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Best Service Solutions

ENVIRONMENTAL SOLUTIONS FOR MILITARY SHOOTING RANGES IN NORWAY AND FINLAND

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Grete Rasmussen, Norwegian Defence Estates Agency
Arnljot Strømseng, Norwegian Defence Research Establishment
Sara Kajander, Construction Establishment of Finnish Defence Administration

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SHOOTING RANGES - A GREAT ENVIRONMENTAL CHALLENGE FOR THE DEFENCE FORCES

- **200 military shooting ranges in Finland and 800 in Norway, rifle and pistol**
- **In both countries about 12 million shots/year, 100 t Pb/year**
- **Environmental legislation applies to military activity as well as civilian → hardened requirements**

- **BAT for constructions? Remediation need and methods? National and international guidelines/recommendations?**

Weight: 8 g

"heart" 6 g:
lead 95…98 %,
antimony 2…5 %

jacket 2 g:
brass (**copper** 90 %,
zinc 10 %)

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THE SHOOTING RANGE PROJECT

- An in-official co-operation project between Norwegian and Finnish armed forces
- Aims
  1. Determine the distribution of metals in shooting range soil and the environmental impacts of a range
  2. Understand processes for leaching of metals
  3. Find the technically and economically best way to prevent migration of heavy metals into soil, surfacewater and groundwater

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METHODS AND SUBSTUDIES

- Consists of six parts:
  1. Surveys of metal contamination and distribution of metals in shooting range soil, and impacts on surface- and groundwater
  2. Studies on metals and their behaviour during episodic events
  3. Collection of background data on remediation techniques and commercially available shooting range solutions
  4. Testing efficiency of various soil amendment products and filters for stabilizing metals
  5. Pilot-scale testing of 3-4 shooting range structures
  6. Recommendations for shooting range structures

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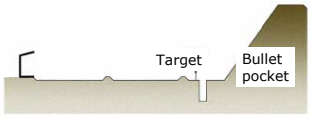
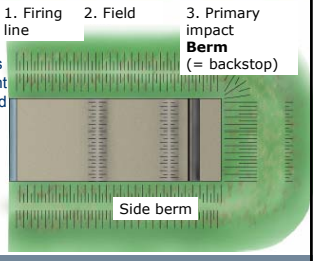
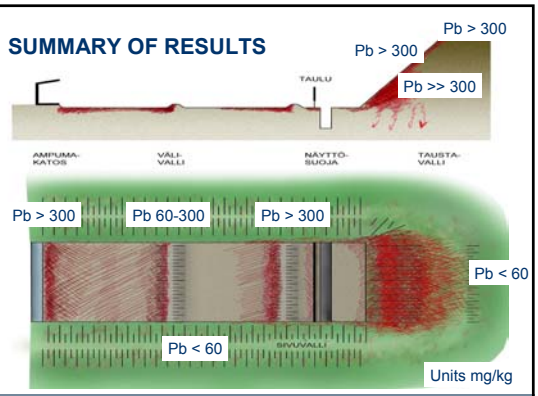
CONTAMINATION OF A SHOOTING RANGE, 2004

- Studies of 9 shooting ranges
- Different shooting activity, age, soil- and groundwater conditions
- Contamination studies of different parts of the range, horizontal and vertical spreading
- Groundwater
- Surface water and sediment
- Dust
- Leaching tests
- Lead content of plants





SUMMARY OF RESULTS



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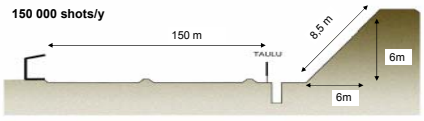
"THE THEORETICAL SHOOTING RANGE MODEL"



	Pb (mg/kg)	Pb (t)	Pb (%)	Soil (t)	Soil (%)
Front of shooting line	300	0,3	6	950	18
Field	100	0,3	6	3100	60
Side berms	50	0	0	0	0
Target area	500	0,01	0	18	0
Berm	1500	0,9	17	580	11
Bullet pocket	**100000**	**3,5**	**67**	**34**	**0,7**
Natural slope (berm)	500	0,2	5	470	9
total		5,2	100	5200	100

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SOME USES OF THE THEORETICAL SHOOTING RANGE MODEL

- Risk assessment for different natural conditions, remediation need assessment, classification
- Usability studies for remediation methods, cost calculations
- Planning new shooting range constructions

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OTHER RESULTS

- Groundwater
  - no groundwater pollution found at any range
- Plants
  - high lead content in the roots of lingonberry behind the impact berm. Much lower Pb in leaves, no accumulation into berries found in other studies
- Dust
  - high total dust amount near firing line and impact berm. Pb-content much higher at firing line. Presumably no health effect.

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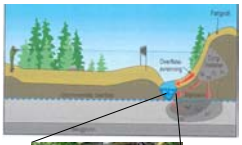
LEACHING TESTS

Shooting range	Hiukkavaara	Hiukkavaara	Hälvälä	Niinisalo
Range	150 m, old	150 m, new	25 m	150 m
Active	Closed	Yes	Yes	Yes
Depth of sample	0,0-0,2 m	0,2-0,5 m	Top-soil	0,5…1 m
Percentage of bullets	21 %	2 %	41 %	7 %
Pb-concentration (< 2 mm mg/kg)	12.000	3.000	69.000	3.400
Total Pb in bullets and < 2 mm fraction	22 %	2 %	48 %	7 %
pH	6,1	6,3	6,4	4,4
Pb leachability				
- $BaCl_2$ –extraction	0,2 %	2,5 %	<0,1 %	6…9 %
- Ammoniumacetate – extraction	41…51 %	25 %	50…60 %	46…52 %
- Aqua regia -excraction	48…59 %	73 %	40…50 %	39…47 %

Leaching of metals (Pb, Cu, Sb, Zn) - impacts on surface water



Aquatic moss and water samples

(Norwegian Institute for Water Research)

25 military training areas – 15 yrs

All will be included from 2007

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Leaching of metals – natural reasons

	Neutral pH (Ca>10 mg/l + low TOC)	Low pH (Ca<5 mg/l + high TOC)
Pb	< 2 µg/l	up to 200 µg/l
Cu	< 8 µg/l	up to 300 µg/l
Zn	< 8 µg/l	up to 100 µg/l
Sb	up to 20 µg/l	

- Most leaching of metals in acidic areas – independent on years in use
- Liming of soil – can increase leaching of particle bound metals

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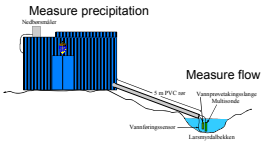
Episodic events and speciation - methods

- Information of bioavailability
- Useful when designing treatment methods
- Important for timing of sampling

1.Snow melt – followed by rain
-Sampling in creek every second day
-Pb, Cu, Sb and Zn

2. Rain
-Size and charge fractionated in situ
-Filtration, ultra filtration and ion exchange (Pb, Cu, Sb, Zn)



Automatic Water sampler

(Norwegian Defence Research Establishment = Forsvarets forskningsinstitutt – FFI)

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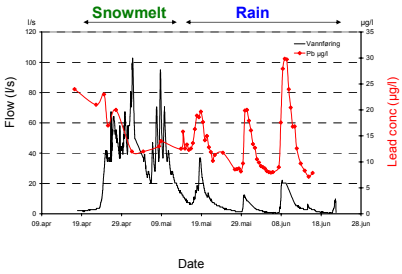
Leaching of lead during episodic event



Snowmelt:
30% of total yr amt
No correlation Pb/flow

Rain:
Higher conc
Correlations with flow:

R^2:
Pb – 0,96
Cu – 0,83
Sb – 0,74

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2nd rainfall event - speciation

Correlations of metals and flow – similar to 1st rainfall event

Speciation:
Particles > 0,45 µm
Colloids < 0,45 µm and > 10 kDa
Low molecular/ionic species < 10 kDa

Pb – particles and colloids (50% – 50%)

Cu – on average 60% in colloid fraction and 35% in low molecular/ionic fraction

Zn - 95% < 0,45 µm, 60 % Zn low molecular/ionic species (positive)

Sb - 97% < 0,45 µm, 84 % of Sb – low molecular species (negative)
– most mobile

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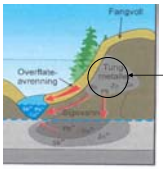
DATA COLLECTION ON REMEDIATION METHODS AND CONSTRUCTIONS

- Remediation methods
  - remediation should be based on risk assessment, combining methods and minimizing migration of metals
- Shooting range constructions
  - several commercial solutions available (STAPP rubber granulate, bullet traps, concrete blocks etc.)
  - very little data on life cycle costs (building, maintenance, close-down)
  - limited data on suitability for military rifles and Nordic climate
  - little data on chemical stabilization

Prevent spreading of metals
Soil amendment - methods



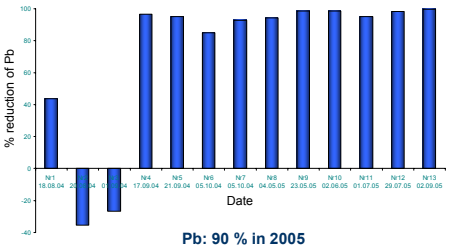
Prevent corrosion of bullets
Stabilize soluble metal species

Parallel columns
Outside – natural precipitation
Berm soil mixed with:
•Bone char (apatite)
•Iron (Fe0) powder
•Alginate
•No additive (reference)
Sampling monthly – 1,5 yrs

(Forsvarets forskningsinstitutt – FFI)

Soil amendment: 2,5% granulated iron (w/w)

Reduction of leaching (%) in column with amendment compared to reference

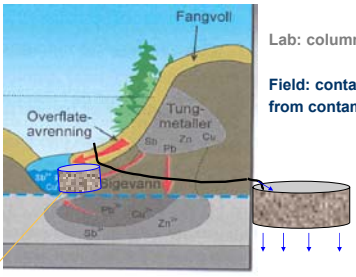


Reference:
4 – 20 mg/l Pb

Pb: 90 % in 2005

Sb: 84 % in 2005
Cu: 86 % in 2005

Prevent leaching of metals
-filters - methods



Lab: columns

Field: containers – collect water from contaminated creek

Filter

In field - containers with filter material

Bone meal/fragments – promising – but leach P and N

Leca – for long retention time

Zeolite – for acidic water (lab)

Granulated peat (Northern Sweden) – up-flow filters promising

Heat treated moss

Peat with algae

None work for all metals - more testing – combinations of materials

(FFI and GEM Consulting)

Mobile lab in field (FFI)

- various places in Norway
- various qualities of water
- various filter material

olivin
iron coated olivin
leca coated with olivin

olivin and iron
activated carbon

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CONCLUSIONS

- There is usually no immediate need for remediation of shooting ranges
- Remediation need arises from change of land use, or high environmental risk (acidic conditions, sensitive ground- or surface-water use)
- Different remediation methods are probably needed for different parts of a closed down range for optimum results
- Soil amendment shows great potential, and has to be further studied

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FURTHER AIMS OF THE PROJECT, 2007 →

- Continuing the soil amendment and filter studies
- Developing a simple general risk assessment model / tool based on the Theoretical Shooting Range Model
- Planning monitoring programmes for different types of shooting ranges (use, natural conditions)
- Pilot scale testing of 3-4 promising shooting range structures, both commercial and self-developed
- Developing structure recommendations for new / renovated shooting ranges for various environments (soil type, surface- and groundwater conditions, pH etc.)