The Use of Lead Projectiles in Small-bore Target Shooting

Executive Summary
The aim of this paper is to provide information to underpin the cost-benefit analysis of banning lead-containing ammunition for small-bore target shooting. Small-bore shooting is arguably one of the most inclusive sports; people can compete almost irrespective of age, gender and disability (including visual impairment). Testing shows that lead-free ammunition is so inaccurate that it would make meaningful competition impossible, affecting everyone from social to Olympic shooters. It is also louder and more expensive than lead ammunition. Analysis shows that the capture of lead projectiles on ranges is 96-99% efficient and that recycling is already well-established.

Introduction
The National Small-bore Rifle Association (NSRA) is the National Governing Body for small-bore Rifle and pistol, air rifle and pistol and crossbow target shooting in the UK. It represents around 1000 clubs in which around 35,000 people take part in the sport of target shooting. The NSRA structure and systems extend substantially beyond this to the far greater number of shooting participants who shoot in the Scout Association, Cadets, Schools and other organisations as well as the individual shooters who shoot informally.

The clubs that affiliate to the NSRA often cover a wide range of disciplines within the sport and the insurance gained by affiliation covers them for the majority of the other shooting disciplines as well as small-bore. These include centre-fire rifle and pistol shooting, clay shooting and shooting in the field. The NSRA runs National and International competitions with clubs, counties and regions; these deliver practice and competition under NSRA rules. Several of the disciplines covered by the NSRA are Olympic, Paralympic and Commonwealth Games events.

Current Situation
All the disciplines that take place in NSRA affiliated clubs use lead ammunition of some kind. These projectiles are either propelled by compressed air (airguns), and referred to as “pellets” or as part of a cartridge (.22 rim-fire and other calibres). The .22 rim-fire cartridge most used in NSRA activities is known as .22 Long Rifle and is referred to in this document as .22LR. This activity takes place both indoors and outdoors according to the discipline and the competition requirements.

This document examines the requirements of the sport for ammunition and looks at the potential issues created by the removal, either whole or in part, of lead ammunition – in particular relating to:

- Accuracy comparison of lead and lead-free projectiles
- Ballistics of lead and lead-free projectiles
- Recovery rates of lead in target shooting
- Noise
- Cost and availability of lead-containing ammunition in comparison with substitutes

Basic Accuracy Tests

.22 Rim-fire

Test method

Eley limited allowed the NSRA to use their test range in Birmingham. This is a facility that provides a fixed test rig to hold the rifle in a solid position and a 50m indoor shooting range where there are no variables due to wind and other climatic conditions. This is the world-leading facility used by most nations to choose their ammunition for the Olympic Games. It provides ideal conditions for ammunition testing and the technology used allows the results to be measured and quickly presented in an accurate and uniform manner, relating them to the target that is used both nationally and in international competition.

The method chosen was to shoot 40 rounds of each product at 50m in groups of 10 shots to produce an overall 40 shot group. This is the standard testing regime used. This is a statistically significant number of shots that can be related directly to the target and disciplines that are shot in Britain and to the Olympic 3 x 40 shot rifle discipline.

Ammunition Used

The lead ammunition used represents the range of cartridges that would be found in competitions and training both at top level and within local clubs. The high quality Eley Tenex round represents the high-end product whilst Eley Club represents a cheaper, reasonable standard round used in clubs across the country.

The lead free ammunition represents what is currently available internationally from high quality manufacturers, all of whom also produce lead ammunition.

Rifle Used

The rifle selected for the test was an Anschutz Match 54 action. This represents a reasonably accurate rifle that is extremely popular and used by the largest number of shooters in Great Britain. This type of rifle has been around for a considerable time, it delivers good competitive accuracy but is not considered the highest-end product.

Results

The full printout of results is included in Annex 1. These results are summarised in the table below.

Material	Type	Group (40 shots) mm	Expected Decimal Score	Integer Score
Lead	Eley Club	27.1	617.36	393
	Eley Tenex	18.9	633.64	400
Non-lead	CCI Copper	48.9	579.13	368
	RWS Green	70.7	534.55	316
	Norma Eco Speed	76.2	532.24	314

It can be clearly seen that the lead-free ammunition is severely lacking in accuracy even over the current, club level, lead-containing round.

However, this must be compared to the standards of competition that are currently experienced in Britain. Below are the results from competitions at 50 metres by shooters with a variety of skill levels.

Postal Competitions

These competitions are the mainstay of target shooting in Great Britain. Competitors shoot the competition in their own club and post the targets to be scored centrally. The competitions are shot on standard international targets as used in the testing at the Eley facility.

Individual 50m (non-magnifying sights)				
Division	**Highest score**	**40 shot equivalent**	**Lowest Score**	**40 shot equivalent**
1	3941	394	3906	391
2	3922	392	3859	386
3	3848	385	3827	383
4	3885	389	3834	383
5	3820	382	3792	379
6	3823	382	3747	375
7	3802	380	3695	370
8	3743	374	3687	367
9	3793	379	3519	352

50m Individual (any sights)		
Class	**Score (ex 1200)**	**40 shot equivalent**
A	1188 - 1164	396 - 388
B	1169 - 1134	390 - 378
C	1149 - 1097	383 - 366

Shoulder to Shoulder Competitions

These scores represent scores shot in National competitions in which the competitors shoot side-by-side on the same range. The classifications cover the range of abilities that enter the competitions.

2019 Bisley National Meeting		
Classification	**Competition 1 Bisley 2019**	**Competition 4 Bisley 2019**
X	399	393
A	394	391
B	390	385
C	389	384
D	380	377

Conclusions on Accuracy Issues

When the results from the tests are compared with the general standard of scores found in competition (both postal and shoulder to shoulder) it can be seen from the results that the standard lead ammunition supports the score levels of both postal and shoulder to shoulder competition across the various skill levels. However, it is also clear that even though the rifle under test set is clamped firmly and fired under ideal conditions, the lead-free ammunition is incapable of delivering the accuracy required even for the lowest level of competitor in either the postal or shoulder to shoulder competitions. The effect of changing to lead-free ammunition would be to turn competitions into a lottery where the vagaries of the ammunition would dominate the results, independent of skill level.

Competitions would be decided by chance rather than skill level. The effect would be that competitive shooting would almost certainly cease as people became disillusioned, not just with the results but also the fact that, no matter how they trained, they could not influence their performance.

This has a major knock-on effect for sport not just for the obvious participation levels, but also at top level. As an Olympic, Paralympic and Commonwealth Games sport, the small-bore and airgun shooting athlete pathway starts, and is largely supported by, NSRA clubs and associations. The NSRA-affiliated organisations provide a feeder for the British Shooting World Class Programme which would no longer have a pool of talent from which to draw. Furthermore, the training of these elite squads would be similarly affected by their inability to use suitable ammunition to practice and compete with their overseas-based counterparts.

Ballistics

These accuracy tests under perfect conditions don't show the whole picture. Whilst they give a strong indication of the difference between lead and potential lead-replacement projectiles there are other factors that influence the performance of the ammunition used in target rifle competition.

Ballistic Coefficient (BC)

The ballistic coefficient of a projectile is a measure of its ability to overcome air resistance in flight. Projectiles that are made of dense material have a high sectional density and fly more efficiently than those made of less dense materials and so are said to have a better ballistic coefficient. A higher number shows a better BC than a lower one. ballistic coefficient is calculated by:

BC = Mass of bullet/Bullet diameter squared x form factor.

The form factor reflects the bullet's shape, but for a given shape and diameter of bullet it can be seen that the BC is basically proportional to its mass i.e. a heavier bullet for a given calibre has a better BC.

There was a great deal of difficulty in finding good data on the BC of non-lead bullets since manufacturers seem not to wish to publish it. The only one that was available was for CCI Copper lead-free rounds from the CCI website and the calculations are based on it.

Cartridge	Bullet Weight	BC
Eley (generic lead bullets)	40 grains	0.150
CCI Copper (lead free Bullets)	21 grains	0.092

This efficiency also affects the bullet's ability to resist the effects of wind deflection in its flight to the target – a very important factor when shooting in outdoor competition.

Using the "Shooters Calculator" ballistics program the following wind deflections were calculated for 2 of the common distances at which competitions are shot outdoors.

Eley Lead	Deflection		
	10 mph	**12 mph**	**15 mph**
50 yards	1.08 inch (27.4mm)	1.29 inch (32.8mm)	1.62 inch (41.1mm)
100 yards	3.85 inch (97.8mm)	4.62 inch (117.4mm)	5.78 inch (146.8mm)

CCI Copper	Deflection		
	10 mph	**12 mph**	**15 mph**
50 yards	1.74 inch (44.2 mm)	2.09 inch (53.1 mm)	2.61 inch (66.3 mm)
100 yards	7.31 inch (185.7 mm)	8.78 inch (223.0 mm)	10.97 inch (278.6 mm)

It can be seen that the overall deflection is far greater with the lead-free ammunition. However, most impactful is that the difference between the deflections at 10, 12 and 15 mph winds (which are often encountered outdoors) is much greater than with lead ammunition. This means that a shooter would have an inordinate amount of difficulty in estimating the small changes in wind strength that significantly affect the flight of a non-lead projectile and then applying the correction accurately enough to be competitive.

Conclusions on Ballistic Efficiency

The poor ballistic efficiency of lead-free materials would make the already relatively inefficient rim-fire cartridge so poor that shooting in any level of wind would be untenable. This would again contribute to the cessation of competitive shooting as people became disillusioned with the results and their inability to affect them by practicing the art of “wind reading”.

Airgun Pellets

Test method

The tests were conducted at the NSRA Aldersley Range at Wolverhampton using a fixed test rig to hold the rifle in a solid position and a 10m indoor shooting range where there are no variables due to wind and other climatic conditions. This test reflects the performance of the lead and non-lead ammunition at the standard Olympic distance of 10m found in clubs. Further testing was done from a bench rest at 25 yards indoors, again to eliminate variables. This was done to examine the accuracy of the lead and non-lead projectiles at a reasonable distance that reflects the variety of disciplines associated with airgun use beyond Olympic distance of 10m.

Ammunition Used

The lead ammunition used for the 10m tests represents the type of flat nosed pellet almost exclusively used in 10m shooting. Those used for the 25-yard tests represent those used for field target, hunter field target, bench rest and lightweight sport rifle competitions and are of the round nosed type.

The lead-free ammunition represents what is currently available from high quality, international manufacturers, all of whom also produce lead ammunition.

Rifle Used

The rifle selected for the 10m test was an Anschutz 9007. This represents a rifle that delivers good competitive accuracy but is not considered a high-end product. Similarly, the Air Arms S400 used for the 25-yard testing is a type of rifle that could be used for any of the listed disciplines, but is an average performer rather than a premium product in order to reflect what would be found in normal use. Both rifles were in the .177 (4.5mm) calibre used for competition shooting.

Results

Photographs of the results are included in Annex 2. These results are summarised in the table below.

10m Testing

Material	Type	Group (10 shots) mm
Lead	H and N Finale Match Light	4.95
Non-lead	RWS Hyper Match	9.12
	RWS Hyper Dome	11.00
	H and N Field Target Trophy Green	8.75

25 Yard Testing

Material	Type	Group (10 shots) at 25 yards (mm)	Group (10 shots) factored to 20 yards (mm)
Lead	JSB Exact	13.2	10.6
Non-lead	RWS Hyper Match	44.7	35.8
	RWS Hyper Dome	73.4	58.7
	H and N Field Target Trophy Green	38.2	30.6

When considering the relative accuracy of the pellets, the group sizes must be related to the size of the target. At 10m the air rifle target is divided into 10 equally spaced rings with the central 10 being 0.5mm in diameter. Due to

the small size of the target (Annex 3), it is essential that rifle and ammunition is capable of very small groups for a shooter to be in any way competitive. The majority of shooters when testing ammunition will only accept lots that produce a group of less than 5.0mm and, for higher level competition, ammunition that produces a calibre size 4.5mm group of 10 shots is required. None of the currently available, lead-free pellets could produce anything like an acceptable level of accuracy required by these disciplines.

Moving out to shooting at 25 yards, the difference in accuracy between lead and lead-free ammunition becomes even more apparent. The discipline of lightweight sport rifle has a 10 ring that is 5.59mm in diameter (Annex 3). For pellets to touch this ring (and so score a 10) requires groups of less than the 10 ring plus a pellet diameter on each side (i.e. ring diameter + 2 calibres) which is 15.4mm. With group sizes from 35.8mm to 58.7mm none of the lead-free pellets could achieve this. Moreover, none of the lead-free pellets could guarantee a score greater than 9.

The benchrest target shot at 25 yards places even greater demands on the rifle and ammunition. The best of the lead-free pellets could only guarantee a score of 4; the worst wouldn't even keep them within the scoring rings. This is in a discipline were, even at local level, most competitions are won with perfect scores out of 200, ties being separated using the even smaller X-ring.

Ballistics

The competitions discussed so far for air rifle take place mainly indoors at fixed distances.
The same issues encountered with .22 rimfire ammunition previously discussed are magnified when using air rifles for field target and hunter field target where the disciplines are shot outdoors at distances up to 50m.
The light weight of the lead-free pellets means that their ballistic coefficient is very poor but, unlike for .22LR, the initial velocity of these pellets is not substantially higher than the lead ones (due to the fact that the muzzle energy of air rifles is limited to 12ftlb in law) which makes their performance in wind almost completely unpredictable.

Conclusions on Accuracy and Ballistic Performance

- Due to the poor accuracy and lack of ballistic efficiency, competitions would be decided by chance rather than skill level

- Almost all competitors would leave the sport as they become disillusioned with the lack of influence of skill on results.

- Olympic, Paralympic and Commonwealth Games sports development and training would be made non-viable by the inability to use suitable ammunition to train and compete.

- Airgun shooting is the easy access to all forms of target shooting, particularly for youth and disabled shooters; If these groups come to consider it as no more than a lottery they will no longer pursue it – and for some it is among the few sporting options available to them.

Bullet and Pellet Catcher Efficiency

All target shooting disciplines have some form of arrangement to bring the bullet or pellet to rest in a controlled manner. This is for the safety of the competitors and of course to ensure public safety outside the range area. These arrangements generally either involve steel plates or absorbent material such as sand. These measures are well known and are rigorously defined in military and civilian documentation on the subject. Indeed for .22LR shooting, the ranges are subject to 3rd party inspection against a stringent set of criteria.

Airgun Pellets

There are several types of pellet catcher in use, but they all basically work in the same way. They hold the target and use an angled or flat plate to decelerate and collect the pellets. Four typical pellet catchers generally in use at the NSRA centres were emptied and a fixed number of pellets fired at them at 10m. The lead that remained was compared to the initial weight of the unfired pellets.

Pellet Catcher Efficiency
The pellets used were .177" (4.49mm) – these are a standard lead pellet used in competition and were fired from rifles and pistols that are generally used by competitors.

Test 1 – 10m Electronic Target – 20 shots
Weight of 20 pellets = 10.74 grams
Weight of recovered pellets = 10.36 grams
Percentage recovered pellets = 10.36 / 10.74 x 100 = **96 %**

Test 2 – 10m Standard Range (fly-by-wire target changers) – 200 shots
Weight of 200 pellets = 103.5 grams
Weight of recovered pellets = 102.0g
Percentage recovered pellets = 102.0/103.5 x 100 = **99%**

.22LR Bullet Trap Efficiency

There are several systems used to control and bring to rest the .22 bullet in a safe manner. These involve either flat or angled steel plate or some kind of penetrable medium such as sand or rubber/plastic granules. By far the most common are steel plates and sand.

Sand
Sand is one of the most frequently used means of collecting bullets and is used on the majority of outdoor ranges. It is very efficient at controlling the bullets deceleration, cannot generate any ricochet hazard, is cheap and is easy to maintain. Clubs use banks of sand behind the targets and volunteers de-lead them at intervals recycling the lead via local scrap metal merchants. There are also companies that have set up to offer a de-leading service to mechanically extract the lead for recycling and return the sand to its original condition.
To test the recovery rates that can be anticipated when using a sand backstop, 50 rounds of .22lr ammunition was fired at a sack of standard builder's sand (see Annex 4). The test was done in this manner to ensure that, whilst utilising the actual medium that is used, the figures were a true reflection of the rounds fired and didn't include other rounds that might be found in a club range that is in use.
The CCI ammunition uses the standard 40grain lead bullet that is used in the majority of .22 rim-fire cartridges and is the type of ammunition commonly used. After firing, the sand was run through a standard garden sieve in the manner that a club would use when carrying out a de-leading operation on their range.

Test 5 – 25 yard range – 50 shots, .22LR
Weight of 50 bullets = 129.6 grams (2000 grains)
Weight of recovered bullets = 131.8 grams (2034 grains)
Percentage recovered bullets= 131.8 / 129.6 x 100 = **101.7 %**

The test results show a recovery rate of over 100% since some sand adheres to the surface of the recovered bullets, but it indicates that a very high percentage lead recovery can be anticipated. In the pictures shown in Annex 5, it can be seen that the bullets, while deformed, are very largely intact. Minimal fragmentation making very high efficiency recovery more certain.

Steel Bullet Traps
Steel bullet traps are used extensively indoors and also on some outdoor ranges. Test firing was carried out on the 50m at Rugely Rifle Club in Staffordshire that uses this type of bullet trap. A section of the butt stop area was cleared of all debris and 50 rounds of .22lr ammunition fired into it giving the following results:

Test 6 – 50m range – 50 shots, .22LR
Weight of 50 bullets = 129.6 grams (2000 grains)
Weight of recovered bullets = 126.8 grams (1957 grains)
Percentage recovered bullets= 126.8 / 129.6 x 100 = **97.8 %**

It can be seen that the recovery rate of lead is again very high when using steel bullet traps and this underpins efficient recycling.

Other Media
The bullet traps using plastic granules or rubber crumb also have very high recovery rates. This is because they bring the bullet to rest in a gradual way and are less abrasive to the outer surface of the bullet. The bullets are hardly deformed (less than in sand) and can easily be recovered making 100% recovery possible.

Other Factors
Although the specifications for ranges are very firmly established in documents like the Military JSP 403 and its civilian equivalent "The Design Construction and Maintenance of Target Shooting Ranges", they are all based on the use of lead ammunition. The specifications would need to be reinvestigated if lead ammunition were no longer available for use and would no doubt mean that clubs would have to revisit the construction of their ranges in order to ensure compliance. The majority of clubs are run by volunteers and operate on an at cost basis,thus if significant changes are required; the cost would be carried by the membership. This would affect accessibility to the sport from a financial perspective.

Conclusions on Recovery Rates

- The recovery rate of lead is very high (>96%). Since only a tiny proportion of the lead used in Britain is used in firearms the impact on the environment is minimal.
- Clubs need no encouragement to recycle the lead they use. They collect it from the various bullet/pellet catching arrangements at regular intervals. They can then either recycle it themselves (by making it into bullets for other disciplines) or simply to take it to a scrap dealer and exchange it for money.

Noise
The .22LR lead rounds used by shooters for practice and competition are usually travelling at around 1060 fps. This is below the speed of sound and so makes relatively little noise in use. If a projectile is made of low-density material, it loses velocity quickly (see section on Ballistic Coefficient) so manufacturers increase the initial speed by using more propellant. This is in order to gain some little extra ballistic advantage to compensate for the inefficiency of the lightweight, lead free bullets; they are made to travel at greater speed (1750 to 1850 fps). This speed is greater than the speed of sound and so when fired produces a supersonic "crack" as the bullet breaks the sound barrier. Not only does this create a higher level of noise overall, but the quality of the sound is considered to be more intrusive.

Tests were carried out on an outdoor range to compare standard lead ammunition against the lead-free alternative. Shots were fired using a CZ 457 rifle with a 508mm long barrel which represents a standard sporting rifle that may be found in use in clubs in the UK. A sound meter was placed 1m away from the shooter and the following results recorded in decibels (A-weighted)

Cartridge	Average dB(A)
Eley (lead ammunition)	110.4
CCI Copper (lead free ammunition)	118.8

It can be seen that the lead free ammunition gives an increase of 8.4 dB(A) which, due to the logarithmic scale used, represents an increase of 6.9 times the acoustic intensity (power level) or approaching twice (1.79x) the level of loudness. This was confirmed anecdotally during the test by other shooters using the range who remarked on the excessive noise generated when testing the lead-free ammunition.

For outdoor ranges in particular, this is a major issue. Noise nuisance must be kept to a minimum and, since many ranges are situated in residential areas, it could result in the closure or severe restrictions to use. Indoor ranges are currently made with the shooting of sub-sonic ammunition in mind and so major upgrades to sound deadening would be required, particularly between range and club room.

Cost and Availability

Small-bore and airgun shooting are generally the least expensive forms of target shooting and attract a wide range of people from different social backgrounds who can afford to engage with the sport. It is also pursued by schools, uniformed groups (Scouts, Guides, Cadets etc.) and other youth organisations. Activity centres for young people often offer a shooting experience with airguns. Due to the less physical nature of the sport, it is also suited to older and disabled people, including those with visual impairment.

.22LR Cartridges

For many of these groups of people, maintaining accessibility is a key factor and cost a major part of it. It can be seen from the table below that the lead-free rounds are all more costly than the standard Eley Club ammunition. Indeed, the majority approach or exceed the cost of the highest-grade ammunition available from the UK (Eley Tenex)

Ammunition Type		Cost (per box of 50 rounds)
Lead Rounds	Eley Club	£5.25
	Eley Tenex	£11.75
Lead Free Rounds	CCI Copper	£11.95
	RWS Green HV	£10.50
	Norma Eco Speed	£8.07

If only lead-free ammunition were available it would be very impactful on the ability of many people to participate from a financial perspective. There is also a major issue with supply. Lead-free ammunition is only currently stocked by a very small number of retailers and then in very limited quantities.

.177 Pellets

Ammunition Type		Cost	Cost (factored to 500)
Lead Rounds	H and N Finale Match light	£10.00 per 500	£10.00
	JSB Exact	£11.00 per 500	£11.00
Lead Free Rounds	RWS Hypermatch	£8.99 per 250	£17.98
	RWS Hyperdome	£7.49 per 200	£18.73
	H and N Field Target Trophy	£11.99 per 300	£19.98

The cost of lead-free airgun pellets is considerably higher than their lead counterparts. This has even more impact than for .22LR since airgun shooting represents the easy access end of target shooting sport; the ranges are easier to build and access, and there is no requirement for a firearms certificate. Again, availability is a major challenge with lead-free airgun pellets.

Conclusions on Cost and Availability

- Due to the higher cost and lack of availability of lead-free ammunition there would be a large impact on the ability of people to take part in target shooting if lead projectiles were not allowed. The cost will be particularly relevant to youth organisations and schools, but also to many club members who have to balance the cost of their sport against the financial demands of normal life.

- Target shooting, being a sport of stillness, appeals to many people who cannot access other sports requiring dynamic movement, including those who are older and those with a disability. These groups are particularly vulnerable to difficulties in accessibility and cost of sport in general, and a lead ban would take away one of the sporting pastimes in which they can become involved denying them access to the associated health and social benefits.

Overall Conclusions

From the perspective of small-bore and air rifle target shooting it can be seen that the move to lead-free ammunition would have the following impacts:

- The inaccuracy of lead-free ammunition and its ballistic inefficiency would turn competitive shooting into a matter of chance rather than skill, both for small-bore and air rifle shooting disciplines.
- The result would be that competitors would leave the sport as skill development would not be possible.
- Subsequent loss of talent and training opportunities for Commonwealth, Olympic and Paralympic events.
- The contraction of the sport as a whole would mean that older and disabled people would lose access to a sport they can truly engage with - this includes blind people.
- Schools, scouts and other uniformed groups would lose an activity that is truly accessible to everyone irrespective of age, gender, ability/disability or physical strength.
- As small-bore and particularly airgun shooting is relatively cheap, the use of more expensive lead-free products would disadvantage many people who currently access sport cheaply.
- The change would have a disproportionately high impact on sport for people who do not (or cannot) engage with other dynamic sports. This includes disabled people and older participants.
- The increased noise would force many clubs to close and for those that remain open, the environmental impact would be high for those in the surrounding area.
- The positive overall change in environmental impact would be negligible as the lead recovery and recycling rates are very high.