

## Environmental Risks Arising from Changes in Ammunition Materials

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SLIDE	Notes:
1	<b><u>Environmental Risks Arising from Changes in Ammunition Materials.</u></b> 24th European Shooting Confederation General Assembly, Moscow 17 May 2013.
2	<b><u>Risk!</u></b>  (1) <i>Risk is a combination of the probability, or frequency of occurrence of a defined hazard, and the magnitude of the consequences of that hazard. We have to understand that 'Risk' itself, is not 'Hazard'. Poisons are hazardous. Having a poison safely contained and locked up, whilst being a hazard, poses little risk.</i>  (2) In the context of land contamination, and environmental risk, we have to understand the concept of " <u>pollutant linkage</u> ". Essentially it's the chain of criteria that must be in place for a 'hazard' to become 'risk'. There are 3 essential components to the pollutant linkage chain:  (3) Firstly, there has to be an environmental hazard in the form of a contaminant or pollutant or some other property that has the potential to harm or to cause pollution of controlled waters.  (4) Secondly, there has to be a receptor, i.e. a body that would potentially be harmed by the hazard, in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property, or a water body.  (5) Thirdly and most critically there has to be a pathway or route by which the hazard can impact the receptor. No matter how big the hazard, if there's no potential pathway, there's no risk.
3	<b><u>The Contaminant – Metallic Lead?</u></b>  In terms of Sport shooting on ranges, let's consider our risk model by first addressing the Hazard represented from potential pollutants.  (1) I don't think we can reasonably argue otherwise that there is a massive amount of data to suggest that lead and many of its compounds can be harmful to humans, animals and the environment. The data to suggest that birds ingest lead shot and as a consequence are poisoned is unequivocal.  (2) Risk is greater if lead becomes soluble or mobile. That is not to say that lead in all its forms represents equivalent risk to the environment.  (3) Risk is greater from lead's corrosion products through the fineness of their physical form. Soluble lead compounds such as lead sulphate pose significantly more risk, principally because of their ease of transport and ingestion. (NB: It is important to note that for mixtures, European regulations require that the

	<p>toxicity and environmental impact implications of deliberate additives and impurities of greater than 1 part per thousand, be reflected in the suppliers Health and Safety data, and labelling.)</p> <p>(4) Lead metal is generally stable. Archaeological Lead above pH 6.5 exhibits a corrosion rate that would equate to 2,000 to 3,200 years for European shot sizes 7 to 9 to corrode.</p> <p>(5) Practical experience of shot in ranges indicates shot corrosion within circa 200 years – even in neutral soils. Why the difference?</p> <p>Refs:</p> <p>(a) “Measurement of corrosion content of archaeological lead artifacts by their Meissner response in the superconducting state; a new dating method”, S Reich, G Leitus and S Shalev, Deutsche Physikalische Gesellschaft. New J. Phys. 5 (July 2003) 99.</p> <p>(b) C.P. Rooney Ph.D. Thesis (2002), Lincoln University, Christchurch New Zeland</p> <p>(c) Jørgensen, S.S. and Willems, M. (1987). The fate of lead in soils: The transformation of lead pellets in shooting-range soils. <i>Ambio</i> 16, 11-15.</p> <p>(d) Lin, Z. (1996). Secondary mineral phases of metallic lead in soils of shooting ranges from Orebro County, Sweden. <i>Environmental Geology</i>, 370-375.</p>
4	<p><b><u>Metallic Lead Corrosion?</u></b></p> <p>(1) Corrosion of metals is primarily an electrochemical or ‘redox’ process. This process usually requires a sacrificial metal or compound and an electrolyte. Typically where dissimilar metals or compounds are in contact, one will be oxidised and the other reduced.</p> <p>(2) The lower the pH, the better the electrolyte and the faster the reaction will proceed. Every drop in pH by one unit can be expected to increase the corrosion rate by a factor of 10.</p> <p>(3) In many cases this corrosion is slowed or halted by a build up of surface corrosion products, effectively breaking the electronic circuit. In the case of lead, its corrosion crust does not slow the process. Once initiated, corrosion is linear in nature. Lead corrosion products form a felt mat of needle shaped crystals. They do not bond tightly to the surface of the corroding lead but can be easily flaked away, and as such the corrosion scale does not create a barrier to contact with an electrolyte. If anything it serves to keep moisture in contact with the metal’s surface.</p> <p>(4) Soil comprises the corrosion product of rock and is essentially iron aluminosilicates – plus the oxides and aluminosilicates of many other metals, including other heavy metals; copper, zinc, chrome, cadmium, etc. As such, soil is usually</p>

	<p>abundant in sacrificial metal compounds.</p> <p>(5) In the absence of sacrificial materials Lead is highly resistive to acid attack. That's why the roof of the pantheon is still in good order after 500 plus years. Essentially there is no corrosion cell established, merely acid rain metal interaction.</p> <p>(6) Soil free study, indicates pure lead shot will corrode at a rate 5 times slower than buried antique lead.</p> <p>(7) However, today shot and bullets are usually made from ballast or secondary lead, whose principal source is lead-acid batteries. Antimony was introduced into batteries to improve what chemist's term the 'electron yield'. To the lay person; to make the lead corrode faster, and by doing so, yield up its electrons faster and improve the amp rating of the battery.</p> <p>(8) Only a small proportion of antimony significantly changes the picture. 1.25% antimony in lead alloy increases corrosion rate 22 fold compared to pure lead. This would indicate without the influence of soil electrolytes a projected corrosion time of 1,200 years. But add iron oxides from steel shot corrosion and this reduced to 190 years. Add in the effects of soil electrolytes and other sacrificial compounds, and we can quite easily understand rapid corrosion of lead shot in-situ in range soils.</p> <p>(9) So given what we have learned, It should be apparent that in managing lead we have to manage the other metals it incorporates or comes into contact with. Which begs the questions: What's in our shot? What's already in our range soil? What effect will steel shot have on our range?</p>
5	<p><b><u>Unified Numbering System (UNS) designations for pure lead grades and lead-base alloys.</u></b></p> <p>It might be a surprise to some, but what you regard as 'lead' isn't just simply metallic lead.</p> <p>There are up to 5,300 categories of Lead recognised by distinct UN identification codes. Why so many designations? Quite simply they all have quite different properties and uses.</p> <p>Pure lead is extremely valuable. Antique pure lead free from radio-nucleotide contamination sells for 10 times the price of commodity grades, for application in electronics solders, where radioactive decomposition of trace contaminants usually present in fresh mined lead would otherwise cause spontaneous microelectronic pulses.</p> <p>Purer leads in ancient times were priced for being soft leads and used to line roofs of buildings and for construction of piping. Plumbing of the Roman baths at Bath are still in place 1,700+ years. The present lead roof of the pantheon in Rome is still intact after its restoration in the Renaissance some 500+ years. The lead clad drum tower of Ely Cathedral still up after nearly 700 years. Pure lead exposed to the elements is durable.</p> <p>At the other end of the spectrum, lead-silver alloys are still used as sacrificial metals in</p>

larger seagoing vessels and they are purposely made to be unstable. A 20Kg block bolted to a ship's hull might corrode in only 25 years, but in doing so protect the steel hull from corrosion.

Naturally occurring lead-arsenic alloys were historically used as 'hard lead' to frame and hold stained glass windows. Very stable to corrosion, shot made from this material should survive more than a few thousand years. Owing to its durability, and antifouling qualities, today it's still the material of choice for sheathing sub-sea cables.

Lead-antimony alloys you should all be familiar with as a major component of secondary lead, the source of the majority of ballistic lead. Secondary lead from the 1970's was perhaps 4% antimony. Owing to its tendency to corrode shortening the lifespan of lead-acid batteries, it has gradually fallen out of favour. Secondary lead generally contained circa 2% antimony in 2000. Today the average antimony content in secondary lead is below 1%. However, antimony is still added to many ballistic lead alloy grades to improve hardness and melt flow characteristics.

Quite clearly the composition of secondary or ballast lead has been changing over the last 100 years as its primary feedstock moved from being recycled roofing sheet and plumbing, to battery lead and then again as car batteries have evolved to use different alloys, with widely differing qualities.

So quite simply 'lead shot' isn't just lead, and has varied significantly in its content and potential 'contaminant' behaviour over the last 100 years. Thus, any attempts to examine historic lead corrosion in-situ in ranges and extrapolate future corrosion rates would be problematic to say the least.

Which begs the question what's in your shot and bullets 'now'?

What's antimonial lead been replaced by? -- Lead-tin, lead-calcium, lead-aluminium, lead-copper and lead-selenium alloys. Both selenium and antimony are more tightly regulated than Lead. Discharge limits for selenium are typically half to 1/5<sup>th</sup> that of lead. Selenium has recently been added to the US-EPA hit list for control. Discharge limits from industrial sources are now set at 1ppm. There is possibly 100,000 tonne of lead shot fired in Europe annually, which now might comprise of 1,000 tonnes plus of selenium.

refs:

- (a) [Journal of Applied Electrochemistry, February 1992, Volume 22, Issue 2, pp 116-124, 'Corrosion rates of lead based anodes for zinc electrowinning at high current densities' R.H.Newham](#)
- (b) [Hydrometallurgy 2008: 6th International Symposium, 17 - 21 August, Phoenix, AZ, 'The effects of periodic open-circuit on the corrosion of lead alloy anodes in sulfuric acid electrolytes containing manganese.', McGinnity, J. and Nicol, M.](#)
- (c) [EP EP20010942679/1248864 A1 / WO2001053549A1, Oct 16, 2002 'Alloy for thin positive grid for lead acid batteries and method for manufacture of grid', David R. Prengaman](#)

**The Contaminant – Metallic Lead?**

Let's take a close look at lead projectiles in the form of polished and un-etched cross-sections through an electron microscope.

- (1) In ancient times, hard lead was used for the first lead bullets. These illustrated are circa 1<sup>st</sup> Century BCE Roman peltast bullets from the Danube valley. They are quite common and usually found in an excellent state of preservation.
- (2) Under the microscope a polished section shows a metallic shine. The alloy is a quite uniform 'unitary' Lead 4% arsenic alloy. The large crystal grains are only just evident through the presence of a thin layer of arsenic and lead oxides. Not bad for an alloy of circa 2,000 years age.
- (3) In comparison if we examine current shot manufacture (e.g. No.7 shot, with 4%Sb), we can see it has a somewhat matt texture with a porous dendritic structure. Lead antimony does not form a unitary alloy, and as such creates the potential for internal redox cell formation and accelerated corrosion.
- (4) In enlargement, shrinkage porosity is fully evident (as black areas) caused by withdrawal of molten antimony rich eutectic during cooling and solidification. The larger elongated nodules are less rich in antimony, but contaminated with speckles of Lead oxides and sulphate (the white components).
- (5) This is a comparable section of an imported No.8 pellet of a South American brand, circa 2% antimony but containing circa 5% oxide. The oxide originates from lead acid batteries. Lead acid batteries are somewhat misnamed. They derive their electrical properties principally from conversion of lead (II) dioxide to Lead (I) sulphate, which are held in the battery as pastes supported on lead alloy plates. Lead oxides and sulphates comprise approximately half of the weight of the Lead in the battery. The lead metal provides very little of the battery's output. When battery lead is reprocessed it undergoes a primary melt and treatment with lime, yielding a molten emulsion of lead metal and lead oxide. In order to convert this material to metal, the smelter must add carbon, (in the form of crude oil, petroleum coke, coke or even old tyres) to obtain a reductive burn. Incomplete processing leaves Lead oxides and sulphates in the final product. Naturally, we would expect the degree of residual oxide to compromise alloy stability, as it is after all, 4% corroded already. This grade by no means represents the worst on the market.
- (6) This material, from a new manufactured bullet core, is circa 20% plus PbO and is quite evidently unrefined solid lead metal/oxide emulsion. The polished cross-section doesn't even resemble metal at this magnification, it looks more like a crumbly grain biscuit marketed as a 'hob-knob' in the UK. Quite clearly we wouldn't expect this product to have the same impact and corrosion characteristics as refined lead alloy. How does this material appear on the market? To be blunt - probably for environmental – and ultimately for economic reasons. In the secondary refining process, initially melting batteries gives very little pollution. However, the reductive burn to reduce the oxides to metal results in the form of copious discharges of hot lead contaminated CO<sub>2</sub> to atmosphere. Within Europe and North America, with ever tightening restrictions on such

	<p>discharges and very high costs of installing and running suitable scrubbing facilities, a significant amount of secondary lead processing has been offshored to the developing nations. From the secondary lead processor's point of view it would be convenient if he could just sell his primary melt material, which is conveniently metallic looking, even if a little paler and pearlescent in appearance than metallic leads. It is after all of comparable density and ballistic performance. That's if you don't consider its inferior mechanical properties – especially on impact, and of course it's questionable corrosion characteristics.</p> <p>Effectively what we have as our projectile or contaminant is not so much metallic lead as a destabilised lead alloy composite, peppered with oxides and sulphates – essentially comprising a discharged battery plate. If provided with an acidic environment and an electrolyte we will get re-initiation of the electrochemical process and associated physical changes being manifested as accelerated corrosion.</p>
7	<p><b><u>The Contaminant – Metallic Lead?</u></b></p> <p>Here we have 2 bullet cores the top one is the same grade as our high oxide contaminated core which has very low levels of antimony from the previous slide. The lower is a hardened lead containing 10% antimony. You can quite clearly see a difference in appearance.</p> <ol style="list-style-type: none"> <li>(1) If we take a closer look at our contaminated core, the field of view being approx 1 mm through an optical microscope, we might be forgiven to think we are looking at a solid metallic surface.</li> <li>(2) However if we place the core in aerated deionised water at 20°C, we notice significant and rapid changes to the surface. Initially we see a rapid loss of the surface through erosion, which we attribute to oxidation and hydration of lead oxide to lead hydroxide leading to surface swelling and fracture. We see that sub-surface fissures are exposed. This process occurred over 4 days. Thereafter we see the rapid growth of a mottled pale scale of lead hydro-carbonates#. The build up of scale is unstable and falls free from the surface, exposing a fresh face to the elements. The de-scaled lead carbonate formed a ring around the base of the core in the test beaker.</li> <li>(3) Peeling back the surface we can roughly estimate that the surface scale thickness at circa 20 microns. And all this occurred with exposure to water at pH 6.0 to 6.5 at 20°C, in 6 days.</li> </ol> <p># There are a number of basic lead carbonates and related compounds, including: White lead / basic lead carbonate, <math>2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2</math>, Shannonite - <math>\text{PbCO}_3 \cdot \text{PbO}</math>, <math>3\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2 \cdot \text{PbO}</math>, <math>\text{PbCO}_3 \cdot 2\text{PbO}</math>, Leadhilite - <math>2\text{PbCO}_3 \cdot \text{PbSO}_4 \cdot \text{Pb}(\text{OH})_2</math>, Cerussite <math>\text{PbCO}_3</math></p>
8	<p><b><u>The Contaminant – Metallic Lead?</u></b></p> <ol style="list-style-type: none"> <li>(1) If we take a look at our high antimonial lead at the same magnification. We again see an apparently metallic surface though of a radically different looking patina.</li> <li>(2) Incubated in water for the same period we see initially the rapid formation of localised surface blooms of lead oxide hydrates, probably occurring through redox</li> </ol>

	<p>discharge of localised surface corrosion cells. These surface blooms subsequently dissolve giving way again to an unstable mottled pale grey scale of lead hydro carbonates.</p> <p>(3) Peeling away the surface we estimate that the corrosion scale build up is circa 10 to 15 micron in with exposure to water at pH 6.0-6.5 at 20°C, in 6 days.</p> <p>The rates of surface decomposition of oxide contaminated and high antimonial lead are significantly faster than purer lead grades. And we would contend that the corrosion scale does not provide protection against ongoing corrosion.</p>
9	<p><b><u>Does Steel Shot Reduce Environmental Risk?</u></b></p> <p>Having considered the nature of the hazard from our potential contaminant, let's consider the wider issue of application to our range with regard to risk.</p> <p>(1) There have been several studies of the behaviour of lead in ranges. Illustrated is a picture from the work of Corinne Rooney. Worldwide data including the work by Rooney suggests that on mature ranges legacy lead in surface soils can reach levels of 10 gram per Kg. Rooney concluded that lead shot could survive in the soil conditions she examined, (which are not widely dissimilar to European soils), for 10,000 years and be largely retained on-site. Personally I think her estimates are 'optimistic'. Experience tells me that at such levels of lead unless the surface is permeable and subsurface geology is clay rich, lead migration problems are likely to occur. Steel has been widely promulgated as a 'non-toxic' alternative to lead. And in some cases, local regulators have insisted that ranges cease firing lead altogether. I am not a shooter. I'm an environmentalist and a scientist. I fully believe that lead is harmful and that lead shot poses a significant risk to waterfowl, but I have grave reservations of the universality of the switch to steel and other alternatives in all shooting applications.</p> <p>(2) Let's take a closer look at the impact of shooting steel, and in particular at shooting steel over lead. Illustrated is a shooting range situated in Florida. The range is circa 50 years old – and unfortunately sited adjacent a wetland wildfowl reserve. The local regulator has imposed a mandatory prohibition on shooting lead. The photo, whilst not an empirical study, illustrates the overview of anecdotal observations of range owners. Whilst both lead and steels shot types, when concentrated in principal region of shot fall, will adversely impact vegetation, where steel is used we do observe greater impact. Here we can see from the grass rhizomes that normally run within the soil thatch, are now fully exposed and shrivelled. As this is from the centre of the shot fall region I think we can take it that we are not observing wear from a high level of foot fall. Whilst the particular picture does not have a detailed scale (apart from the ubiquitous dropped pen), we can see the obviously corroding lead and steel shot. We can also just make out that some of the lead shot has corroded to below 1mm. (NB: The narrow gold band on the pen is circa 1.5mm wide.)</p> <p>(3) If we look at the shot in hand...</p> <p>(4) The steel shot (right) was originally U.S. No. 4 to 6.5 (or 3.6 to 2.77 mm) and the lead shot originally largely U.S. No. 7.5 to 8 (at 2.26 to 2.39 mm). It is evident that</p>

	<p>lead is corroding at a very significant rate. The increased lead shot corrosion is fully expected and we can understand the mechanisms of the shot interaction, but what's happening in the soil? I would like to put to you a summary of what we believe is happening on this site, and likely happening on very many other sites where steel is now being fired over legacy lead, with consideration of the likely impact on environmental risk...</p>
10	<p><b><u>European Soils – Typical Profile</u></b></p> <p>If we consider a hypothetical 'typical' European soil, as we might find on a shooting range, we usually see...</p> <ol style="list-style-type: none"> <li>(1) Organic rich horizons descending into less organic rich layers of weathered soils, overlying un-weathered substrata and parent rock.</li> <li>(2) Grasses, herbs, mosses and lichens;</li> <li>(3) rooted in and underlying thatch and dark organic rich horizon.</li> <li>(4) Surface typically pH 5.5-7.5. Some upland areas may be 1 pH unit lower and some Mediterranean coastal fringe soils a unit higher</li> <li>(5) Presence of soil invertebrates.</li> <li>(6) Usually find iron banding / iron pan from natural weathering above less oxygen rich regions.</li> </ol>
11	<p><b><u>Predicted Impact of Steel Shot</u></b></p> <ol style="list-style-type: none"> <li>(1) Add steel shot and what is likely to happen? Steel is not simply an alloy of iron and carbon. Corrosion will liberate colloidal oxides of nickel and manganese in addition to iron. These elements are naturally present in most iron ores and carry through, or are added to finished steel products.</li> <li>(2) Accelerated corrosion of legacy lead, <u>and</u> liberation of other heavy metals naturally present in the soil; through redox corrosion and iron oxide catalysed oxidation. This is an important point as even if you put pure iron onto the range, such is the power of iron and its oxides as oxidation catalysts, they will induce breakdown and leaching of previously stable background metal minerals. In other words: Put a significant amount of iron on your range and even if you hadn't a heavy metals leaching problem, subject to background mineralogy, you are very likely to create one.</li> <li>(3) Most corrosion by-products adhere to colloidal iron oxides, surface clays and biomass. Initially you might see a reduction in heavy metals leaching.</li> <li>(4) Iron corrodes to produce alkaline iron (II) compounds which then go on to acidic iron (III) compounds. Leading to adverse impact on surface soil pH, swings from</li> </ol>

	<p>9.5 to 3.5 in days. Overall effect is a long term increase in site acidity and net increase in metals leaching. We anticipate and observe pH swings, and the act of corrosion in the soil ‘in and of itself’ takes oxygen out of the soil raising the level of the soil’s zone of anaerobic horizon and reducing the zone in which soil invertebrates can thrive.</p> <p>(5) Iron (II) salts are sold as herbicides, specifically to deter moss. So how can you expect steel shot through is corrosion products not to have the same effect on range soils.</p> <p>(6) Demise of soil invertebrates due to pH changes and oxidative stress, with consequential deterioration in sub-soil drainage.</p> <p>(7) Reduction of intolerant herbs.</p> <p>(8) Formation of secondary ‘iron-pan’, leading to deterioration in soil texture (with iron concretion) further impede sub-soil drainage, leading to associated increase in surface run-off. Illustrated is a section of a mature secondary iron pan from a metal processing site, (not a shooting range). Its 1 cm thick but as hard as concrete. Only deep ploughing can break up this type of formation once it occurs.</p> <p>(9) Reduction in grass quality and cover through pH stress, metals toxicity and poorer drainage.</p> <p>(10)The natural consequence of the above is loss of surface biomass and soils.</p>
12	<p><b><u>Site Risk! - Added Contaminants</u></b></p> <p>(1) Contrary to labelling of ‘Steel Shot’ cartridges, not being lead does not make them ‘Non-toxic’. Steel is not non-toxic. If an animal is shot and wounded with it, its survival prospects are at the very least no better than with current lead ammunition types.</p> <p>(2) Colloidal Iron oxide is: An Irritant. Its not classified as a human carcinogen - but is an equivocal tumorigenic agent by RTECS criteria. (Tumors at site or application in rats.) Herbicide. Aquatic pollutant. Toxic to insects / Invertebrates.</p> <p>(3) Steel shot contains both Manganese and Nickel. These elements occur naturally in almost all iron ore deposits and result in low parts per thousand to low single figures percent as background contaminants in iron and steel products. Safe concentration has not yet been established.</p> <p>(4) Nickel salts are carcinogenic. Ni<sup>(II)</sup> compounds are former RED LIST materials and known human carcinogens. EU-WAC limits for Nickel land with unrestricted use, including agricultural use is only 100 mg/kg i.e. Half that of lead. For industrial</p>

	<p>commercial use 1,850 mg/kg, which is at the outer limits of tolerable in engineering and metalworking. Legacy lead on some range surface soils reached over 10,000mg/Kg. Unchecked, steel shot and its corrosion products would reach the same levels.</p> <p>(5) Manganese oxides are Harmful and reduce male fertility. Lead is a known neurotoxin. There is a proven link with manganese – lead co-toxicity and human health, with epidemiological studies confirming the observed biological effect that manganese exposure causes a 3 fold increase in transference of lead across the blood - brain membrane barrier.</p> <p>(6) Increased level of potentially soluble lead and antimony pollutants by redox corrosion and increased acid corrosion of legacy metals.</p> <p>Ref:</p> <p>(a) Roger D. Masters, Brian Hone and Anil Doshi, “Environmental Pollution, Neurotoxicity, and Criminal Violence.” Brain Biochemistry, Neurotoxicity and Criminal Violence, 28 March 1997. Dept. of Government, Dartmouth College, USA.</p> <p>(b) WAC <a href="#">173-340-7492 (2)(c)</a>.</p>
13	<p><b><u>Site Risk! - Added Pathways</u></b></p> <p>(1) What is a transport metal? It’s a metal that forms insoluble compounds which have an ability to sorbe heavy metal compounds <u>and</u> can easily be transported by water. Iron oxides are just such materials. Iron has a density of 7.87g/cc However, iron and its alloys corrode to produce colloidal hydrated iron oxides. Hydrated iron (III) oxide – Limonite, FeO(OH)·nH<sub>2</sub>O has a density of 2.7 – 4.3 g/cc. In comparison clays have density on slightly lighter at 2.16-2.8g/cc . Limonite being colloidal in nature, given sufficient run-off or even a significant breeze, can easily leave a contaminated site. Colloidal iron oxides remain insoluble only where soluble iron in solution around it is in excess. Once transported beyond the zone of iron saturation they simply dissolve to become soluble hydrated iron. Naturally any toxic cargo of heavy metals they have picked up en-route will also be dumped into solution. Transportation of heavy metals in this manner is termed ‘facilitated transport’.</p> <p>(2) It is generally believe that facilitated transport of heavy metals by iron, represents the greatest single cause of heavy metals migration. However, iron alumino silicates and biomass can also perform the same role, sorbing heavy metals on a contaminated site, being carried away in surface run-off only to de-sorbe the soluble pollutants where they reach a zone of un-saturation. Its a classic trait of iron transported pollution, that the maximum concentration of soluble heavy metal contamination is not found adjacent the source of the pollution, but some distance way downstream, whereas the total metal measurements, including colloids will show a steady increase the closer you get to the contamination source.</p> <p>(3) With loss of surface cover in the form of vegetation and thatch, the elements that</p>

	<p>bind surface soils are lost. Thus, surface biomass and topsoil can be lost to erosion. These same eroded materials, owing to their proximity to the origin of contamination, are amongst the most contaminated materials on the site. If they are washed or blown away, they will carry contamination with them – And once in a region of low saturation they can dump any sorbed toxic heavy metals. Thus, migrating topsoil and biomass can facilitate the transport of heavy metal contaminants.</p> <p>(4) Drainage from a contaminated site can leave by one of 2 routes; as surface run-off or subsoil drainage. Where the ability of the soil to drain rainfall is impaired, naturally run-off will increase. Where drainage is through the site soils, there is at least the potential for soluble pollutants washed into the soil, to be sorbed and bound in the soil as moisture percolates through, thereby the potential pollutants can remain close to their source of origin.</p> <p>(5) Contaminants travelling in surface run-off have less potential of being sorbed and retained on-site. So, naturally an increase in surface run-off will increase the migration of soluble heavy metals from the site.</p> <p>Refs:</p> <p>(a) Joan E. McLean and Bert E. Bledsoe, “Behaviour of Metals in Soils”, EPA Ground Water Issue. EPA/540/S-92/018, October 1992.</p> <p>(b) R.W.Puls, R.M.Powell, D.A.Clark and C.J.Paul, “Facilitated transport of inorganic contaminants in ground water: Part II Colloidal Transport”, EPA/600/M-91/040, 1991.</p>
14	<p><b><u>Mitigation of Site Risk</u></b></p> <p>Knowing what is happening to the site chemistry and its physical consequences, mitigation of pollution risk becomes common sense.</p> <p>(1) Don’t shoot steel over legacy lead. The chemistry says it increases risk significantly so why do it?</p> <p>(2) Or shoot ‘better’ lead. Makes sense to not use antimonial lead, and better grades are available at minimal cost uplift. Are birds at significant risk from range lead?</p> <p>(3) Design ranges to better capture spent projectiles. By confining and concentrating the potential hazard we can better manage it.</p> <p>(4) Ranges cannot be sustainable if spent shot is left in-situ. Whilst periodic removal a lead can be problematic, the one saving grace of steel is – its magnetic. Magnetic brooms are routinely used in the U.S. building industry and available from a variety of suppliers, and can be used to recover ‘loose’ steel shot...</p> <p>(5) Treating the range with apatite or similar phosphate as a surface dressing can have a beneficial effect of immobilising lead in-situ. However, plants and other soil flora will see lead phosphate as a nutrient and will attack it liberating the lead once more. Life span of treatment efficacy 1 to 3 years.</p>

	<p>(6) Precipitation on the site will exit by one of 3 routes; surface run-off, subsoil drainage and transpiration. We need to discourage surface run-off so we need to encourage soil drainage, that way lead is retained on-site and in-situ. Transpiration of plants, particularly trees and shrubs is also a pretty good way of getting rid of site water.</p> <p>(7) Maintaining site cover is critically important. We must not to allow highly contaminated bald spots to persist. These are precisely the zones we need to manage.</p> <p>(8) Monitor site soil permeability. We need to know if we're impairing site permeability. As an added note, apatite lime dressing, particularly with iron oxides makes for a pretty good soil aggregation agent or cement and can impair natural drainage.</p> <p>(9) Counter 'iron pan' with mechanical intervention to assist surface drainage. Fork, till or in the last resort – plough.</p> <p>(10) Install range drainage system to capture all run-off and monitor run-off for potential contaminants. This makes sense especially if you have a contaminated site, you have a legal obligation to manage risk on that site. And by creating a fixed route for run-off we can intervene with remediative treatment should it prove necessary.</p> <p>(11) 'IF' intervention proves necessary I would recommend: Incorporate a heavy metals reactive filter/barrier within the range drainage system and projectile traps: There are numerous suitable reagent systems: sulphide based reagents are in my opinion the best in offering long term treatment. Apatite/lime and synthetic apatite, are probably the most widely used. As a slow sand reactive barrier fill they have greater durability in this format than surface treatment because they're not available to be broken down by site flora, but phosphate treatment is not suitable for all heavy metals. Other agents can be incorporated to address other contaminants as necessary.</p> <p>(12) <i>ANY FUTURE CHANGES – THINK HOLISTICALLY!</i> If I leave you with one message from this presentation it is that for any future changes to ammunition materials to 'think holistically'. As a change intended to mitigate wild-fowl poisoning, if extrapolated beyond its immediate intended application can indeed have knock-on undesired environmental consequences.</p>
15	<p>It only remains for me to thank you for your attention for inviting me to speak to you. Should you have and questions I am happy to take any questions from the floor, so please feel free.</p> <p>QUESTIONS:</p>

Should you have any further questions, please feel free to contact me.

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