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Study of Lead Contamination of Soil on Gun Ranges

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1. lead contamination
2. gun range
3. lead mobility

Abstract

This study looks at the problem of lead contamination on gun ranges and determines the size of the problem as well as its impact on society. Analysis of the problem is done by taking into consider the following criteria: the amount of lead already in the soil of gun ranges as well as the amount currently being introduced, the number of gun ranges, and the extent of how much of the surrounding environment and people are affected.

Acknowledgements

We would like to thank Jason Kropp and Professor Bergendahl for their assistance in the research process during the initial stages of our project. Thanks to Jason for the various sites and sources provided were invaluable and led to many other helpful sources. Professor Bergendahl kept us on track with much needed advices and helpful hints.

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Section 1: Introduction

Lead was one of earliest metals known to mankind. Egyptians used lead to make pottery glazes, writing tablets, chains, and sling projectiles. During Roman Era lead found it's usage in many aspects of life because of it's ease of smelting, low melting point, ease in molding, casting and soldering, and relative resistance to corrosion. Despite a long history of beneficial use to mankind, lead is a highly toxic element with no known beneficial purpose in the human body.

Currently, the biggest source of lead introduced into the environment within the United States is through spent ammunition such as lead shots. It is estimated that 4.1 million metric tons of lead is already in the ground at gun ranges across America and roughly 55,000 metric ton is introduced each year [1] across about 4000 outdoor gun ranges across the nation (indoor gun ranges do not pose as great a danger and is excluded by this study) [2]. The military introduces about another 5 metric tons a year at its 1,800 small arms firing range. [3]

At the same time, numerous studies done within and outside the country have shown that gun ranges can become highly contaminated by elevated level of lead concentration. Such sites of relatively high lead concentration have been found at gun ranges on the East Coast. The possibility of lead dissolving and becoming mobile poses a great danger to the surrounding environment. The biggest danger by far is lead traveling into water sources where it can endanger wildlife as well as people living in surrounding areas. Many critics have begun to turn their attention to this problem as gun ranges are coming under more and more scrutiny for their handling of expended lead munitions.

The danger posed by lead contamination is nothing new. Lead is a well-known health hazard to humans as well as wildlife living within a contaminated area. Yet, is lead contamination on gun ranges as large a problem as critics claim them to be? Several studies done on various gun ranges around the country have found that, though soil lead concentration is certainly higher than normal levels for residential areas, it did not pose a serious threat unless ingested directly. The larger problem is then from dissolved lead, which is more mobile and can get into underground and above ground water sources where its effects are much more serious.

In this project, we will be looking at the problem of lead on gun ranges. The focus will be on how much lead is in the soil, how far lead can travel and, thus, how much of the environment and how many people it can affect. Specifically, this project will determine whether the elevated lead levels on gun ranges pose a serious threat to the inhabitants and wildlife living in the surrounding areas. Overall, we hope to gain a better understanding of what impacts lead contamination on gun ranges will have to society.

1.1: Literature Review

Sources for this project include papers prepared by various government and private organizations including the Environmental Protection Agency, the United States Army, Virginia Polytechnic Institute and State University, University of Florida, Sporting Arms and Ammunition Manufacturer's Institute, Inc., the National Association of Shooting Ranges, National Shooting Sports Foundation, and various other sources.

The primary source for health related information came from papers provided by the Environmental Protection Agency (EPA). In particular, the EPA website contained numerous studies on the health effects of lead poisoning, which is essential to the understanding of just how dangerous lead contamination can be. Additional information about the danger lead poses to the environment is also found on the EPA website. No other sources were used for this topic since the EPA website alone had more than enough information. At the same time, the focus is not on the biological details involved with lead contamination, but on the societal impacts it will have.

Information on the amount of lead consumption was obtained through several sources. Data on the use of lead munitions by the military was taken from an evaluation of bullet traps done by the US Army Environmental Center. The study came as a response to environmentalists' complaints of possible health hazards from lead contamination at military gun ranges. Data on lead munitions consumption for sport shooting within the United States was obtained from the report done by Virginia Tech and verified with data made available by the US Geological Survey Circular 1183. Both sources are relatively up-to-date with the Geological survey completed for 1999 while the Army's report was based on data from the last ten years.

Lead mobility data is provided by several sources. Several case studies were used including the two studies done on Florida gun ranges by the University of Florida, a study done by Virginia Tech, and an independent study done by EA Engineering, Science, and Technology Inc. for the Sporting Arms and Ammunition Manufacturer's Institute, Inc. (SAAMI). The various case studies done in Virginia and Florida provided the background information on lead mobility. These two continually referred to the third

source, the independent study done for SAAMI. The SAAMI report contained a lot of information describing the chemical processes of lead dissolution and the formation of organic lead compound. Most of that data are summarized while others are omitted, as they were unnecessary to our report. However, one particular part of the SAAMI report did prove vital to our project, the relationship between lead solubility and soil pH and composition. Coincidentally the results of these studies were quite similar to each other. Overall, the three reports agreed that the level of lead concentration at gun ranges is indeed higher than normal, but the level of lead mobility is very limited.

The last piece of information critical to our estimation criteria is the number of gun ranges involved. The report given by the Army Environmental Center stated that the US military maintains and operates about 1,800 outdoor small arms ranges. However, they do not differentiate between those already using bullet trap systems from those that do not. At the same time, that number also includes ranges outside the United States. Meanwhile, the number of civilian ranges in the United States is roughly around 4000, taken from a list maintained by the National Association of Shooting Ranges (NASF). This included both indoor and outdoor ranges. Both these sites are believed to be relatively recent. The number provided by the NASF is updated for 2003.

Other minor bits of facts and figures are taken from several other sources. One of these is the pH map of the United States, which was vital to the lead mobility estimation. The map was created by the Soil and Fertilizer Institute, CAAS, and made available by the Forage Information System at Oregon State University website. The copyright on the map is 2001 and the data is believed to be current as of 2001. Since the soil pH does not change at a tremendous rate, the data provided by the map is deemed usable.

All sources are double checked and cited where necessary throughout the report. The information are double-checked and crosschecked whenever possible for accuracy. We believe that these sources are reliable and have taken into considerable any possible biases that may have affected the presentation of the data by these sources.

Section 2: Lead Contamination at Gun Ranges

Surveys by the National Shooting Sports Foundation (NSSF), National Sporting Goods Association and others indicate that more than 24 million Americans participate annually in some type of outdoor shooting target practice in the United States. Of this number, it is estimated that 7.5 million engage in trap and skeet shooting, and about 16.5 million participate in rifle or handgun shooting. The typical participant takes part in these sports 13 times per year, with nearly 2 million taking part more than 20 times per year [4]

Over the years, gun ranges have come under increasing scrutiny and various lawsuits have been filed against them. The majority of these legal actions are based on a few environmental regulations, the main one being the Clean Water Act (CWA), the Resource Conservation and Recover Act (RCRA), and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). [5]

2.1 Case Studies:

Of the 3 case studies that were investigated, only one presented any evidence that elevated lead concentration would present any sort of danger to the local community or to

the environment. Upon closer examination of the case studies, the following conclusions are made regarding each individual cases:

2.1.1 Tucson, Arizona:

Actions proposed against the Tucson shooting range were filed in complaints by the local residents. The biggest concern was not from the potential hazards of lead contamination, but from the danger of stray bullets and from the noise level caused by the shooting. AJAY Environmental Consultants concluded their investigation that the areas with elevated lead concentration in comparison to residential levels were limited and would remain that way. Due to the low level of lead mobility, "elevated lead concentrations had no potential to impact groundwater." [6]

2.1.2 New York Athletic Club:

The club operated a trap shooting range that resulted in spent munitions falling into the water of Long Island Sound. Under the Clean Water Act, the gun range was deemed as a legal "point source" and the club needed a National Pollutant Discharge Elimination System (NPDES) permit in order to continue operating. However, this was a case based on technicalities within the law rather than a real environmental danger. No scientific evidence was presented towards whether the gun range's operation created any environmental hazards. In the end, the New York Athletic Club could not obtain the necessary permits and the range was closed. [7]

2.1.3 Connecticut Coastal Fisherman's Association (CCFA):

The association filed a law suit against the Remington Arms Company who operated a shooting trap and skeet shooting club at Stratford, Connecticut, claiming the

company did not have a proper permit to operate the range. According to the CCFA, the gun range qualifies as a dumping ground for hazardous material, lead shots and clay fragments, and posed a danger to the local population of black ducks as well as other species in the surrounding area. Studies done on site concluded that the lead shots did pose an "imminent danger" to the black ducks, but other debris did not. The gun range itself did not require any remediation actions. [8]

2.1.4 Studies done by Virginia Tech:

Several studies were done by master students at Virginia Tech on lead distribution at several public gun ranges in the state. Their primary concern was to determine the level of lead concentration at these sites and how the lead was distributed. Their finding showed that lead concentration were focus primarily within a small area where the lead shot was targeted. Lead distribution did not extend much further beyond this area and mobility was very limited.

Of these studies, it appears that there are not many major problems at gun ranges that have come under investigation. Our initial research seems to indicate that in most cases, the problems at these sites are all based on technical written laws rather than serious environmental danger. However, the interpretation of the law differs depending on who is doing the interpretation. We will proceed to take an unbiased look at this problem and determine whether there is a problem and if so, how big is this problem. [9]

Section 3: Estimation Criteria

Based on the case studies done on various gun ranges around the country, we came up with a set of criteria on which to estimate the size of the contamination and whether it poses any danger to the surrounding environment and communities. The estimation will take into consideration: lead mobility, population density, and the amount of lead present as well as the amount of lead being introduced annually.

The amount of lead present is the accumulation of lead from previous years up to the present day. Being that lead itself is the problem we're focusing on, the amount of lead concentration determines the size of the problem. Combine the amount of lead concentration at gun ranges with the data from the cases studies on lead mobility, we can come up with a rough idea of how far lead can travel. Having a good idea of the range of the problem, we can move on to see how many people or how much of the environment is affected through the population density data.

3.1 Amount of Lead Involved

In estimating the amount of lead contamination around the country, we have to take a look at how much lead has been used, is being used, and will be used in the future. From 1920 to 1997, the total amount of lead that has been made into ammunition is estimated at 3.5 million metric tons. Extrapolating on that number, it is further estimated that the total amount of lead used in the 20th Century would be in excess of 4.1 million metric tons. [10] Granted that some of the lead is used at indoor gun ranges and some has

been removed at some gun ranges, most of the lead used remains in the ground still and so the estimate is thought to be accurate. Currently, lead munitions account for about 6% of the total annual lead consumption within the United States; this includes munitions exported outside the United States. However, this 6% represents the majority of lead introduced into the environment within the United States with approximately 50,000 to 60,000 metric tons being used, and thus, introduced on an annual basis. [11] Of that, roughly 2 million pounds (900 metric tons) are from military uses. [12]

Let's compare this estimate with statistics taken from a sampled gun range. The public shotgun range at the George Washington-Jefferson National Forests in southwestern Virginia has been open since 1993. Within a period of seven years, it has accumulated about 11.1 metric tons of lead within its general shooting area roughly 220 by 300 meters. The annual rate of accumulation is averaged at 1.5 metric ton and is expected to remain so for the foreseeable future. [13]

Figure 1 shows the lead munitions consumption of the United States from 1972 to 1993. As we can see, the rate of consumption is more or less between 50,000 and 60,000 metric tons since 1985. [14]

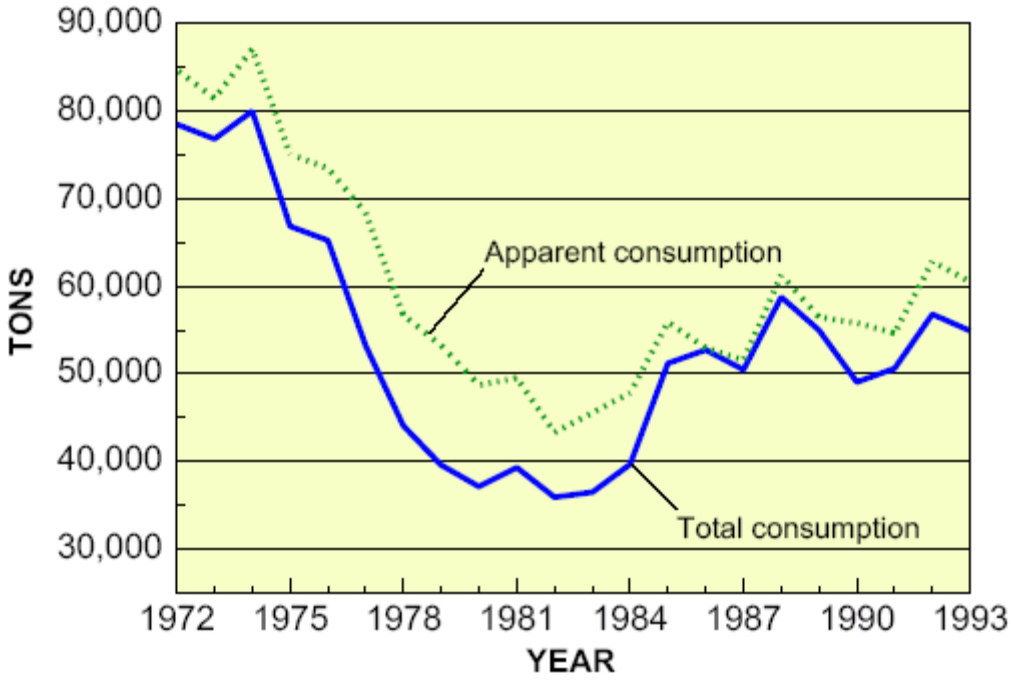

Figure 1: Lead munitions consumption of the United States from 1972-1993

3.2 Lead Mobility

It is expected that the shooting areas of gun ranges will have higher level of lead concentration than normal residential areas outlying the gun range. The concern is whether such levels can be considered contamination or dangerous to the surrounding environment or people living around the gun ranges. Knowing how much lead is released into the environment is one thing, but we must also know how far that lead will travel from its impact points.

It is estimated that the military maintains about 1,800 small-arm ranges all across the country. [15] While a small number of these sites are indoor, a large number of them are outdoor ranges that use bullet-traps or impact berms for capturing fired munitions.

These berms have shown to capture the majority of the lead, about 85% of the bullets. Tests at some berms showed a weight ratio of bullet to berm soil as high as 30%. [16] However, such soils are treated regularly and the shooting ranges are treated according to environmental safety standards.

Many civilian shooting ranges also use the same bullet-trap type berms. However, many also employ open-air target ranges where shots are fired at clay targets and debris are spread across a large shooting area. These open ranges are the center of much concern about lead mobility since the lead are spread across a wider area and more likely to undergo weathering effects. Studies done around world have made connections between lead mobility and several soil characteristics. In particular, there is high correlation between lead mobility and soil composition, pH, and availability of organic compounds.

Soil sampling and testing done on several sites in Florida have shown that a principal cause of lead transport is from oxidation of metallic lead debris from bullets to form carbonates and sulfates. [17] In particular, tests results showed that there was high lead concentration in the subsoil levels at sites with high presence of organic compounds and clay composition in the soil, penetrating as deep as 100 cm below the surface. [18] This was characteristic of sites that maintained bullet traps and berms where the high concentration of lead in one area resulted in deeper penetration of the surface soil.

Other studies done in Virginia and at New Jersey showed that soil lower and higher pH can also result in higher lead mobility. In particular, lower pH mobility is more common in areas with water sources where the lead is dissolved through weathering processes and form carbonates, sulfates, sulfides, phosphates, oxides, and hydroxides. In

particular, the presence of carbonates and sulfates most affect the dissolution of lead and the formation of lead compounds. Depending on the lead compound form, lead solubility varies and so does the concentration of lead at particular level. [19] See Figure 2. At the same time, pH also seems to play a major role in dissolved lead. If the lead is dissolved and enters a solution, its concentration can increase and decrease dependent on pH levels. See Figure 2.

The more problematic method of lead transport is not dependent soil composition, but by means of water. In Figure 3, we see that lead concentration is relatively high for alkaline solutions, common in certain soil types. However, they are just as high in more acidic solutions that are common with water run offs and other liquid-type transport medium. Figure 4 is a pH map of the United States that has a generalized average of pH ranges. If we know the pH for a region, we can make rough estimates of lead mobility. [20]

The biggest concern with most studies is the estimation of lead mobility. As of yet, determining a specific distance that is correlated to a certain pH and soil composition is impossible due to too many different varying natural variables. As a result, studies on lead mobility has only manage to look at travel distances in terms of probable or "possible" distances that the lead can travel, where lead mobility is assumed to be related to lead solubility. We can see this problem expressed in Figure 3 where lead mobility is given in terms of average lead concentration as a function of pH for specific soil type. Since estimating lead mobility in terms of distance is impossible, the estimation criteria used for this project is also done in the same manner as other studies, through lead solubility and lead concentration levels.

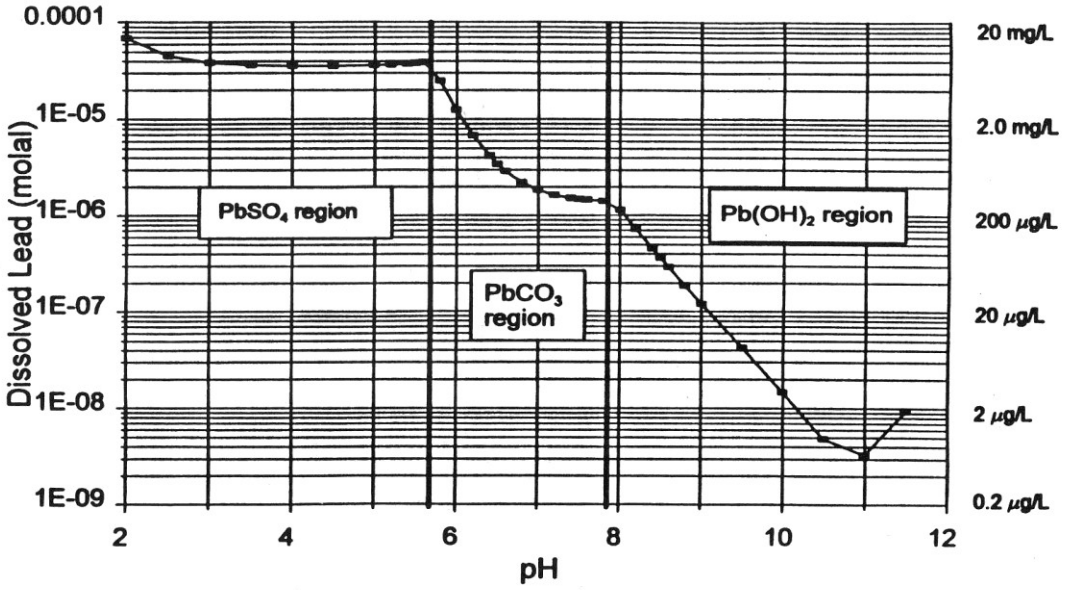

Figure 2: Lead solubility as a function of pH

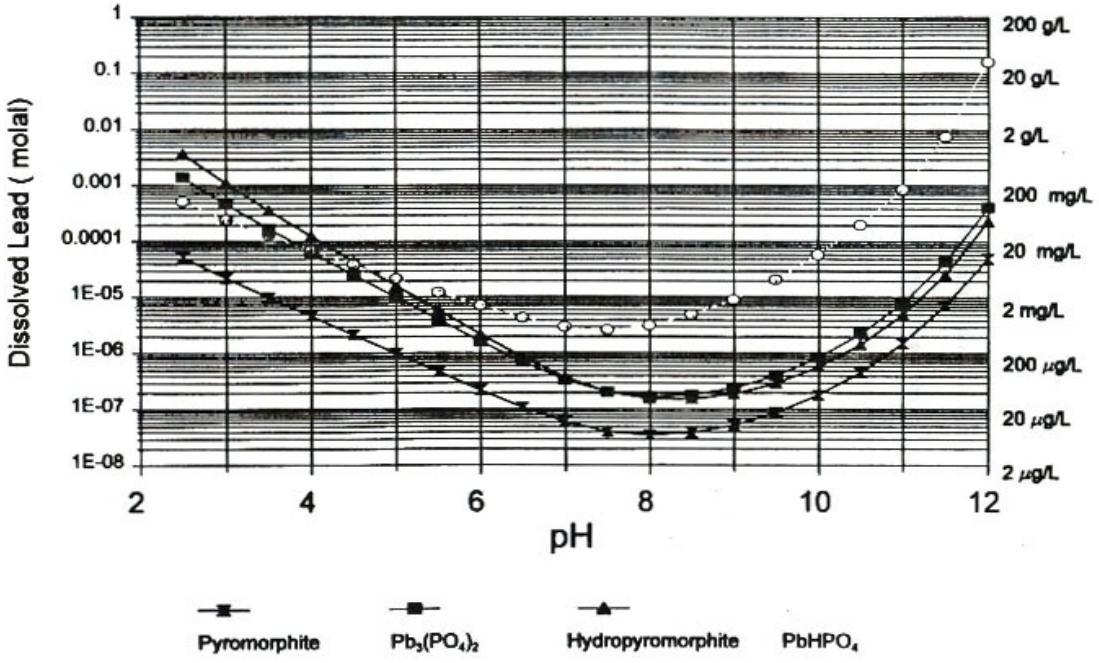

Figure 3: Dissolved lead as a function of pH for different soil composition

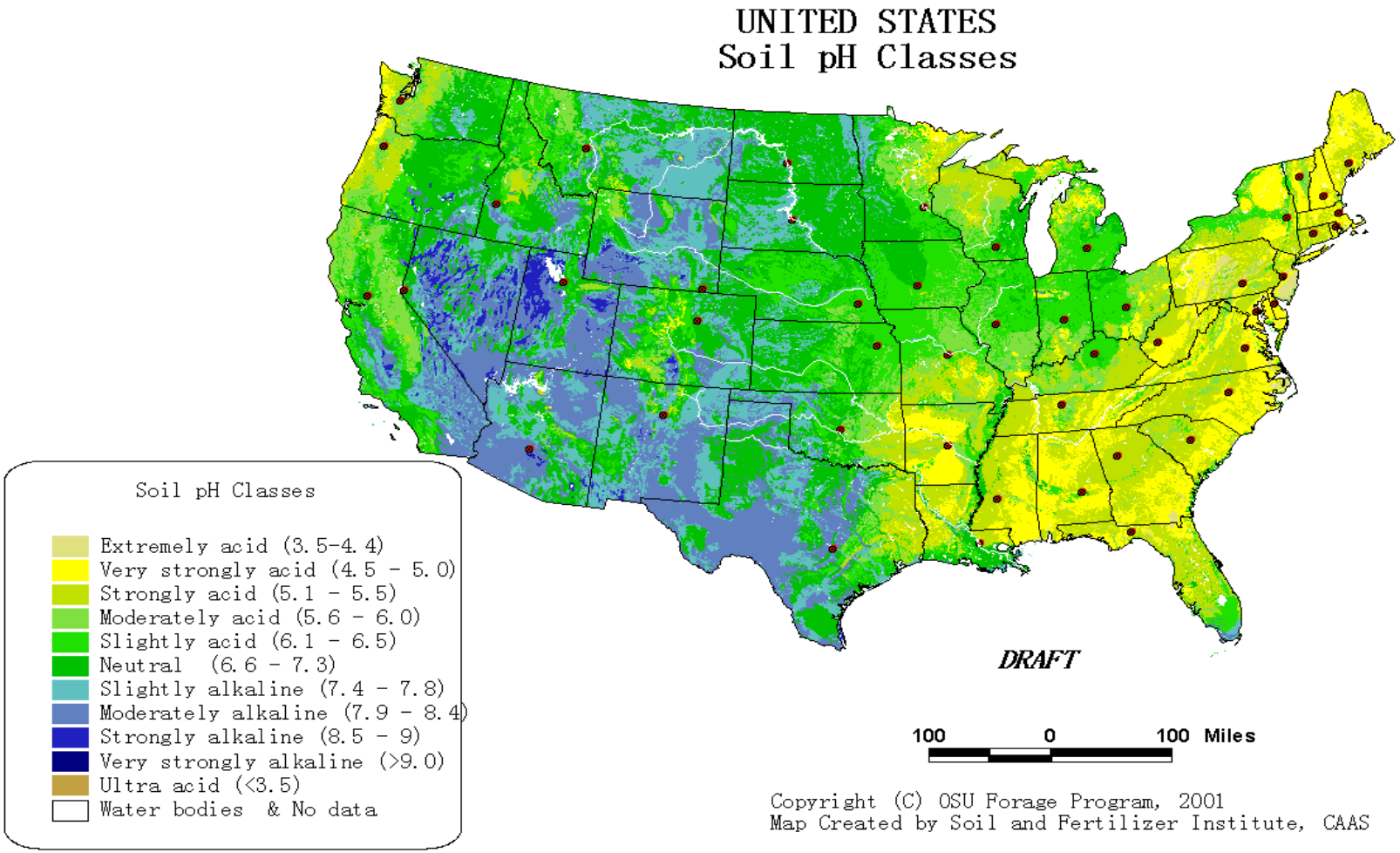

Figure 4: United States soil pH classes

3.3 Number of Gun Ranges involved

In order to determine the size of the problem, how much lead is involved, we also looked into setting an estimate for how man gun ranges is involved. Due to time and bureaucratic difficulties, the exact number of outdoor gun ranges as reported by government agencies was not obtainable. However, upon looking up the number of gun ranges involved through the National Association of Shooting Ranges (NASR), a list of roughly 4,000 gun ranges showed up for sites within the United States. [21]

The NASR list of gun ranges includes only those of commercial or private clubs. The number for military gun ranges within the United States is not included. From the lead mobility studies, we learned that the majority of military gun ranges utilize bullet traps and berms systems. These sites are maintained regularly to meet the standards set by environmental laws. We believe the number of ranges lacking adequate maintenance is limited and would fall under the categories of civilian sites on which we are studying. At the same time, there is very little differentiation given regarding which one of the above ranges is an indoor or outdoor shooting range. If we disregard the number of sites listed specifically as indoor shooting ranges, and therefore not included in this estimate, we can assume that with the inclusion of military and government outdoor ranges would make our estimate to 4,000 for total outdoor ranges within the United States reasonable.

Due to the nature of our estimating criteria, we divide the number of gun ranges into three separate pH regions organized by States. See Tables 2 through 4. By separating the data into smaller groups, it's easier to analyze the data in terms of determining what area of the country faces possible lead contamination problems with its gun ranges. Knowing the pH breakdown of regions of the country, the given population density and the

number of gun ranges, we can proceed to determining the amount of societal impacts within the next sections.

3.4 Analysis of Lead Contamination

As we have seen exemplified by the 3 case studies mentioned earlier as well as the Lead Mobility study, the mobility of dissolved is the main concern for potentially contaminated area. In addition, we have seen that lead mobility is related to pH level. Areas with basic and neutral pH have a lower lead dissolution rate and a lower lead mobility rate than areas with acidic soil. In other words, the areas we should concentrate on are areas with lower pH levels where lead is more likely to travel further and deeper. By identifying these areas, we can narrow down the areas of the country with potentially lead-contaminated gun ranges.

As indicated by Figure 4, we can see that lower pH exists in much of the eastern half of the United States and much of the West Coastal States. There are no data given for the two non-continental states, Alaska and Hawaii. Based on pH levels, we can separate the countries into three groups of States as follows: Acidic to Highly Acidic (pH of 5.5 or less), Neutral to Slightly Acidic (pH between 7 and 5.5), and Neutral to Alkaline (pH between 7 and 9). The following Table 2 through 4 contains data for each of these groups as given by States that have been classified into each groups. Since the pH level of each States differ only slightly within the state, a visual estimate is taken based on the pH map on what the "average" pH of that state is.

Let's look at the first region with soil pH between 7 and 9, Neutral to Alkaline. As indicated by Table 2, the states are Alaska, New Mexico, Nevada, Wyoming, Utah, North Dakota, Montana, Arizona, South Dakota, Idaho, Texas, Nebraska, Arkansas, Kansas,

Colorado, Oklahoma, Iowa, Hawaii, and Wisconsin. These 19 states account for little over 60% of the entire United States in terms of total area.

To get an idea of how many people are affected, we limit it to the number of people within a 0.5 mi radius of the gun range. We believe that, given the data from the lead mobility studies, the area of interests would not exceed the 0.5 radius from the gun range, as is considered the extreme case of lead contamination in a water source. Also included in that table is the population density of each State along with the number of gun ranges. Using these numbers, we calculate for the total number of people living within a 0.5 mi radius of a gun range per State. To get a better grasp of the number of people involved, that number is taken as a percentage of the State's total population. From those estimates, we take the averages for each individual pH region and the statistics are compiled for easier comparison in Table 1

	Neutral Soil	Slightly Acidic	Acidic
Average Number of gun ranges	51	131	84
Average # of people within .5 mile radius	29	100	557
Average % of State Population Within .5 Mile Radius	0.047	0.15	0.44

Table 1: Averages for each soil pH regions

The Neutral to Alkaline region has a range of pH between 7 and 9. Refer back to Figure 3, Dissolved Lead as a function of pH, we can see that the Lead concentration for soil within this pH range could reach as high as 25 micrograms per liter. This is higher than the 15 micrograms/Liter set by the EPA for safe water level. Even lead concentration for this pH range could be considered contamination, is this really a problem? We see that

the average total number of people within a 0.5 mi radius of a gun range for states under this group is only a little over 1600 people, roughly lower than 0.05% of the State's total population. The State with the highest percentage is Iowa with about 0.26% of its population living within a 0.5 mi radius of a gun range. See Figure 5. (NOTE: Hawaii is not included in the pH map so Iowa is used instead). Looking at the pH map, Iowa is primarily between a pH of 6.6 and 7.3. The level of contamination for that soil level can reach above 200 microgram/Liter. However, the number of people affected by this is less than 3000 for the entire state. This estimate of the number of people involved is representative of an extreme case for one state of this section.

State	Population (2000)	Population per sq. mile	Number of Gun Ranges	Total Area Sq. mi.	Land Area Sq. mi.	Area per Gun Range (sq. mile)	# of People in .5 mile Radius From Gun Range	Total # of People Within .5 mile Radius	% of State Population Within .5 mile Radius
Alaska	627	1.1	19	615,230	570,374	32380.5263	0.86	16.41	0.0026
New Mexico	1819	15	20	121,598	121,364	6079.9	11.78	235.50	0.0129
Nevada	1998	18.2	24	110,567	109,806	4606.95833	14.29	342.89	0.0172
Wyoming	494	5.1	27	97,818	97,105	3622.88889	4.00	108.09	0.0219
Utah	2233	27.2	29	84,904	82,168	2927.72414	21.35	619.21	0.0277
North Dakota	642	9.3	25	70,704	68,994	2828.16	7.30	182.51	0.0284
Montana	902	6.2	61	147,046	145,556	2410.59016	4.87	296.89	0.0329
Arizona	5131	45.1	50	114,006	113,642	2280.12	35.40	1770.18	0.0345
South Dakota	755	9.9	37	77,121	75,896	2084.35135	7.77	287.55	0.0381
Idaho	1294	15.6	49	83,574	82,751	1705.59184	12.25	600.05	0.0464
Texas	20852	79.6	175	267,277	261,914	1527.29714	62.49	10935.05	0.0524
Nebraska	1711	22.3	54	77,358	76,878	1432.55556	17.51	945.30	0.0552
Arkansas	2673	51.3	39	53,182	52,075	1363.64103	40.27	1570.55	0.0588
Kansas	2688	32.9	66	82,282	81,823	1246.69697	25.83	1704.55	0.0634
Colorado	4301	41.5	90	104,100	103,729	1156.66667	32.58	2931.98	0.0682
Oklahoma	3451	50.2	70	69,903	68,679	998.614286	39.41	2758.49	0.0799
Iowa	2926	52.4	72	56,276	55,875	781.611111	41.13	2961.65	0.1012
Hawaii	1212	188.6	9	6,459	6,423	717.666667	148.05	1332.46	0.1099
Average			50.8888889	124,411			29.28	1644.40	0.0473

Table 2: Statistics for States with neutral – alkaline pH soil types

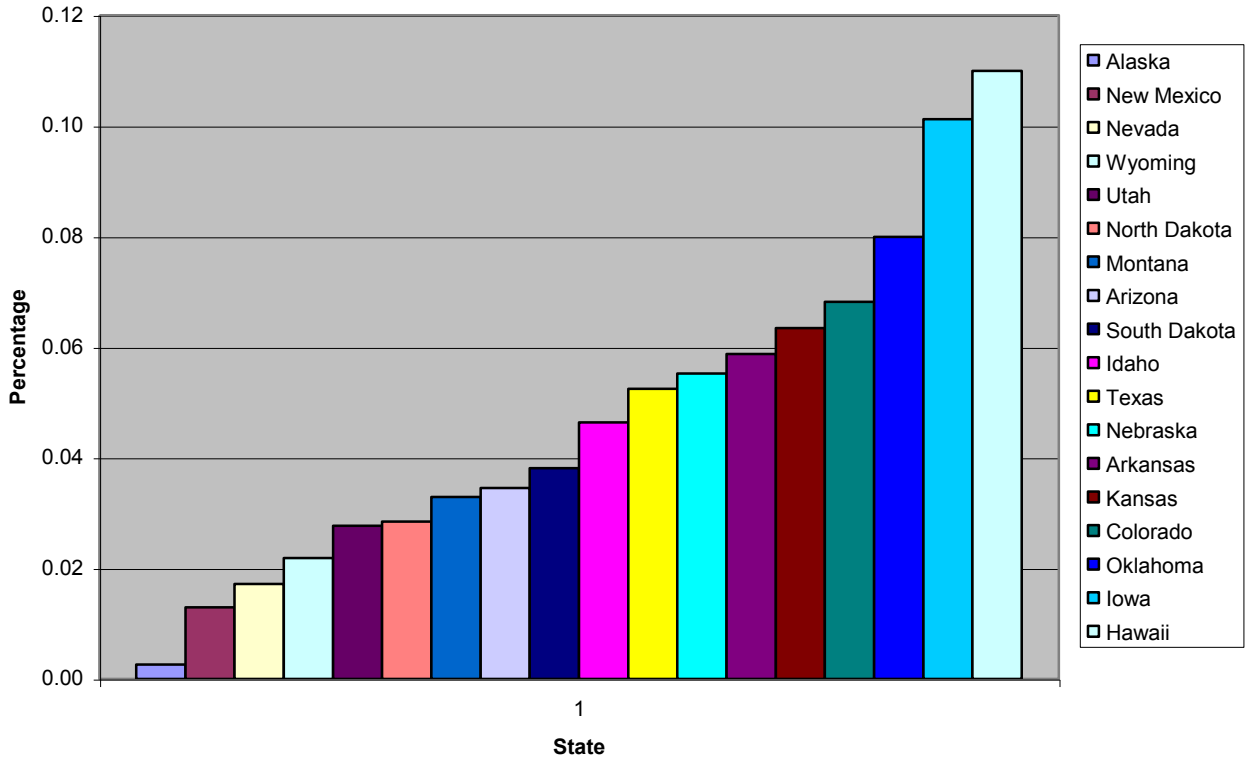

Figure 5: Percent of state population within 0.5 mile radius of a gun range for states within the neutral – alkaline region

The next section is the Neutral to Slightly Acidic region, which has an average pH level between 5 and 7. Looking at Table 3, we see that this group has only 9 States: Illinois, Oregon, California, Minnesota, Washington, Indiana, Michigan, Ohio, and Wisconsin. The average total number of people living within the 0.5 mi radius of a gun range for this group is slightly higher than 14,000 with California being the extreme case of about 34,000 people. Percentage wise, Wisconsin has the highest percentage of total population within the 0.5 mi radius of about 0.26% with the average for the group around 0.15 percent.

Let us take Wisconsin, having the highest percentage, as the extreme case. See Figure 6. The State has slightly more than 14000 people living within the maximum affected area. Looking at the pH map, Wisconsin has areas with pH levels ranging from neutral to strongly acidic. Theoretically, it is possible for the pH to drop to 5 and the lead concentration to reach close to 2 milligrams/Liter.

State	Population (2000)	Population per sq. mile	Number of Gun Ranges	Total Area Sq. mi.	Land Area Sq. mi.	Area per Gun Range (sq. mile)	# of People in .5 mile Radius From Gun Range	Total # of People Within .5 mile Radius	% of State Population Within .5 mile Radius
Illinois	12419	22.4	153	57,918	55,593	378.55	17.58	2690.35	0.022
Oregon	3421	35.6	62	97,132	96,002	1566.65	27.95	1732.65	0.051
California	33872	217.2	202	158,869	155,973	786.48	170.50	34441.40	0.102
Minnesota	4919	61.8	118	86,943	79,617	736.81	48.51	5724.53	0.116
Washington	5894	88.5	118	70,637	66,581	598.62	69.47	8197.76	0.139
Indiana	6080	169.5	85	36,420	35,870	428.47	133.06	11309.89	0.186
Michigan	9938	174.9	161	96,705	56,809	600.65	137.30	22104.74	0.222
Ohio	11353	277.2	133	44,828	40,953	337.05	217.60	28941.07	0.255
Wisconsin	5364	98.8	183	65,499	54,314	357.92	77.56	14193.11	0.265
Average			135				99.95	14370.61	0.151

Table 3: Statistics for States with neutral – slightly acidic pH soil types

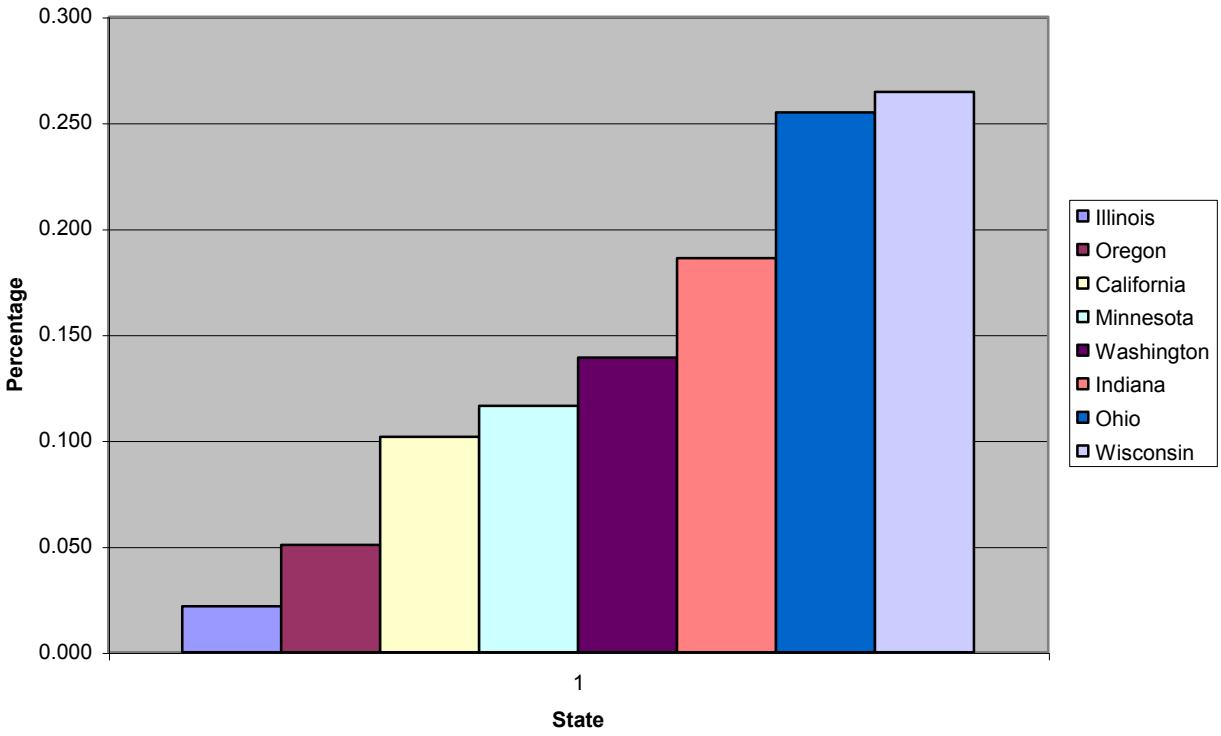

Figure 6: Percent of state population within 0.5 mile radius of a gun range for states within the neutral – slightly acidic region

Of the three groups, lead is most dissolved, and therefore most mobile, within this last group, Acidic to Strongly Acidic, where pH is lower than 5.5. At the same time, this group has the most number of States, 23 in all. See Table 4. This group accounts for only about 19% of the United States in terms of land area. However, it contains about 48% of the country's total population. Of the States' total population, an average of 22000 people live within the 0.5 mi radius of a gun range, an average of close to 0.5 percent. Here, there are two extreme cases. Percentage wise, Connecticut has a percentage of 1.4% of its total population encompassed within the affected. Meanwhile New York, with only 0.5% of its population in the affected area, has almost 100000 living within the 0.5 mi radius of a gun range. See Figure 7.

State	Population (2000)	Population per sq. mile	Number of Gun Ranges	Total Area Sq. mi.	Land Area Sq. mi.	Area per Gun Range (sq. mile)	# of People in .5 mile Radius From Gun Range	Total # of People Within .5 mile Radius	% of State Population Within .5 mile Radius
Louisiana	4469	102.9	41	49,651	43,566	1211.00	80.78	3311.84	0.074
Alabama	4447	87.6	52	52,237	50,750	1004.56	68.77	3575.83	0.080
Maine	1275	41.3	34	33,741	30,865	992.38	32.42	1102.30	0.086
South Carolina	4012	133.2	34	31,189	30,111	917.32	104.56	3555.11	0.089
Georgia	8186	141.3	78	58,977	57,919	756.12	110.92	8651.80	0.106
Tennessee	5689	138	58	42,146	41,219	726.66	108.33	6283.14	0.110
North Carolina	8049	165.2	69	52,672	48,718	763.36	129.68	8948.06	0.111
Virginia	7079	178.8	75	42,326	39,598	564.35	140.36	10526.85	0.149
Florida	15982	296.3	109	59,928	53,937	549.80	232.60	25352.91	0.159
West Virginia	1808	75.1	51	24,231	24,087	475.12	58.95	3006.63	0.166
Kentucky	4042	101.7	89	40,411	39,732	454.06	79.83	7105.27	0.176
Vermont	609	65.8	26	9,615	9,249	369.81	51.65	1342.98	0.221
Mississippi	2845	60.6	156	48,286	46,914	309.53	47.57	7421.08	0.261
New Hampshire	1236	137.8	37	9,283	8,969	250.89	108.17	4002.40	0.324
Maryland	5296	541.8	60	12,297	9,775	204.95	425.31	25518.78	0.482
New York	18976	401.8	312	53,989	47,224	173.04	315.41	98408.86	0.519
Delaware	784	400.8	15	2,396	1,955	159.73	314.63	4719.42	0.602
Pennsylvania	12281	274	364	46,058	44,820	126.53	215.09	78292.76	0.638
Massachusetts	6349	810	80	9,241	7,838	115.51	635.85	50868.00	0.801
New Jersey	8414	1134.2	95	8,215	7,419	86.47	890.35	84582.97	1.005
Rhode Island	1048	1003.2	16	1,231	1,045	76.94	787.51	12600.19	1.202
DC	572	9316.9	1	68	61	68.00	7313.77	7313.77	1.279
Connecticut	3406	702.9	91	5,544	4,845	60.92	551.78	50211.66	1.474
Average	5515.391304		84.4783	30,162			556.71	22030.55	0.440

Table 4: Statistics for states with acidic – strongly acidic pH soil types

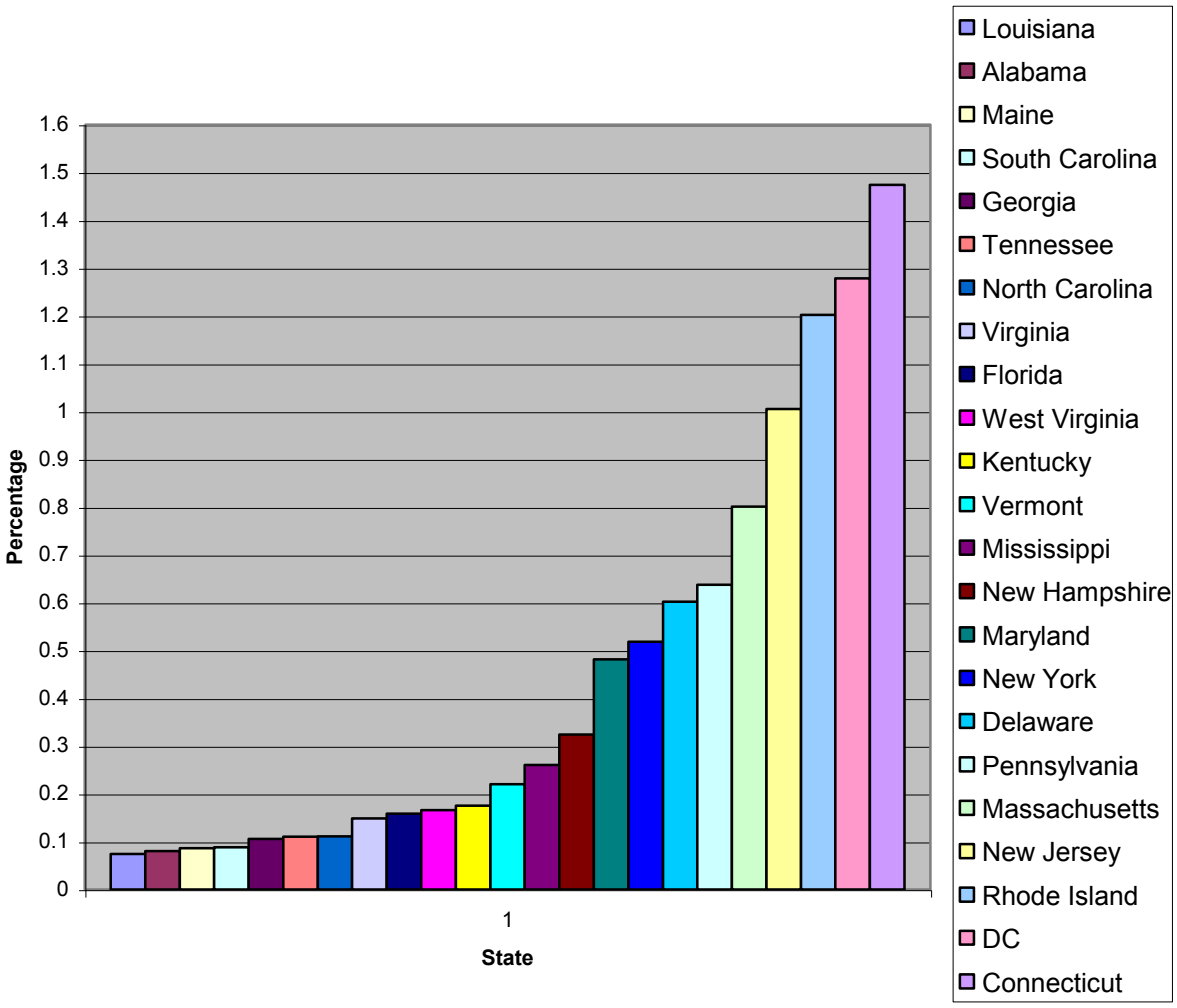

Figure 7: Percent of state population within 0.5 mile radius of a gun range for states within the acidic – strongly acidic region.

To determine the amount of contamination involves too many different variables that are unaccounted for by the available data. However, we do know that the major factors that determine the level of lead contamination include: the number of possible sources of contamination (the number of gun ranges) and lead mobility. Take note that we've simplify the determination of lead mobility to just pH levels since we cannot account for such various unknown variables as water source or vegetation level which are different for each range.

In terms of pH level and number of gun ranges, the region with the lowest statistics for both category is the Neutral to Alkaline region which has an average of only 1600 people within the affected area per State for a total of about 900 gun ranges for the region. While the pH for this region is the least suitable for lead mobility, the region itself has the least amount of land and people affected. As indicated by Table 1, less than 0.05% of the total population for a state in the region is actually within the 0.5-mile radius of a gun range. In short, the overall amount of lead contamination and the danger that gun ranges in this region poses insignificant. On a side note, we were unable to find any specific case studies done on gun ranges in any of the states within this group. Perhaps this is an indication that there are very little problems with lead contamination of gun ranges in this group, or if there are any problems, they're not a big enough problem as to raise concerns.

The pH for the Neutral to Slightly Acidic region is somewhat suitable for lead to travel a noticeable distance. Looking at the data, we see that the average number of people within the affected area for a State within this group is around 14,400 people while the total number of gun ranges is roughly 1200. Even though there are less States, the number of people and land that can be affected by lead contamination is a lot of higher than the previously mentioned Neutral to Alkaline group. Certainly the possibility of lead contamination becoming a danger is higher. In an extreme case, up to 2 mg/L of lead can be dissolved in a water source given the pH typical of this region. This is more than 10 times higher than the safety level of 15 micrograms/L. Given that about 0.15% of the total population of a given state within this group possibly lives in the affected area, the possibility of the extreme case raises concerns. On the other hand, it is very

unlikely that the danger pose would be anywhere near the described extreme case. From the lead mobility studies, we see that the pH levels of this group is suitable for a wide range of lead mobility, but it is unlikely that lead will travel for more than a few meters at most. The chance of lead getting to and contaminating a water source is very low.

By far the Acidic to Strongly Acidic group represents the most danger of the three groups. This group has an average of 22,000 people living within the affected area around a gun range for a total of about 1900 gun ranges spread across 23 states. The fact that this group occupies only 19% of the total land area of the United States while containing almost 50% of the gun ranges in the country results in a lot of people living within the affected region. Furthermore, the pH of this region is most suitable for lead to travel a greater distance. Considering an extreme case such as New York, where up to 100,000 people can live within the 0.5 mi radius of the gun range, this would pose a very large problem. At most, up to 1.5% of the State's population could be affected by lead contamination of gun ranges, such is the case of Connecticut. Again, these are only extreme cases. As indicated by the case studies, even though the theoretical danger is there, reality is slightly different. Of the 3 case studies done in Florida and West Virginia, only one sample from the Florida study showed that lead traveled a significant distance due to the extremely low pH and the soil condition. Even the two cases in New York and Connecticut that lead to the closing those gun ranges showed negative results for lead contamination (Refer to section with case studies). Overall, there is not enough evidence to suggest that lead concentration on these sites can lead to problems for the environment and people within the affected area.

Section 4: Conclusion

From our analysis, we see that the current situation with lead contamination is not a dangerous one. On a national level, there are no problems with the threat of elevated lead concentration becoming a contamination crisis for the surrounding environment and population. The rate at which lead dissolves prevents its mobility and limits it from traveling far outside a small affected area. However, there will be certain odd cases such as the two sites in New York and Connecticut where the firing of lead shots occurred over water sources and posed a greater danger to the environment.

In terms of breaking the country into smaller regions, we can see from the analysis of soil types and pH levels that certain areas of the country will have a higher threat level from possible lead contamination than others, such as Florida and Connecticut. Though there is a chance of contamination, it is relatively low. In addition, the number of people that could be affected is relatively low given our analysis extended the affected zone to an area within a 0.5 miles radius of the gun range. The damage that could be done on the surrounding environment is just as minimal if any.

In the end, an estimation of the lead contamination problem can only be done on a case-by-case basis where individual ranges of concern are studied for their particular pH level, soil type, and other characteristics.

Appendix A: health hazards associated with lead

Lead, despite a long history of beneficial use to mankind, is highly toxic element with no known beneficial purpose in the human body. Lead attacks many different body systems and organs, including nervous, blood-forming, reproductive and urinary systems. People can get lead in their body by: putting their hands or other objects covered with lead dust in their mouths, breathing in lead dust, eating something containing lead particles. It has been found that lead is even more dangerous to children than adults. Young children and babies have higher tendency to put their hands and other objects in their mouths. These objects can have lead dust on them. Children's brains and nervous systems are more sensitive to the damaging effects of lead and their still growing bodies absorb more lead.

Blood-lead concentration is a commonly used measure of body lead burden. An extensive body of research relates health effects of lead exposure to blood-lead concentration. An advantage is that blood-lead concentration could be easily and inexpensively measured. However, it reflects a mixture of both recent and past exposure. Since lead cycles between the blood and bone, a single blood lead measurement cannot distinguish between low-level chronic exposure and high-level acute exposure.

Lead enters the body primarily via ingestion and inhalation. Once entered the body, lead is absorbed, distributed throughout the body, and removed. Deposition/absorption rate is varying depending on age, size of the particle, and way of entry to the body. Table A1 shows deposition/absorption rates for various age groups and ways of entry of lead to the body.

Inhalation/Ingestion Entry to the Body	Age Group	deposition/absorption rate
Inhalation	General Population	30-50%
	Children	25-45%
Ingestion	Adults	10-15%
	Pregnant women and children	Up to 50%

Table A1: Lead absorption/deposition rates for various age groups

Health effects of lead could be seen at the subcellular level as well as at the level of general function of all systems in the body. The biological basis for many aspects of lead toxicity appears to relate to lead's ability to bind (attach) to substances crucial to various physiological functions. For example, lead may interfere with cell function by competing with essential minerals such as calcium and zinc for binding sites on membranes and proteins. Although lead primarily targets central nervous system, virtually all parts of the body can be affected especially at high exposure levels. Adults can suffer from: difficulties during pregnancy and other reproductive problems, high blood pressure, digestive problems, nerve disorders, memory and concentration problems, and muscle and joint pain. If not detected early, children with high levels of lead in their bodies can suffer from: damage to the brain and nervous system, behavior and learning problems, slowed growth, hearing problems, headaches

A.1 Neurological Effects of Lead

Encephalopathy is the most dangerous neurological effect of lead. Early symptoms of encephalopathy include irritability, poor attention span, headache, muscular tremor, loss of memory, and hallucinations. More severe symptoms: delirium, convulsions, paralysis, coma, and death appear as encephalopathy progresses. Studies have shown that children's IQ scores are inversely proportional to lead exposure. A study of the long-term effects of low-level lead exposure found that children with higher dentin lead levels were more likely to drop out of high school and have a reading disability

A.2 Other Effects of Lead

Other effects of lead includes:

- **Hematological Effects:** The effects of lead on the blood's biochemical functions are interrelated and have variable biological impact.

- **Death**: It is well known that severe lead poisoning can lead to encephalopathy and death.

- **Gastrointestinal Effects**: Colic is an early symptom of lead poisoning.

- **Renal Effects**: Both acute and chronic nephropathy (kidney disease) are known to be caused by elevated lead exposure.

- **Vitamin D Metabolism**: Lead may interfere with the conversion of vitamin D to its hormonal form, 1,25-dihydroxyvitamin D. This effect is most apparent in studies of children with high lead exposure.

- **Thyroid**: There is some evidence that lead may adversely affect thyroid function in occupationally exposed workers. However, no effects of lead on thyroid function have been reported in children.

- **Development**: Lead-related effects on children's development, such as reduced birthweight, reduced gestational age, and neurobehavioral developmental deficits, have been reported.

- **Immune System**: The data on immunological effects of lead in occupationally exposed adults are inconsistent, but indicate that, while lead may have an effect on the cellular component of the immune system.

- **Reproduction**: High levels of lead have been shown to cause adverse effects on reproduction in both men and women. Women who are exposed to high levels of lead during pregnancy have experienced an increased rate of miscarriages and stillbirths. In addition, women who were significantly exposed during childhood may be at increased risk of spontaneous abortion and stillbirth and their children more likely to experience learning disabilities

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