature rose from -5°C at the beginning to $+10^{\circ}\text{C}$ at the end of the trial, it was clear sky and no wind. After dispersion the contamination was 185 MBq/m^2 of ^{140}La and 9.4 g/m^2 of coloured silica.

The track for self-decontamination was on dry grassland.

5.3 Sample taking and results

On the day for the trial 24 water-filled bowls and 12 adhesive plates were put in a regular pattern along the track. The placement of the plates and bowls and their codes are shown in Appendix 4. The purpose was to get a picture of the uniformity in the contamination, by taking the bowls and plates in for measurements after the dispersion of the test substances. After that

the Swedish and the French test substance in that order were spread and the trial were performed according to the plan.



Figure 7 Taking samples of the test substance. It is necessary to wear protective masks and tight clothing due to the risk of external and internal contamination with ^{140}La

Taking samples was done with the same method as in the trials at the National NBC-school. The selected test areas were flushed and the flush water was collected into cans for later analyse. All cans had the same size because their contents of ^{140}La were to be measured in a specially designed and calibrated measuring device, see Appendix 2.

The detection limit for the amount of silica particles coloured with methylene blue in a sample was 4 mg. As the relation between the dispersed amounts of coloured and radioactive particles was known, it was possible to estimate the lowest activity of ^{140}La in a sample needed to make it possible to measure the amount of methylene blue in the same sample. This lowest activity was estimated to about 80 000 Bq, and as the highest activity measured in a sample was 4020 Bq it was very unlikely that measurable amounts of methylene blue would be found in the samples. This conclusion was later on confirmed when the samples were analysed in Umeå. A comparison between our non-radioactive and the French radioactive method has therefore not been possible to do, so in that respect the result was negative.

Table 3 Measured activity of ^{140}La in samples

test area	dimensions (m)	code	activity (Bq)		
			after moment 1	after moment 2	
1	0,4×0,4	1B	210	1A	19
4	0,19×0,4	4B	370	4A	22
5	0,6×0,4	5B	120	5A	32
6	0,19×0,4	6B	60	6A	63
7	0,19×0,4	7B	650	7A	43
8	diam: 0,5	8B	1700	8A	305
9	diam:0,5	9B	3130	9A	752
10	0,2×0,4	10B	4020	10A	499
12	0,4×0,5	12B	30	---	
13	0,4×0,6	13B	2940	13A	3940

As seen in figure 7 a lot of ground material was accumulated in the tracks, but no samples were taken here. The reason was mainly the difficulty to define what the sample represented, for example regarding area.

Analyses and comparisons of the bowls and plates put out before the dispersion of test substances, shows that neither the dispersion of silica with methylene blue or with ^{140}La becomes uniform along or cross the pathway. Results regarding dose rates, ^{140}La -activity and the later on measured amount of coloured silica are shown in Appendix 4.

One interesting notification could be made. The radioactive test-substance was spread so that there was about twice as much radioactivity on the outer part of the track as on the inner part. This difference is seen in the result from the automated measurements made on the vehicle after it had been driven along the track. In the measured points on the vehicles right side, which has faced the outer part of the track, the mean value of the dose-rate is 25 % higher than the mean value from the left side, see Appendix 3.

In the same way as after the trials at the National NBC-school it is possible to see the effects of self-decontamination, by comparing measured values from before and after driving the self-decontamination track for the corresponding test areas. Based on the values in Table 3, and corrected for the observed inhomogeneity mentioned above, you get the following table:

Table 4 Residual amounts of ^{140}La after part 2

test area (see Figure 6)	remaining amount of ^{140}La (%)
1	7
4	5
5	21
6	82
7	5
8	14
9	19
10	10
13	100

Due to the fact that the test gave a limited result, a decision was made that the track should be left to dry and then a new trial should be made in June 1997. All equipment and the remaining test substance were for that reason left at DEP. The trials could however not be performed, because of heavy rain for a long period of time. The test site did not get dry enough to do the tests, and the equipment is now back in Umeå.

6 Discussion

The tests at the National NBC Protection School in Sweden and at DEP in France shows that vehicles are contaminated when driven in an area with dispersed silica particles. Particles are transferred from the ground and sticks to the vehicle and later on they come loose again. It is reasonable to believe that these processes are independent of if the particles are carrying Rhodamine, methylene blue or some radioactive nuclide. If the ground deposition is expressed as the amount of silica particles or the number of bequerelles per unit area should for that reason be unimportant, as long as you talk about the relation between the ground deposition and vehicle contamination. The size of the particles we have chosen in the test lies in an interval relevant for deposition areas where the transport time for the particles is less than 24 hours. In areas more far away the particles will be smaller, but as the contamination process means that radioactive particles comes with ground material the size of these particles will be of small importance. The results and tendencies from our test should be general to fall-out areas in common.

The tests we have made so far are of course far too limited and give to little data to permit far going conclusions to be drawn from them. The result anyhow gives some interesting hints and give rise to questions. With more test data, under different conditions, it should be possible to have an idea of which contamination levels you can expect in a certain deposition situation. You also should gain more knowledge of where on vehicles the radioactivity probably will be accumulated and what doses this will give to personnel inside.

The three trials are indicating important differences on how contamination and self-decontamination depends on the ground conditions. The highest contamination we did have during winter conditions on a wet gravel road, followed by summer conditions, with the same road dry and dusty. The lowest contamination came when the ground was very wet clay soil. A

reason for this can be that no small particles whirled up, it was nothing or large clods. If you give the contamination as the transferred amount per unit area in relation to a unity deposition, the relation between the three trials are approximately as 1 – 0.1 – 0.001, see Appendix 5.

On the other hand the results indicates that self-decontamination is more effective during winter conditions. If it in general is so that conditions giving a heavy contamination also mean an effective self-decontamination, maybe the doses will not be the largest when the contamination (transfer of ground material) is at maximum.

A contaminated vehicle constitutes a risk in two ways. Firstly, the accumulation of radioactivity will create a radiation source, giving external irradiation of personnel inside the vehicle or in the vicinity of it. The resulting doses must be put in relation to doses because of radiation from radioactivity on the ground. The resulting doses from these sources must be put in relation to the dose generated from the radioactivity deposited on the ground.

To drive through an area with no ground deposition gave a very small reduction in the accumulated amount on the back of the vehicle, and it is possible that decontamination efforts should be concentrated to this part.

Secondly, the radioactive particles can be transferred to personnel coming in contact with contaminated parts of the vehicle. Here the handles are the most relevant objects. They accumulated a lot of particles, but were effectively cleaned when the vehicle drove along an uncontaminated road, at least during the winter test. What this means regarding risk is uncertain.

The test in France showed the importance of good preparations and trial conditions. It is important to have the dispersion of test substances well in hand. If the deposition not is uniform sideways, our method to take samples on different sides before and after the decontamination will give wrong values in decontamination constants. This is due to the fact that the calculations are based on the assumption that both sides of the vehicle are contaminated equally much. To deal with this problem you either must have a dispersing method you know will give a uniform deposition, or you must measure the non-uniformity and correct for it when interpreting the result.

7 Coming activity

In the beginning of 1999 we will make another trial, this time with the radioactive ^{24}Na mixed with sand as test substance. We will use All-Terrain Carrier 206 and the trials will take place on the testing site belonging to the National NBC-defence School in Umeå. Parallel to the trial calculations will be made of the resulting doses, based upon data from the test.

8 References

FOA orienterar om Kärnvapen, nr 15 1990 (in Swedish)
ISBN 91-7056-076-5

Appendices

Appendix 1

Non-radioactive test substances

RhodaminB (RhB)

Colouring silica gel (silica particles)

The silica gel used has a size of 70 230 *mesh*, which corresponds to 60 – 200 μm . In the colouring 44 μg RhB was used per gram silica gel. RhB was mixed with water and added to the silica. Then more water was added, about 3 times as much as the amount of silica, and the mixture was left for 30 minutes under stirring. After this the water was removed by filtering and the silica gel was further dried by mixing with a desiccant. The silica gel was then separated from the desiccant by sifting and stored in plastic can in a freezer. Analysis of the filtered water shows that practically all RhB was absorbed on the silica gel, which gave 44 μg RhB g^{-1} silica.

Sample preparation and determination of RhB

The samples were filtered to separate silica from water (filter Munktell no 3). The filter paper together with silica and sand was put into a test tube and mixed with 10 ml of ethanol (95%) for extraction of RhB. For some samples, containing much sand and silica, more ethanol than 10 ml was needed. Up to 30 ml was used for some of the samples. The samples were extracted during at least three days with agitation. The samples were then filtered once more to separate ethanol and RhB from the silica (filter Munktell OOH). The content of RhB in the ethanol was determined with a fluorometer. The excitation wavelength was 546 nm and the emission wavelength was 578 nm. The system was calibrated using RhB in methanol and the detection limit was 0.5 ng RhB ml^{-1} in practice, which corresponds to 0.1 mg of test substance if 10 ml of ethanol was used. The extraction yield for RhB in ethanol was determined to 89% (std 2%, n=6) for concentrations up till 440 ng RhB ml^{-1} .

Checking the test substance before the tests

It was shown that RhB degenerates when the coloured silica gel is in contact with air. A thin layer of coloured silica was completely decoloured within 24 hours. This was advantageous as it makes it possible to repeat the test in the same place a few days later, without interference from earlier tests. Storage of the coloured silica in filled plastic cans in a freezer limits the degeneration substantially, but it was still necessary to make corrections for the degeneration when analysing the samples from the tests. Another factor that had to be accounted for was the moisture of the silica gel. Drying the test substance by means of a desiccant did not remove all the water from the silica and as the silica weight was dependent on the amount of water, the concentration of RhB per gram of silica was changed if the silica was not dry. It was shown that the weight of silica could be up to 30 % higher after colouring, due to moisture. It was therefore necessary to determine the content of water in the silica gel prior to the tests. A check of the test substance before the tests was done by four weighed portions of the coloured silica (2×30 and $2 \times 80\text{mg}$). RhB was extracted with ethanol and analysed as mentioned above. The result, corrected for the extraction yield, was the true content of RhB in the test substance.

Reference samples

To determine the yield of the sample preparation and possible losses of RhB due to degeneration, four reference samples were used. The reference samples constitutes of weighed

amounts of the test substance in plastic cans, 2×30 and 2×80 mg. The samples were prepared as close as possible to the time when the test substance was dispersed. In this way the time for air exposure of the reference samples and the test samples will be approximately the same. The reference cans were filled with de-ionised water (about 400 ml) and stored overnight in a refrigerator in the same way as the other samples. The reference samples were then prepared and analysed in the same way as the test samples and the yield was evaluated as the analysed amount divided by the known, weighed amount. The yield has varied between 30 and 50 %.

Methylene blue (MeB)

Colouring silica gel

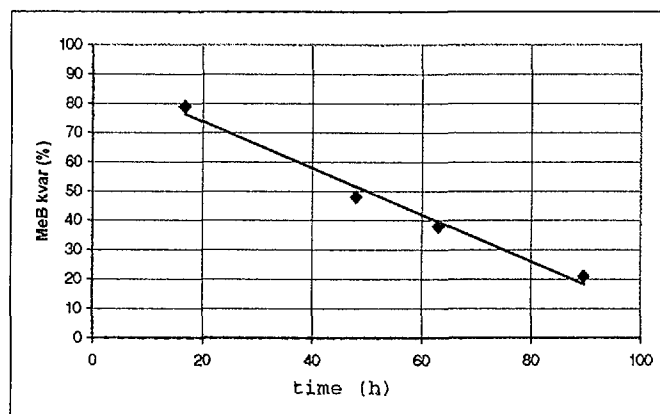
Three grams of methylene blue was used to dye 1 kg of silica gel (70 – 230 mesh). Silica and a solution of methylene blue in water was mixed and left for a couple of hours. The mixture was stirred some times during that time. The mixture was then filtered and the silica was dried in an oven at approximately 80°C. The coloured silica was stored in a refrigerator in plastic cans. Analyses of the water after the colouring process showed that practically all the MeB stuck to the silica, which gave 3 mg MeB g^{-1} silica.

Sample preparation and evaluation of MeB

The samples were filtered (Munktell no 3) to separate silica and soil from the water used when taking the samples. The filters with silica and soil were dried in an oven. The mixture of silica and soil was weighted and homogenised before a fraction (at least 20 mg) was taken for analysis. 25 ml of dimethylsulphoxide (DMSO) was added and the samples were extracted under rotation overnight. The samples were then centrifuged and the amount of MeB in DMSO was measured in a spectrophotometer at 665 nm. The background was measured at 520 and 740 nm. The practical measuring limit was about $0.5 \mu g ml^{-1}$, which corresponds to approximately 4 mg test substance if 25 ml of DMSO was used. The extraction was complete (100% yield) if maximum 20 μg MeB per ml DMSO was extracted. Based on visual control of the content of test substance, different amounts of sample were taken for analyse. From 20 mg (large content) up to 700 mg (small content) have been used.

Stability of the test substance

The reason to use MeB instead of RhB in Bourges was that the degeneration of MeB in air was slower than for RhB. The degeneration rate for MeB is shown in the figure.



Due to the initial high activity of ^{140}La in the samples they had to be stored in a refrigerator before the analysis of MeB, awaiting the decay of ^{140}La . The stability of the test substance in water was therefore checked before the trial. No degeneration/leaching could be detected for 100 mg of test substance in 100 ml of water after 7 days in a refrigerator.

Reference samples

At the trial in Bourges, water filled bowls were placed on the track before the test substance was dispersed. These bowls were later collected and analysed to give a measure of the uniformity of the deposition. These samples substitutes the reference samples used at the trials with RhB and were used to correct for effects of a possible degeneration of MeB.

Appendix 2

Arrangement for the measuring of ^{140}La

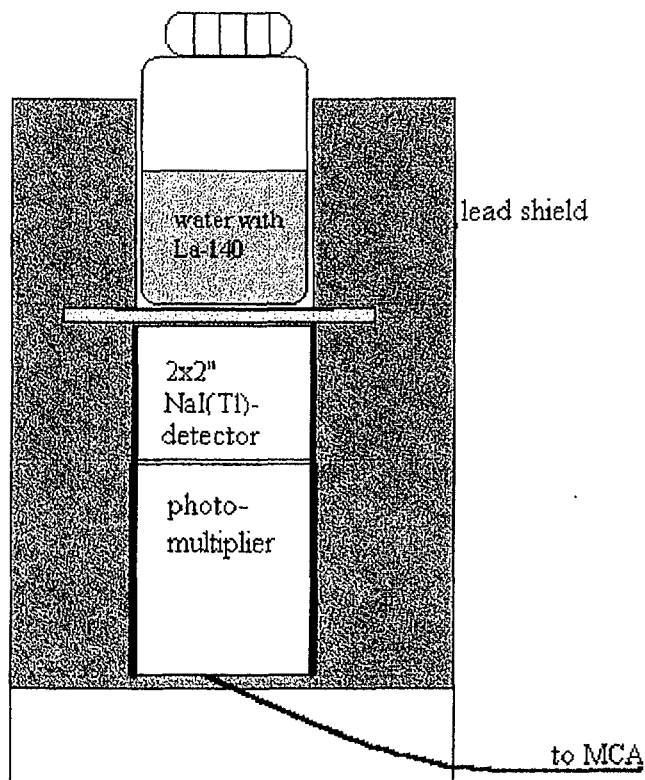


Figure Principal sketch on measuring arrangement

Facts about ^{140}La

^{140}La transforms through β^- -decay into ^{140}Ce .

The half-life is 40,27 hours.

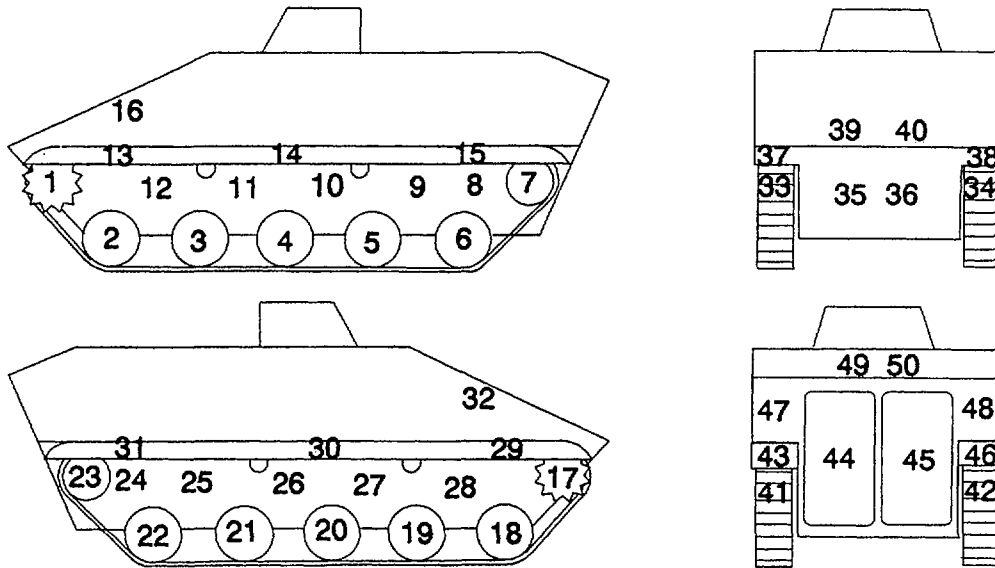
The most common gamma-lines are

energy (MeV)	abundance (%)
0,329	20,7
0,487	45,9
0,816	23,6
1,596	95,4

In the evaluation the photo-peak from 1,596 MeV is used

Result from automated measure of gamma dose-rate

CONTAMINATION AVEC DU GEL DE SILICE ACTIF DE L' AMX10



Essai du 9 avril 1997

points de mesure	mesures avant décontamination	mesures après autodécont.	résiduel
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Mesures exprimées en mrad/h

1	120	30	25%
2	64	16	25%
3	67	16	24%
4	72	18	25%
5	71	20	28%
6	78	21	27%
7	103	34	33%
8	90	29	32%
9	92	38	41%
10	85	21	25%
11	138	20	14%
12	73	20	27%
13	48	12	26%
14	52	13	25%
15	81	38	47%
16	15	4	25%
17	199	54	27%
18	91	30	32%
19	85	30	35%
20	88	30	34%
21	86	33	38%
22	93	37	40%
23	117	55	47%
24	128	49	39%
25	130	76	58%

points de mesure	mesures avant décontamination	mesures après autodécont.	résiduel
------------------	-------------------------------	---------------------------	----------

Mesures exprimées en mrad/h

26	131	35	27%
27	115	26	23%
28	105	28	27%
29	64	22	35%
30	62	22	36%
31	65	30	46%
32	22	8	35%
33	87	27	31%
34	60	17	29%
35	7	1	15%
36	5	1	20%
37	15	4	31%
38	9	2	25%
39	6	2	34%
40	5	1	30%
41	77	29	38%
42	88	64	73%
43	29	15	51%
44	6	3	53%
45	8	4	52%
46	42	43	102%
47	5	2	44%
48	6	5	83%
49	7	3	38%
50	6	2	39%

	66	23	35%
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Results from samples along the track

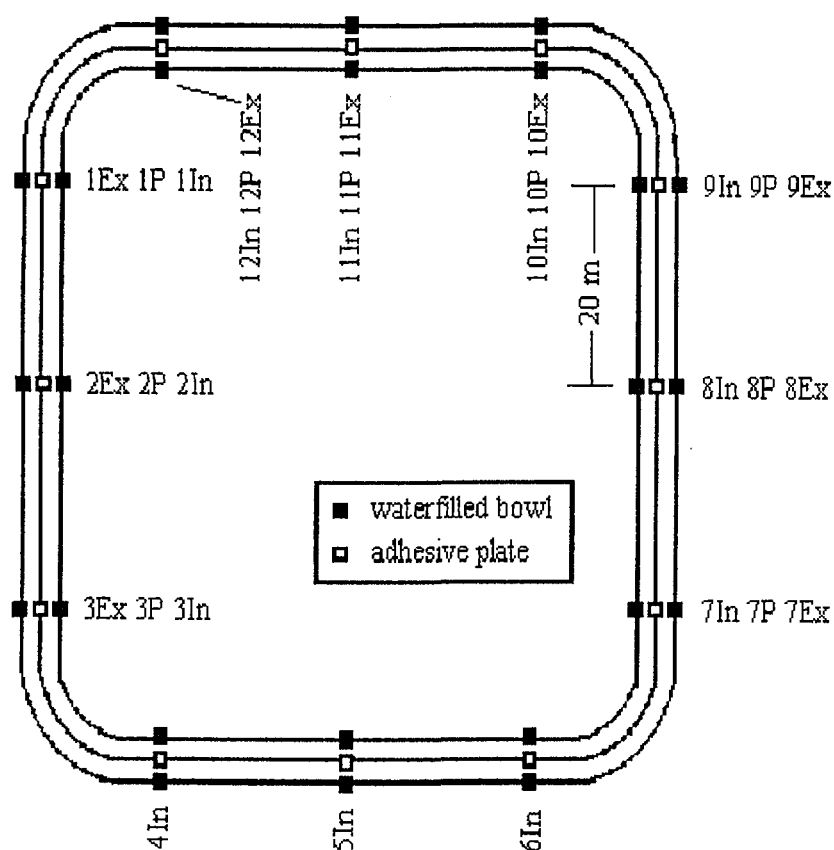


Figure Placement of bowls and plates along the track

position	DEP measurements (bowls and plates, mrad/h)			FOA measurements (cans, La-140, MBq)		FOA measurements (cans, MeB + silica, mg)	
	IN	EX	P	IN	EX	IN	EX
1	29,5	24,8	5,3	29,5	33,8	<4	<4
2	1	21,1	9	0,74	13,8	243	103
3	7,1	22,4	4,4	4,42	14,5	305	158
4	0,6	5,5	11,1	0,37	3,31	4	235
5	1,5	8,8	8,5	0,91	5,18	302	206
6	0,5	15,1	7,6	0,2	9,97	153	85
7	2,4	5,1	9,9	1,47	3,2	289	301
8	8,3	14,9	4,7	5,15	9,41	361	217
9	2,7	6,2	5,6	1,76	3,69	390	<4
10	3,6	21,4	6	2,27	14,6	612	<4
11	2,3	10,8	9,1	1,47	6,98	173	38
12	3,9	12,4	9,5	2,24	7,51	335	5

Appendix 5

Transfer from ground to test areas on the vehicles

Trials at Skydds

test area	area (m ²)	winter		summer	
		silica (mg)	transfer (g/m ²)/(g/m ²)	silica (mg)	transfer (g/m ²)/(g/m ²)
front door	0,123	7,38	1,0E-02	0,39	4,3E-04
rear door	0,123	4,63	6,5E-03	0,3	3,3E-04
front handle	0,022	7,05	5,5E-02	0,6	3,7E-03
rear handle	0,022	5,4	4,2E-02	0,78	4,9E-03
air inlet	0,046	0,95	3,6E-03	0,28	8,3E-04
flap	0,215	81,84	6,6E-02	2,23	1,4E-03
back side, trailer	0,25	486,74	3,4E-01	1,74	9,5E-04
front side, trailer	0,163	6,42	6,8E-03	0,26	2,2E-04
handle, trailer	0,022	1,1	8,6E-03	1,69	1,1E-02
back edge	0,06	408,4	1,2E+00	176,3	4,0E-01
		mean: 1,7E-01		mean: 4,3E-02	

Trials in Bourges

Test area	area (m ²)	activity (Bq)	transfer (Bq/m ²)/(Bq/m ²)
1B	0,16	210	7,1E-06
4B	0,076	370	2,6E-05
5B	0,24	120	2,7E-06
6B	0,076	60	4,3E-06
7B	0,076	650	4,6E-05
8B	0,196	1700	4,7E-05
9B	0,196	3130	8,6E-05
10B	0,08	4020	2,7E-04
12B	0,2	30	8,1E-07
13B	0,24	2940	6,6E-05
		mean: 5,6E-05	