A New Design for a Short Distance Backstop with Drainage and Run-off Treatment

Rolf Keiser, Ursina Morgenthaler
Guisanplatz 1
3003
Switzerland
rolf.keiser@armasuisse.ch
ursina.morgenthaler@armasuisse.ch

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ABSTRACT

Over the last century, live-fire military training led to contamination of soil by heavy metals such as lead, antimony and copper. Due to their potential toxicity, this became a public health concern. Indeed, the spent ammunition and their weathering products are releasing heavy metals in the environment. This is particularly a problem on small arms shooting ranges, where heavy metal soil contamination has reached high levels. To address the problem, the Swiss regulation recommends a process, beginning with a historical investigation, which gives a first indication of the potential pollution. Followed by a technical investigation, which consists of a detailed field examination and includes sampling and analysis of soil and water to determine the effective level of contamination as well as the expansion of the contaminated area. Followed by a risk assessment, which evaluates the potential environmental and health consequences. As a result, a remediation concept is established, which aims for the best compromise between the contaminants cleaning and environment preservation at the lowest possible costs. For small arms shooting ranges, the best way to prevent pollution is to improve construction properties of backstops. Therefore, a new type of backstop has been developed, which has a sealed bottom and a run-off water treatment. The secretary general of the Swiss Federal Department of Defense, Civil Protection and Sport published a guideline on the technical, the construction and use of this new type of backstop. The Swiss Federal Office for the Environment already passed several construction permits for such backstops.

1.0 INTRODUCTION

Contamination of shooting range soils by lead (Pb), antimony (Sb) and copper (Cu) released from corroding ammunition has become a public concern over recent years. Military exercises on small arms shooting ranges include weapons up to 0.50 calibre firearms, such as handguns, assault rifles and machine guns. Lately, this issue has gained attention in a global scale [4]. In the last about 100 years, military training has led to an accumulation of about 10'000 tons of lead and several hundred tons of antimony, copper and other heavy metals in the environment in Switzerland. During the world wars and the cold war, the Swiss army has used several hundred shooting ranges. Most of them were small and are no longer in use because of new weapons, training requirements and a reduction of the army size. Therefore, it is necessary to investigate all ranges and to analyse which of them pose an environmental risk. As a first step, a so-called historical investigation is conducted. There, all data from the archives is analyzed and an inspection of each site is conducted. This gives a first indication of the potential pollution. The historical investigation is followed by a technical investigation, which consists of a detailed field examination and includes sampling and analysis of soil and water to determine the effective level of contamination as well as expansion of the contaminated area. This is followed by a risk assessment, which evaluates the potential environmental and health consequences. As a result, a remediation concept can be established, which aims for the best compromise between the contaminants cleaning and environment preservation at the lowest possible costs.

In recent years, about half of the small arms bullets used by the Swiss army are used on short distance ranges. Furthermore, most of this short distance ranges are also used for training by the border guard and the police. This has led to the construction of a new type of backstop for such ranges, in order to prevent leaching of metals to ground- or surface waters. The backstop is sealed off from the environment with a watertight membrane and the collected water is treated onsite. A soil filter or a combination of a soil filter with amendments can do the treatment. By using different filters, the system can be optimised for specific pollutants and/or legal requirements. The treated water can either be released to a nearby river or infiltrated into the ground. In the long-term, these new backstops will lower the environmental impact of military training and future costs for remediation. This also contributes to get permits for the installation of new constructions on existing ranges.

2.0 INVESTIGATION PROCEDURE

To make sure that all sites are treated in the same way, a standard procedure for an investigation with several steps was introduced [1]. This also allows to integrate new data and re-evaluate a site if necessaire. At the end of every step, a report is compiled, which summarises all findings.

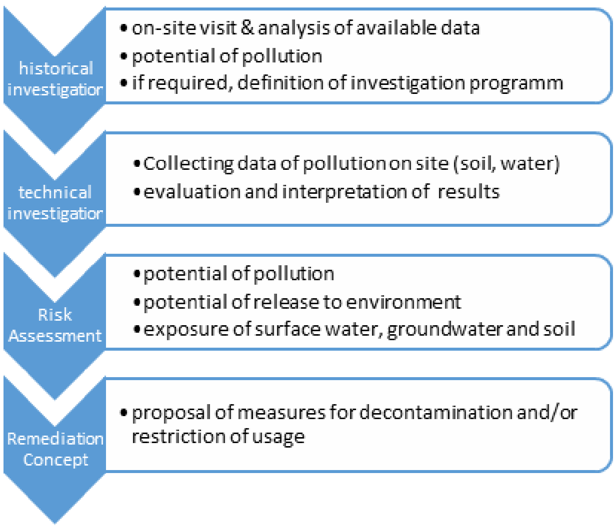

Figure 1: Management steps for the evaluation of contaminated sites on small arms shooting ranges.

2.1 Historical Investigation

For all contaminated sites, the historical investigation gives a first impression on the potential pollution of the area, thus determining the need for monitoring and/or clarifying if further investigations are required. A very central step for the historical investigation of shooting ranges is the establishment of contact with the people in charge of the shooting range, which usually have the best knowledge on past and current shooting activities. Together with them, an on-site inspection is carried out, during which the area is photographically documented and all ownership structures and contractual arrangements are noted.
The evaluation of the history of the site further includes a documentation of all shooting target areas (former and current) of the shooting range. It is very important to gather all available information on the shooting activity, especially on the kind of weapons and ammunition used. This information combined with an estimation of the number of rounds fired over the past years, allows an estimation of the pollution

load entering the environment through shooting activities.
The evaluation of the obtained information concerning the pollution situation of the site results in a pollution hypothesis, which categorizes the areas of the shooting range into the following categories:

- Heavily contaminated areas
- Medium contaminated areas
- Slightly contaminated areas
- Areas not contaminated (e.g. flyover areas)

This classification is mostly based on the extension of the target area and the total amount of pollution entering the environment. To make sure all ranges are classified in the same way, the categories should be defined in a guideline. The sites, which are classified as slightly or not contaminated, do not pose an environmental risk and can therefore be considered as environmentally safe.

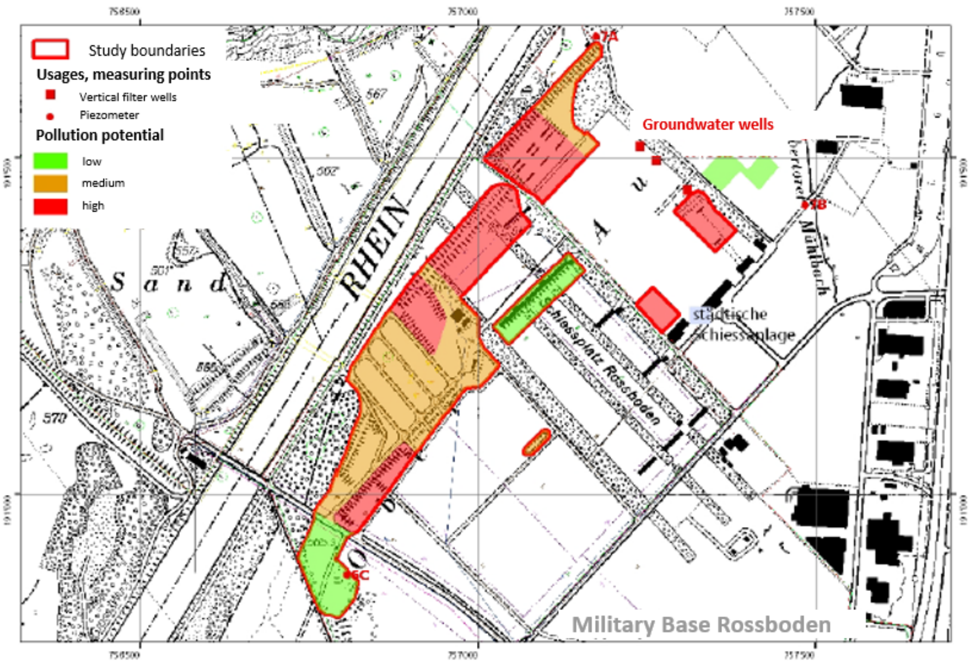

Figure 2: Example of a pollution map after the historical investigation

The environment of the shooting range is best described by documenting the hydrogeology, geology and the vegetation of the area. For this task, all available geographical information (e.g. web mapping), including historical photographs, of the site can be helpful for evaluating the surrounding area. Any structural changes in the landscape assists in understanding the pollution situation of the site.

In addition to describing the environment, all natural resources that are potentially affected by the contaminated site are examined in detail. Pollutants derived from shooting practices enter the environment via the soil. Through chemical weathering, however, these pollutants can also leach into ground- or surface waters. All these findings, in the shape of text, photographs, and maps, are compiled in a report. There, maps and photographs are the most important feature, because they contribute to the understanding of the situation

2.2 Technical Investigation

A technical investigation is foreseen, if the historical investigation indicates a potential contamination. The technical investigation is a detailed in-situ examination, which involves sampling and analysis of soil in order to determine the lateral and vertical expansion of the contaminated area and the severity of pollution.

Figure 3: Example of a bullet and fragments in the soil.

As a first step, the areas are sampled according to the investigation strategy developed in the historical investigation. The sampling should be adapted to the current conditions and documented in detail. The location of all sampling areas is assessed with a Global Positioning System (GPS) in order to portray the exact position on maps. For field measurements, a portable m-XRF is used, which has, depending on the soil matrix, a reliable measuring range form 100 – 2000 mg Pb / kg soil. As a general rule, areas with visible bullets or bullet fragments (Figure 3) are heavily polluted and do not need further sampling. It has to be kept in mind, that the portable m-XRF is a field measurement device and therefore has to be used carefully.

Additionally, if requested within the scope of the investigation strategy, groundwater and surface water samples are analysed for their Pb, Sb and Cu content. Whenever possible, a reference sample taken upstream of the site (i.e. uninfluenced) should be sampled in order to address the background concentrations. All errors of sampling, sample processing and analysis have to be discussed and taken into consideration for future work.

Figure 4: Groundwater sampling with the help of a groundwater pump from a borehole next to the backstop.

2.3 Risk Assessment

The risk assessment evaluates the potential environmental and health consequences of the contaminated area based on the results of the technical investigation. The aim of the assessment is to establish the need for future measures. The assessment is based on

- The pollution potential according to the technical investigation
- The potential for release of the pollutants into the environment
- The exposure of each environmental compartment: groundwater, surface water and soil

General rules for a risk assessment of target areas of small arms shooting ranges do not exist, as most targets sites are unique in both, the type of shooting activity, and the environmental setting. Thus, the above-mentioned points need to be described for every individual target site. However, the frame for the remediation of environmental risks is usually stated in legal guidelines, as explained for water bodies and soils separately in the following sections. In order to address the problem with agricultural use of former shooting ranges, a guideline was published by the secretary general of the defence department [3]. This guideline for example stipulates that polluted areas have to be fenced-off in order to avoid health risk for grazing livestock (Figure 5).

Figure 5: Target areas have to be fenced-off to limit exposure of heavy metal pollution to grazing livestock.

According to Swiss regulations, a soil exceeding 2000 mg/kg lead needs to be remediated. Soil with lead concentrations of 200 to 2000 mg/kg requires a risk assessment, which evaluates the potential risk and the allowed uses. Soil with lead concentrations below 200 mg/kg are free for all uses according to Swiss regulations. For livestock the two major factors in the risk assessment are exposure time (how long stays the livestock on a site) and the species. Sheep are more on risk than other livestock because they eat more soil while grazing. Therefore, an easy way to lower the risk is to limit the time livestock is on a specific site.

Surface- or groundwater quality is considered at risk, when pollutant concentrations exceed legal threshold values. For groundwater captures, which are located downstream of the target site and are used for drinking water, the detection of contaminants alone may be considered as potential health threat. However, the origin of the contaminants must be directly linked to the shooting range. Thus, for the evaluation of the results it is important to take a background sample upstream from the polluted site and to consider all contaminated sites and geogenic sources in the area. It has to be noted that because of the lack of groundwater wells, the sampling of water in the immediate discharge of the site has proven difficult in practice. In addition, the sampling of nearby surface waters can cause complications because of the difficulty to decide where and when sample. Groundwater is directly threated with contamination, when the retention of pollutants by the contaminated soil is insufficient. This is especially the case, when the distance between the contaminated site and the groundwater table is small, and when the soil has a low clay and iron mineral content. In addition, erosion of heavily contaminated soil into surface waters states a risk for contamination.

2.4 Remediation Concept

To eliminate the risk presented in the risk assessment of the contaminated site, measures of remediation and usage restrictions are proposed within the scope of a remediation concept [3]. The main goal is to find a remediation solution, which eliminates as much contaminants from the site as possible at the lowest possible cost, whilst causing no further harm to the environment. The result must be optimized according to the future usage of the site. In alternative to the elimination of the contaminated soil, pollutants can be made immobile by adsorption to special materials. Covering the contaminated soil with clean soil is normally only a short term solution.

The remediation concept includes a variation study of different remediation objectives. Based on the technical investigation and the risk assessment, a measurable accountable remediation target of the polluted area is defined with respect to the protection of the environment. These targets generally refer to values defined in environmental laws (e.g. soil protection, water protection and contaminated sites). It is possible to suggest different target values for different areas and soil depths, depending on the exposed environmental compartment. If the remediation concept suggests alternative measurements, which avoid the excavation of pollutants, long-term effects in particular have to be addressed. Remediation actions are highly depending on regulations and future land use. Remediation projects are, therefore, site-specific and will not be further discussed in this article.

3.0 POLLUTANT MANAGEMENT TECHNIQUES

3.1 General Aspects

The aim of current military training practices regarding its pollutant management is to release the minimum amount of contaminants and to avoid areas with environmental conservation value or groundwater resources. Thus, every technique should at least consider one of the following principles:

- Reduction of pollution load
- Limitation of exposure of the environment (avoid sensitive areas)
- Prevention of spreading of contaminants to soil or water

Already small adaptations of the training exercises allow a reduction of the pollution potential and pollution load. For example, practice rounds implicate less contaminants. Therefore, by using practice rounds or simulators for shooting practices, the overall amount of pollutants released to the environment is reduced. These adaptations should be implemented within reason. Even though the acquisition costs for such adaptations may be expensive, their implementation will most likely result in lower long-term management costs of the shooting range.

On every shooting range, areas under environmental protection should be identified and documented, and then included in the discussion of the further use of a site. No matter if its groundwater protection or endangered birds brooding in the heath, if these areas are avoided during military training exercises, the harmful influence of the shooting practice is minimized from the beginning. In order to minimize the exposure of water bodies, target areas should be placed with distance to surface waters and with a certain height to the natural groundwater level.

A key factor to prevent spreading of contaminants on small arm ranges is the construction of the backstop. The backstop construction must always fulfil maximal safety requirements, because possible safety shortcomings could include more ricochets. These could lead to accidents and to a higher impact of the shooting activity on the environment. In order to minimize the environmental impact of target areas, artificial backstops have become a standard over recent years. Two construction principles are mainly in use:

- Bullet traps (e.g. boxes)
- Systems with water treatment

The following section focuses on a new backstop with water treatment for short distance ranges.

3.1.1. Short Distance Ranges

In Switzerland in recent years, almost half of the small arms munition was used on short distance ranges. Furthermore, the historical data shows that with the importance of short distance shooting in military training, these ranges also became one of the most important sites for heavy metal pollution. Therefore, short distance ranges came in focus to develop an environmental friendly backstop. A conventional short distance range includes the practice area, which usually is around 35 m by 15 m, and a backstop, which consists of a natural slope or an artificial berm. For safety reasons the whole surface is covered with a 30 to 50 cm thick layer of woodchips. Several of this so called short distance boxes could be placed side by side with a bulletproof wall between them (Figure 6).

Figure 6: Standard short distance range in Switzerland with a complete cover of woodchips to prevent ricochets. The green structures are noise barriers.

The advantages of this simple construction are its low costs, its easy maintenance and its excellent safety properties. Doe to the excellent safety properties, a wide variety of exercises, weapons and munition are allowed on these ranges. Due to the weather consitions in Switzerland, these woodchips stay moist all year long, allowing the use of tracer rounds on these sites. However, there is a draw back from an environmental point of view: meteoric water can leach pollutants from the backstop into surface- or groundwater. Therefore, measures must be developed, which prevent water from leaching and transporting pollutants into the next waterbody.

3.1.2. A New Artificial Backstop for Short Distance Ranges

The idea behind the new backstop was to create a system that has about the same usability and ease of maintenance as a standard short distance range with a minimal environmental impact. After evaluating different systems, the decision fell on a variant with a sealing under the backstop. The reasons for this decision were the low construction costs, the easy maintenance and the high safety of the backstop.

A guideline document for such emission-free backstops was prepared and discussed in a collaboration of the secretary general of the defence department and the federal department of the environment, and finally approved by the latter. This document is online available under the following links in German and French:

German: https://www.kbs-vbs.ch/docs/emissionsfreie_Kugelfänge_VBS_d.pdf

French: https://www.kbs-ddps.ch/docs/emissionsfreie_Kugelfänge_VBS_f.pdf

The only major difference to a standard short distance range is the sealing. The sealing consists of a watertight membrane or bentonite or some equivalent material. When the target area is sealed-off from the environment, the infiltrating water needs to be collected. One option of releasing the drainage water of the target area is via a cleaning and infiltration system to the underground as shown in figure 7. The cleaning of the water can be done by amendments or filtration through a soil or sand column or a combination of both. In addition, an inspection shaft should be in place to control the contamination status of the water before it is released into the environment. The advantages of this system are:

- No need for a nearby water stream
- No long pipe system to bring the treated water to the water stream

The disadvantages are:

- The infiltration pond needs maintenance
- The infiltration pond requires space

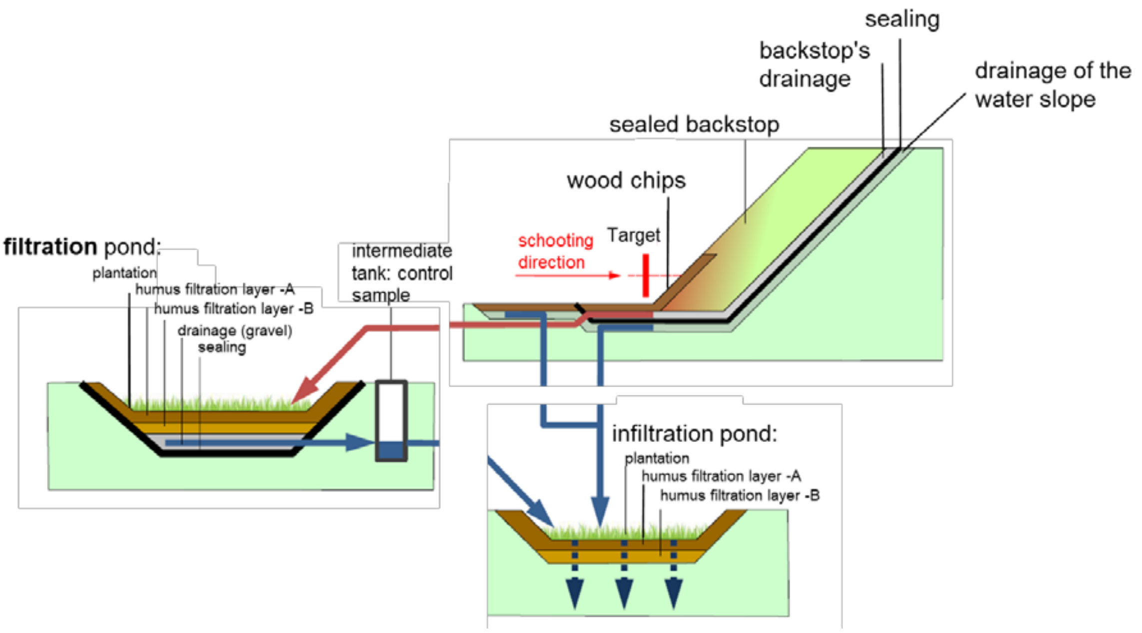

Figure 7: Variant 1 of the new system with infiltration of the treated water into the ground.

A second option of the same cleaning system is shown in figure 8. Here, the cleaned water is released directly to a nearby river, instead of infiltrated into the ground. However, this system can only be implemented if the ratio of water released to the river to that in the river does not exceed 1:10. Otherwise, the additional water might disturb the river's ecosystem. The advantages of this system are:

- No infiltration pond needed, only the filtration pond need maintenance
- It does not need much space

The two major disadvantages are:

- In Switzerland, a permission is required for the release of water into a river
- The construction of the sewer pipe can be expensive

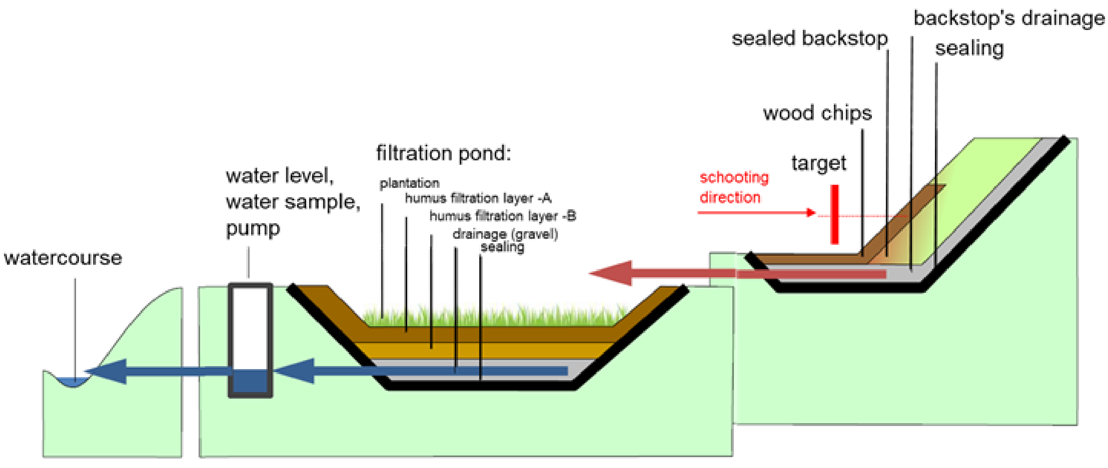

Figure 8: Variant 2 of the new system with treated water reaching a nearby river.

It has to be discussed separately for every shooting range, whether variant 1 or 2 is more appropriate in respect of the hydrogeological conditions and the protection of the river or the groundwater.

3.1.3 Future Use of the New System

Even though, the new backstop is designed for short distance ranges it can be adapted for other ranges. Such adaptions will probably involve changes in the construction, but the basic principle of collection and treatment of contaminated water works for all kind of ranges. By changing the treatment system, the same design could also work for other contaminants like energetics. The use of different amendments (alone or in combination) could also improve the efficiency of the treatment and extend the lifespan of the system. However, further analyses are needed to test the different amendments for their usability. Long-term experience with the system under real word conditions will further help to improve the technology.

Under certain environmental conditions, it is also possible to implement an unsealed water management for large target areas. For example, if the underground of the target area consists of crystalline bedrock or clay rich sediments, the run of water can be collected and treated. If the water meets legal guideline values, it can be released to the environment. Otherwise further treatment is necessary.

4.0 CONCLUSIONS

The first step in dealing with environmental aspects of shooting ranges is to compile all necessary data to characterise a range. This includes knowledge about all ranges in use during the last century and beyond, and about the manner of use. In detail, this means the exact location of all firing positions and targets, the type and amount of rounds fired etc. Based on this data the environmental risk of each range is evaluated. For those ranges, which pose an environmental risk, an onsite investigation is conducted, which includes the sampling and analysis of soil and water. Once the scope and severity of pollution is documented, riskreducing measures are developed. Such may include remediation, in situ treatment or prevention of leaching. The possibilities are, however, often limited by setting, hydrogeology, accessibility or by meteorological aspects. Such challenges further can increase the costs of a planned method. Therefore, prevention of pollution is much more efficient and cheaper in the long run. For small arms, possible prevention options are emission free backstops, while sealed backstops with an onsite water treatment represent an easy and cheap option for short distance ranges. The results on such new backstops from the first test ranges are very promising: The water quality after the treatment meets the legal demands and the new backstops are accepted by the troops as well as by the maintenance crew.

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