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UNITED STATES ARMY ENVIRONMENTAL HYGIENE AGENCY

ABERDEEN PROVING GROUND, MD 21010-5422

WATER QUALITY INFORMATION PAPER NO. 43
LEAD IN POTABLE WATER SUPPLIES

HSHB-ME-WR
SUBJECT: Water Quality Information Paper No. 43

CONTENTS

DEPARTMENT OF THE ARMY
U. S. ARMY ENVIRONMENTAL HYGIENE AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

REPLY TO
ATTENTION OF

HSHB-ME-WR 16 March 1988

SUBJECT: Water Quality Information Paper No. 43

LEAD IN POTABLE WATER SUPPLIES

1. PURPOSE. The purposes of this information paper are to create an awareness and understanding of the sources for lead in drinking water and the concomitant potential public health significance, as well as to provide viable remedial strategies for the detection and/or minimization of exposure to this material.

2. SOURCES.

a. The potential for exposure of potable water sources (either ground or surface water) to indigenous sources of lead, in quantities significant enough to entrain appreciable concentrations, is quite limited. Lead occurs in nature principally as a sulfide ore (galena), and is basically limited to areas in Missouri, Idaho, and Utah (reference 23). Concentrations of lead up to approximately 0.04 mg/L have been detected in isolated domestic water supplies in these regions. This material is readily removed when exposed to conventional water treatment systems providing protection to all except those utilizing contaminated supplies without any form of treatment (e.g., residential wells). Consumer exposure to natural lead remains rare, therefore. The primary source of lead input into potable water supply systems is through the distribution system, including service lines and interior plumbing systems. The utilization of lead piping, solders, and flux have been widespread, and lead may be readily leached into the system, particularly when conveying soft, aggressive waters.

b. Through the first half of the 20th century, lead and lead-lined galvanized pipe were used extensively for service hookups between the supply/street main and household systems, as well as within buildings, due to their prolonged life expectancy of 30-50 years or longer (reference 19). The age of the dwelling/piping and the amount of lead pipe used directly impacts the degree of exposure experienced by consumers, for newly installed and very old leaded materials tend to leach greater quantities of lead. The use of these materials dates back to 1st century A.D. Rome, where it was a symbol of privileged status to have water purveyed via lead piping. Many historians attribute the downfall of this powerful Empire to this continuous exposure to lead.

c. Lead-based solders and fluxes have proven to be the cause of much of the lead observed in drinking water systems. Soldering interior copper piping with a 50:50 or 60:40 lead:tin material has been demonstrated through time to be both effective and easy to use. The relatively low temperatures required to perform this operation minimizes the risks of heat damage and distortion of the components being joined (reference 25). When these solders, or fluxes, remain in contact with an aggressive water supply over a period of time, though, they may begin to leach significant concentrations of lead into the water. As with the piping systems mentioned above, this process remains more pronounced during the first few years (approximately 5) subsequent to installation. After that time frame, the observed values of lead diminish rapidly but still may persist at detectable concentrations. The use of lead-based solders has been documented as far back as ancient Egypt, circa 5000 B.C., with potential public health impacts reported around the 4th century B.C. (reference 26).

d. Other materials and appurtenances which might contribute to the amount of lead evident within the water system include copper piping, brass or bronze fixtures, and water coolers. Copper tubing is ubiquitous in plumbing systems throughout the country and remains the material of choice for interior plumbing despite the increasing popularity of plastic piping. Lead impurities in the manufacture of this material have not been limited or regulated; therefore, pipe containing a greater percentage of lead may impact the conveyed water to a substantial degree. Brass and bronze, conversely, are metal alloys which may possess a maximum, regulated quantity of lead (as established by the American Society for Testing and Materials). Faucets and fixtures of brass are common. This copper-zinc alloy can contain up to 12-percent lead. Similarly, the copper-tin alloy, bronze, may contain a maximum of 15-percent lead (reference 19). Residences utilizing these materials, in conjunction with lead-based solder and flux, may exhibit alarmingly high concentrations of lead to which consumers may be exposed over a period of time. In an office or commercial setting, several brands of water coolers have been implicated as the responsible agent for observed lead contamination of water supplies. The potential problem stems from the use, by several major manufacturers, of lead-lined tanks or lead soldering in coils of the refrigeration units.

3. REGULATORY BACKGROUND.

a. In 1962, the U.S. Public Health Service published drinking water standards (reference 34) which described lead as a cumulative poison, and reasoned that since exposure via ingested foodstuffs and ambient air had not been addressed, a limit on the ingestion of lead in drinking water should be imposed. The value of 0.05 mg/L (50 µg/L) was promulgated as a safe exposure level over the period of a lifetime. In addition, the PHS published "safe" limits based upon a brief exposure (i.e., a few weeks) of 2.0-4.0 mg/L. Upon establishment of the U.S. Environmental Protection Agency (EPA), the standard of 0.05 mg/L was accepted and implemented as a part of the National Primary Drinking Water Regulations. This figure still represents the regulated level of lead in drinking water, as documented in the most recent version of the National Primary Drinking Water Regulations (reference 7). Although 0.05 mg/L of lead is twice the National Academy of Sciences recommended standard for children (reference 28), EPA originally considered this criterion easily attainable and yet protective. More recent analysis of the potential impact upon infants and children, however, has caused EPA to propose a revised maximum contaminant limit (MCL) of 0.02 mg/L.

b. It is estimated that 40-million Americans are routinely exposed to lead in excess of 0.02 mg/L in their drinking water. The EPA has performed an extensive economic evaluation in an attempt to quantify the costs and benefits of lowering the lead MCL from 0.05 mg/L to 0.02 mg/L (reference 15). The costs of instituting effective corrosion control for all affected water supplies are estimated at $115-$145 million per year, or about $3.80 per person annually. However, the projected benefits resulting from reduced medical costs, diminished costs for compensatory education, and the prevention of decreased future earnings for affected children, along with similar savings predicated upon reduced hypertension, fewer strokes, and generally lower death rates for exposed adults, approach $1.1 billion annually. Material savings created by the enhanced corrosion control were also considered. According to this analysis, the benefits of reducing the MCL for lead exceed the projected costs by a ratio of about 4:1 (reference 15). The actual proposal for this change is scheduled to be published in the Federal Register by June 1988.

c. The Safe Drinking Water Act Amendments of 1986 (reference 6) imposed new restrictions regarding the utilization of lead materials in contact with potable water supplies, with the goal of eliminating its use altogether. Among the provisions of this law are:

(1) Effective 19 June 1986, the use of lead solder or flux exceeding 0.2 percent lead has been prohibited in new installations and repairs of public water supply systems, residences, and other buildings connected to such systems. The lead content in pipes in, or connected to, such systems may not exceed 8 percent (reference 10).

(2) Effective in June 1988, all public water supply systems are required to notify their customers of the possibility for lead contamination and potential adverse health effects.

(3) Effective in June 1988, all States must have a mechanism in place to enforce the lead prohibition and customer notification requirements.

(4) Effective in June 1988, the Department of Housing and Urban Development and the Veteran's Administration may not ensure or guarantee a mortgage (e.g., FHA or VA, respectively) for a newly constructed home unless the property/structure contains only lead-free pipe, solder, and flux (reference 24).

d. The lead content requirements delineated in paragraph 3c(1), above, basically coincide with the acceptable impurity limits for lead established for each of these materials. Specific guidelines regarding public notification procedures and content, as identified in paragraph 3c(2), were subsequently provided in the 6 April 1987 Federal Register. The first public notices must provide an explanation of the potential sources of lead, the adverse health effects associated with such exposure, reasonably available methods of reducing the lead content, whatever steps are being taken by the utility to mitigate lead contamination, and information regarding the availability of alternative supplies. Such notification is to occur through the media (for mass appeal) and via individual mailings on an annual basis for a minimum of 5 years (reference 10). The likely mechanism for accomplishing the mandate mentioned in paragraph 3c(3) would be through amendments to the State or local plumbing codes. Failure to implement such enforcement will result in the Federal government witholding up to 5 percent of the State's "Public Water System Supervision Program Grant" (reference 26).

e. The American Water Works Association issued a position statement in early 1987 (reference 35) which endorsed the aforementioned changes regarding the utilization of lead. This organization strongly "supports a ban of the use of lead pipe and solder in new construction of public water systems and in drinking water services, including home potable water plumbing. The association recognizes the need to continue to use certain amounts of lead materials to maintain existing public water system." The latter portion of this statement refers to the practical need for limited amounts of lead materials to be used in the repair of, or connection to, systems utilizing cast-iron pipes. Available alternatives which may be effectively employed in these circumstances are extremely limited. However, the use of lead in these instances should not pose an elevated risk to consumers, as it will not be in contact with the water supply, if used correctly.

f. Since the leaching of lead into potable water supplies is frequently a direct function of the water's corrosivity, a brief discussion of the regulations pertaining to corrosivity appears appropriate. The National Secondary Drinking Water Regulations (reference 8) address the aesthetic significance of corrosivity, and specify a regulatory requirement that the water supply be noncorrosive. Corrosion is addressed in the National Primary Drinking Water Regulations (reference 7) from the perspective of potential health effects associated with metals such as lead. Although EPA has not promulgated numerical standards for corrosivity, a requirement for distribution system monitoring one sample per year for systems utilizing surface sources and one sample every 3 years for ground-water sources has remained in place since 1980. There exists numerous indices for the determination of a water's aggressive/corrosive character; however, the Langelier Saturation Index, as described in Standard Methods for the Examination of Water and Wastewater (reference 9), has received the greatest use. A computed value less than -0.5 for this index indicates the corrosive nature of the source.

4. HEALTH SIGNIFICANCE.

a. Despite the presence of lead in many foodstuffs, it possesses no known beneficial/nutritional value. On the contrary, lead has displayed many debilitating effects based upon acute and chronic exposures. Acute lead poisoning is relatively rare. When it does occur, it is evident primarily in young children, who are considerably more susceptible to such injury. The most frequently detected sequelae include anorexia, vomiting, malaise, and convulsions due to increased intracranial pressure (reference 36). Chronic adverse effects of lead toxicity are observed primarily in the hematopoietic system, central and peripheral nervous systems, and kidneys. Further, chronic exposure to lead may interfere with the blood-forming process (as this metal concentrates in the skeletal structure) and vitamin D metabolism, may retard the mental and physical growth of children, and is associated with increased frequency of hypertension and strokes in adults (reference 33). Lead encephalopathy occurs primarily in children up to 3 years of age. Of those surviving, approximately 94 percent experience some measure of permanent psychological abnormality (reference 12). The effects of lead toxicity manifest slowly and are not unique to lead poisoning, often leading to misdiagnosis. Lead poisoning can only be confirmed through blood-lead testing.

b. Generally, MCL's are established based upon consumption of the subject material by a 70 kg adult at a rate of 2 liters of water per day over the period of a lifetime. This pattern does not provide adequate protection in the case of lead ingestion, however. It is estimated that an adult's body absorbs 10 percent of the total lead ingested, with the remaining 90 percent harmlessly excreted. In comparison, the lead uptake in children up to 3 years old is closer to 45-50 percent. This, combined with the increased susceptibility to developing related sequelae, serves to exemplify the significant problem posed by lead. Further, several studies have shown that absorption of lead can vary depending on the state of the gastrointestinal system. Specifically, lead ingested on an empty stomach (e.g., at breakfast) has a much higher absorption rate than does lead ingested on a full stomach (reference 15). First flush water used to prepare concentrated liquid formula for infants may have an even greater impact, due to this phenomenon. As stated, the onset of lead toxicity is rather slow. Short-term effects of exposures to lead via drinking water (up to approximately 10 days) are not readily expressed. It takes a minimum of 35 days to achieve a blood-lead level of greater than 15 µg/dL (micrograms per deciliter), which is the value at which adverse health effects become manifest (reference 18). With increased lead intake, blood lead levels achieve new, elevated values in approximately 60 days.

c. Lead has the potential for crossing the placenta beginning in the 12th week of pregnancy and continuing until birth. Irreversible effects of lead may result from this early exposure, and would be of greater consequence since this would be the baby's only source of nutrition and its absorption rate would be far greater than that of the mother. Infants often receive their greatest exposure, with respect to drinking water, from the liquids that constitute their total diet. For example, liquid concentrated formula and juices may be hydrated and mixed with first flush water from the tap. At any point, exposure over a prolonged period may result in the stunting of a child's mental and/or physical development. The EPA has suggested that, as of 1985, "the lead epidemic causes slightly lower intelligence among 143,500 children every year" and "also produces a higher risk of pregnancy complications in 622,000 women" annually (reference 35). In support of these statistics, reports have documented a high correlation between high dentine lead levels and teacher's ratings of 11 defined negative classroom behaviors (reference 31) and a direct correlation between elevated lead levels detected in children's teeth and a fourfold increase in the risk of having IQ scores less than 80 (reference 32). Teeth, ribs, and other portions of the skeletal structure provide a select sink/collection point for lead in the body.

d. Studies completed by international health organizations have further defined the relative impacts of lead toxicity causing a re-evaluation of the levels at which such reactions may become manifest. The World Health Organization (WHO) maintained a longstanding safe daily intake limit of lead of 300 µg/person (reference 33). This value assumed that no more than the 10-percent absorption observed in adult subjects occurred, and that the concomitant 30 µg lead/100 grams of blood (30 µg/dL) was safe. After continued investigation, the enhanced sensitivity of children was identified, with adverse effects observed at blood lead levels as low as 10 µg/100 grams of blood (10 µg/dL). The Centers for Disease Control (CDC) arrived at a similar conclusion (reference 15). Although no explicit threshold could be identified for many effects, their definition for lead toxicity was lowered to 25 µg/dL from 50 µg/dL. While CDC detected subtle changes in biochemical measurements at 10 µg/dL, WHO identified the prevalence of enzyme inhibition at this level. At 15 µg/dL, WHO researchers found changes in echoencephalogram readings and elevated zinc proporphyrin. Between these values, there is further disruption of biochemical processes, including the uptake and utilization of vitamin D. The first evidence of interference with the development of globin and red blood cells has been observed at approximately 20 µg/dL. Most of these effects either directly or indirectly affect the mental processes of children, and severe retardation and death may occur when blood lead levels reach the range of 80-100 µg/dL. The WHO has also reached the conclusion that many urban dwellers approach or exceed the recommended levels for lead exposure through the route of ambient air, alone (reference 12). Because of this, it becomes imperative that the lead in drinking water be regulated within rather strict limits.

5. CORROSIVITY AND LEAD.

a. The leaching and entrainment of lead into potable water supplies from service lines and interior residential plumbing is generally directly dependent upon the relative aggressiveness or corrosivity of the conveyed water. The characteristics of water which have the greatest impact on corrosiveness are pH, alkalinity, total dissolved solids, hardness, temperature, dissolved oxygen and carbon dioxide concentrations. Soft waters with low pH and alkalinity, and high total dissolved solids and carbon dioxide concentrations, which are characteristic of many ground-water sources, have proven particularly corrosive to plumbing materials. What makes this problem so pervasive is the fact that almost all individual residential supplies, as well as many public supply systems, are purveyed virtually untreated for corrosion.

b. The "master control variable" with respect to the solubility of lead is pH (reference 15). Water has proven to be quite plumbosolvent (i.e., able to leach lead from plumbing materials) at pH less than 6.8 or greater than 10.2. The plumbing material most susceptible to such conditions is lead contained in solders and fluxes. Lead from these sources is frequently found in water systems due to its widespread use and ready solubility. The type of corrosion prevalent may vary, as well, depending upon the water conditions and plumbing materials present. Galvanic corrosion, which occurs when two dissimilar metals (with different electrochemical potentials) are exposed to each other under certain environmental conditions (i.e., corrosive water supply), occurs most frequently at low pH levels. When galvanic action occurs, the material associated with the anodic end of the galvanic series (reference 4) generally will corrode first. The progression of this series for commonly used materials is as follows: anodic end>magnesium>zinc>aluminum>carbon steel>cast iron>lead>tin>brass>copper>bronze>silver>carbon>gold>cathodic end. As can be observed, when a lead:tin solder is used to join copper piping, the lead will preferentially corrode and dissolve. This action usually creates the most serious problem with respect to new plumbing, where lead levels reaching over 200 µg/L can be leached overnight (reference 15). When the pH remains below approximately 6.5, this galvanic action generally provides relatively uniform corrosion of exposed surfaces/materials. Adjustment, or natural readings, of pH between 6.5 and 8.0 might display a measure of lead leaching, as well; this would likely result from discontinuous pitting of the exposed surfaces and joints. A combination of treatment measures will be necessary to maintain suitable corrosion control, as pH control alone will not have any impact in waters exhibiting low levels of carbonate or bicarbonate alkalinity. Although secondary drinking water regulations (reference 8), where enforced, require that pH levels be maintained between 6.5 and 8.5, a number of utilities require that a pH of greater than or equal to 7.5 be consistently maintained in order to minimize corrosion damage (reference 27).

6. DETECTION OF LEAD.

a. For many years, the presence of lead in drinking water supplies has been a peripheral concern, as it was seldom detected at levels approaching the MCL. As recent as 1970, the National Research Council published a report (reference 30) stating that approximately 1.4 percent of the nation's water systems exceeded the 1962 standard of 0.05 mg/L. More recently, though, the estimated number of Americans exposed to elevated lead levels has risen significantly. This is partially due to an upgraded approach in sampling and analytical techniques, and partially because of comparison with the proposed standard of 0.02 µg/L. Lead levels as high as 43,000 µg/L have been identified in Huntington, New York (reference 28). While such extreme levels are the exception, many more utilities have reported consistently higher concentrations (i.e., in excess of 0.02 µg/L) since utilizing first flush samples from household taps.

b. Historical data documenting the presence of lead in potable water supplies are somewhat misleading, for they were obtained from traditional drinking water samples required by regulation on an annual basis. The traditional use of random sampling locations and conventional sampling techniques, to assure compliance with primary and secondary MCL's, involved the thorough flushing of lines in an effort to provide a sample representative of the water in the supply mains. Such samples, however, would not prove suitable for an accurate characterization of the presence of lead and other corrosion byproducts associated with piping, solders, and flux. This sampling scheme may provide a false sense of security, regarding metals contamination, and may contribute to misdiagnosis of related health problems. For example, the rare death of a child in Smithtown, New York, attributed to lead poisoning with significant input from potable water consumption, was originally discounted because the utility exhibited a 15-year record of lead-free distribution samples (reference 28). However, followup first-flush sampling identified consistently high concentrations of lead emanating from the service line and interior plumbing in this household.

c. As mentioned above, lead and other materials associated with corrosion problems may only be identified through an amended sampling scenario which includes the collection of water which has been sitting in the plumbing system for a period of time (e.g., overnight). A comprehensive monitoring program, which would provide a thorough analysis of the presence/extent of lead, should include such a first-flush sample as the first of three samples collected at each site. This initial sample should be taken from a commonly used tap (e.g., kitchen faucet) in the morning before any water is wasted, or any other household faucet is used or toilet is flushed (after sitting for a period of approximately 6-8 hours). The water used by consumers to make coffee, juice, or baby formula may be closely approximated by this sample. A second sample, representing water from the service line, could be collected immediately after the water temperature at the sample location begins to equilibrate (reference 14). This sample may be eliminated at the discretion of utility/regulatory authorities, should they determine that such a sample would not be useful or would be difficult to differentiate from one of the other two samples collected. The final sample, which must be included in this scheme, would be obtained after allowing the faucet to run for 3-5 minutes. This effort mimics the conventional metals sampling procedure, and would provide a characterization of water in the supply mains. Detection of lead via this scheme would not only aid in the determination of who was exposed to this material, but would also serve to help identify the location of the problem source.

d. Obviously, it would prove a time-consuming and costly endeavor to perform such a thorough analysis of every building/residence served by a water system. It is, therefore, necessary to develop an effective protocol to include prioritization of locations to be sampled at a given time. A number of criteria may be used to determine what sites might be examined first in a corrosion byproduct monitoring program (reference 17). For example:

(1) Locations where corrosion problems are suspected due to numerous consumer complaints, etc.

(2) Buildings with interior plumbing containing copper, lead, or galvanized steel pipe.

(3) Service lines containing these same materials.

(4) Recently constructed buildings or recently renovated plumbing systems.

e. To take this a step further, hospitals and locations housing or serving infants and small children may be selected for immediate investigation, due to the individuals' enhanced susceptibility. Alternatively, or on a routine basis subsequent to the initial phase, quarterly samples could be collected from an established number of sites based upon the population served (e.g., 5 sites for a population of 1,000, 10 sites for a population of 5,000, etc.; reference 32). This quarterly sampling routine could be continued for sites where elevated levels of lead are found, until the concentration falls below 0.02 mg/L. At that time, the frequency could be dropped to annually. It is imperative that not only lead, or specific corrosion byproducts, be analyzed for by the support laboratory but also the parameters necessary to determine the corrosiveness/aggressiveness of the water supply.

f. The effective implementation of such a program will prove burdensome and costly for large utilities, in particular. One, or a combination, of several available alternative approaches may be used to define the extent of the immediate problems. Historical records and archives may be consulted for organizations which have documented such activities and have remained well organized over the years. This approach has proven especially useful for larger, older systems, for it significantly reduces requisite manpower requirements (reference 32). In some cases, the local or County health department may already have documented the presence of such materials in response to a 1980 edict by EPA for all public water suppliers to inventory the use of various plumbing materials. (The Army has not complied with this edict, except for a few isolated cases.) Such information would preclude the need for a thorough initial screening of all sections of the system. Also, utility personnel (e.g., meter readers and repairmen) could augment existing information regarding plumbing materials used as a routine part of their jobs. This effort would prove rather slow and manpower intensive; however, it would provide an accurate depiction of actual conditions of the existing system. A final option, which could only be implemented in utilities having relatively few connections because of the requisite time and manpower requirements, would entail house-to-house surveys/interviews conducted by utility or contracted personnel. The replacement of lead materials in plumbing systems would be accomplished over a period of time, in a systematic manner. Once again, facilities housing more susceptible personnel (e.g., schools, day-care centers, etc.) should be addressed first, followed by areas determined to possess a high potential for leaching via appropriate monitoring or because of the corrosive nature of the water supply and the presence of susceptible materials.

7. APPLICABILITY TO ARMY ACTIVITIES.

a. Based upon available U.S. Army Drinking Water Surveillance Program data and information gathered during specific U.S. Army Environmental Hygiene Agency (USAEHA) consultations, lead contamination of potable water supplies has not been accurately evaluated and documented at Army installations. Until very recently, these samples have been collected via the flushed-line technique (described in paragraph 6b) and analyses reviewed have been compared to the existing 0.05 mg/L standard. These procedures have been updated to reflect the guidance offered in this paper for the few installations recently requesting such nonroutine/special USAEHA support. Routine analytical support provided to meet regulatory obligations will likely reflect the historical approach, however, until such time as the regulations are officially amended. The status of many Army water systems is such that it would indicate that the potential for lead exposure exists, as many systems convey very corrosive water with virtually no treatment other than disinfection which may serve to further lower pH where natural buffering capacities are limited. These systems generally possess numerous areas exhibiting stagnant water (e.g., little or no flow due to lack of use and/or poor design) in contact with aging lead, copper, and galvanized steel piping, lead-based solders and fluxes, affected water coolers, and brass valves and plumbing fixtures.

b. Due to the recent advent of this problem, existing Army regulations and guidelines do not adequately address it. In accordance with AR 40-5 and TM 5-810-5 (references 1 and 5), the design and installation of water lines and appurtenances are to be accomplished in accordance with the current National Standard Plumbing Code (reference 29), which still endorses the use of leaded plumbing materials. The primary emphasis, in this regard, in Army guidelines appears to involve only the causes of corrosion and recommended control measures. While TB MED 576 (reference 3) provides a cursory look at corrosion control from a preventive medicine/health perspective, TM 5-660 (reference 4) offers a rather extensive review of corrosion sources, impacts, and control for potable water systems. Still, little mention is given the potential presence or effects of corrosion byproducts. These issues must, therefore, be addressed via procedural guidelines and the implementation of good engineering/health practices.

8. REMEDIAL MEASURES.

a. The mode of treatment which could be implemented to ameliorate the leaching of lead into drinking water supplies depends greatly upon the extent and source of the problem. A number of remedial options can be readily instituted in a cost-efficient manner for community suppliers utilizing a centralized source and distribution system; whereas the alternatives are considerably more limited when only an individual residence (or group of buildings utilizing individual supply wells) is involved. Among the options to be evaluated are: stabilization of the water supply via chemical and physical treatment processes, corrosion control achieved through chemical addition, point-of-use/point-of-entry devices, use of alternative sources, flushing the faucet thoroughly prior to use, and the replacement of susceptible piping and solder. The ultimate goal, according to EPA, is to achieve lead-free water systems. This can be accomplished through a combination of several approaches (reference 22), including the monitoring of water systems and issuance of public notifications, the treatment of water supplies to remove lead or minimize corrosion, and/or the replacement of leaded plumbing materials.

b. Lead in the water supply can be very effectively removed via conventional treatment systems (e.g., coagulation/sedimentation/filtration or lime softening). Removals of 85-90 percent of lead can be obtained through the basic removal of turbidity. However, lead is rarely in such a form, or in sufficient concentrations, in raw water supplies that treatment accomplished via a conventional surface water plant would prove necessary. Lead concentrations observed at points within the distribution system are generally the result of corrosion of the distribution system. As a corrosion byproduct, the presence of lead is more directly impacted by the factors delineated in paragraph 5a. The institution of pH adjustment alone, although it is the primary factor of concern, has often proven insufficient for waters with inadequate buffering capacity, for the protective coating formed on the piping interior will not be durable or persistent. The use of chemicals such as soda ash or sodium bicarbonate for pH adjustment are preferred because they address both problems (albeit a greater quantity of other chemicals would be required to change pH than would be necessary with lime or caustic soda). This approach has proven extremely successful as a treatment mechanism for lead. In the presence of 30-40 mg/L alkalinity (as $CaCO_3$), lead exhibits a minimum solubility at a pH of about 8.5 (reference 13). It will take a significant quantity of soda ash or sodium bicarbonate in comparison with lime or caustic soda for ground waters exhibiting a natural pH of approximately 5.5-6.0. The injection of explicit corrosion inhibitors is another option which has displayed periodic success. This approach requires very tight control on system pH, for maximum effectiveness occurs within a very narrow pH range. Zinc orthophosphate has proven to be the most common and effective form of inhibition practiced. It is recommended that State health/regulatory authorities be consulted prior to instituting major changes in water treatment operations.

c. Extensive treatment of water supplies is not practical for extremely small scale utilities or individual residences. Such systems require easily implemented, low maintenance, low technology solutions. Calcite filters placed in-line, at the point-of-entry to a structure, have proven quite effective while meeting these criteria. This type of arrangement would serve to stabilize the water supply entering the consumer's premises; thus, minimizing the leaching of lead from interior plumbing materials and appurtenances. Yet another approach involves the use of point-of-use devices (at a specific tap) to remove whatever lead may have been introduced via distribution system materials prior to consumption. Units utilizing reverse osmosis and distillation processes have been effectively employed for this purpose. These units do require a measure of operation and maintenance, however, and may be effective only within a narrow range of water quality characteristics. Commonly used point-of-use filters containing carbon, sand, or woven cartridges will not consistently remove lead or other corrosion byproducts (reference 16). Although this is condoned by EPA as an effective interim measure, the installation of point-of-use or point-of-entry devices within the Army is generally not encouraged. Approval must be obtained from DA and major command authorities prior to installing such devices. Another common practice which should be avoided, if possible, where the potential for lead exposure/toxicity has been identified, is the installation of in-line water softeners, which serve to remove hardness from the low pH ground waters generally withdrawn for household use.

d. The most easily implemented remedial measure which may be employed is to allow the water to run through the kitchen/household tap for several minutes prior to use. This is particularly recommended for susceptible buildings in the morning, or after other periods of extended nonuse. First-flush concentrations of lead are generally much greater than those experienced during normal, routine operation; therefore, it is assumed that consumers will not be exposed to harmful levels after the water which has remained stagnant in the piping has been flushed thoroughly. Also, it is recommended that water from the cold water tap always be used for drinking, cooking, and especially for preparing baby formula. Hot water tends to be considerably more corrosive; thus, possessing the potential for exhibiting a significantly greater lead content. Should the water quality deteriorate to such a point where this procedure is insufficient to avoid significant exposure, it may be necessary to procure an alternative water supply (e.g., bottled water) as an interim measure.

e. Regardless of the treatment option selected, the ultimate goal is to replace all compromised plumbing materials with lead-free materials. Alternatives to using service lines composed of lead are readily available and practicable. Plastic piping has become increasingly more popular for household/commercial water systems; however, it has yet to supplant copper for interior systems. Therefore, a major consideration when projecting a lead-free system is the replacement of conventional lead-based solders and fluxes. Traditionally, a 50:50 or 60:40 lead:tin solder has been used for plumbing systems. These materials form a solid, lasting joint and are relatively easy to use. They also provide a ready reservoir of lead if exposed to corrosive waters. Several other solders are available (i.e., 95:5 tin:antimony, 95:5 tin:silver, or 95.5:4.0:0.5 tin:copper:silver); however, many plumbers and utilities personnel have been hesitant about using them due to additional costs incurred and stories that they were more difficult to work with and provided an inferior bond. Although certain of these claims are true, to an extent, most are unfounded. The lead:tin solder costs about $4.50/pound, as opposed to $8.00/pound for the tin:antimony and $20.00/pound for the tin:silver types. While this appears to be a considerable difference, it takes less than 1 pound of solder to complete a single residence. Reportedly, the tin:antimony solder provides a stronger joint than the traditional lead:tin version, and the shear strengths of both the tin:antimony and tin:silver solders far exceed that of lead:tin solder (reference 28). These alternatives demand better control of temperatures achieved while soldering, as their effective melting ranges are narrower than that required by the lead-based material, which means that plumbers may have to alter their technique somewhat to achieve a reliable, enduring bond. Quality control for these plumbing materials will likely come under much more stringent scrutiny than has been experienced in the past. The American Society for Testing and Materials standards allow for up to 0.2 percent lead as an impurity in tin:antimony solder; however, some manufacturers have historically not been concerned that excess amounts were introduced. This standard must be strictly enforced in order to attain the requirements mandated by the new Safe Drinking Water Act Amendments.

9. SEQUENTIAL SURVEY APPROACH. Following is a rather simple approach to determine the potential for, and presence of, lead in the potable water distribution system. This listing is provided as general guidance, and may not be completely applicable to each installation. The absence or presence of detailed plumbing records, a materials inventory, and/or available personnel resources will impact this approach. Outside/commercial resources (e.g., laboratory support or large-scale plumbing replacement) may be utilized, as needed. The USAEHA assistance may be solicited for evaluation of potential hazards, the review of proposed remedial action plans, and/or limited analytical support.

a. Initially, responsible preventive medicine service (PVNTMED Svc) and Directorate of Engineering and Housing (DEH) personnel must communicate and address this situation jointly, as it directly involves utilities/plumbing personnel and poses a definite threat to the health and welfare of consumers.

b. The DEH should possess, or obtain, an inventory of plumbing materials and activities which have the potential to introduce lead into the distribution system (e.g., lead pipes, lead-lined galvanized piping, lead solders or flux installed within the previous 5 years, and specified water coolers).

c. Historic records and data may be used to perform subsequent evaluations/prioritizations of sites. This includes current as-built drawings and material listings, past analytical results for the system, and consumer complaints.

d. For concerns involving water coolers, specifically, the previous steps should be accompanied by the acquisition of information delineating the brand and model number of the subject coolers and data by which the remainder of the interior system may be characterized. The EPA and USAEHA are attempting to gather information which would allow some correlation between problems observed and the types of coolers involved. Such data gathered by the installation may serve to augment this data base, as well as be compared to preliminary findings. Lead results from a point in the sampling area, other than from a cooler, will provide some indication as to whether the problems observed are a function of the water coolers, or result from a more pervasive problem with the interior plumbing system.

e. The PVNTMED Svc and DEH personnel should evaluate the findings from paragraphs 9b, c and d to determine the potential for lead leaching and prioritize the investigation/monitoring of locations possessing an apparent hazard.

f. Schedule requisite laboratory support (in-house or via contract) and implement a sampling program as described in paragraph 6.

g. Evaluate analytical results with respect to the existing MCL of 0.05 mg/L and the proposed MCL value of 0.02 mg/L.

h. If detected lead levels approach or exceed 0.02 mg/L at any site, initiate a program to provide stabilization of the water supply (e.g., pH control) and remove/replace all leaded plumbing materials at those locations.

i. As an interim measure, prescribe that occupants of affected buildings allow water to flush for a minimum of 3 minutes prior to use/consumption particularly during the early morning hours.

j. Provide notification to all consumers regarding the potential health hazard, interim remedial actions, and the programmed systemwide approach, in accordance with regulations implementing reference 6.

k. To remain in compliance with Public Law 99-339 (reference 6), the use of leaded plumbing materials is prohibited (limited to 0.2 percent lead from solders and fluxes and 8.0 percent from piping materials) for all future new installations and repair/modification of existing facilities. Eventually, all leaded plumbing materials should be eliminated.

10. RECOMMENDATIONS. It is imperative that the Army begin evaluating the potential for exposure to lead via potable water supplies particularly for housing areas and designated facilities such as hospitals, day-care centers and schools where sick persons, infants and young children might be exposed. Installation DEH, with support from PVNTMED Svc personnel, should review/inventory plumbing materials and appurtenances, as well as the relative corrosive nature of their water supply, and initiate appropriate remedial measures, if warranted. If there remains any question regarding the presence of lead, the water should be tested by an approved laboratory. Historical data gathered to meet regulatory requirements will not provide an accurate assessment of the prevalence of lead. Also, ensure that future water samples collected to determine the presence of lead, and other corrosion byproducts, are gathered via the recommended approach delineated in paragraph 6c.

11. TECHNICAL ASSISTANCE. Requests for services should be directed through appropriate command channels of the requesting activity to Commander, U.S. Army Environmental Hygiene Agency, ATTN: HSHB-ME-WR, Aberdeen Proving Ground, MD 21010-5422, with an information copy furnished to the Commander, U.S. Army Health Services Command, ATTN: HSCL-P, Fort Sam Houston, TX 78234-6000.

12. REFERENCES. See the Appendix for a listing of references.

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