ORIGINAL ARTICLE

"Lead Leached into Water from Select Plumbing Fixtures" Could Lead to Health Hazard

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Abstract:

Background: Lead is an inert metal and is resistant to corrosion. It also increases tensile strength of many common materials in daily use. Lead was used during the Roman period to transport water (hence the name plumbing/plumber is common terminology even in the present day). Lead enters the biological system through the air, water, and dust. Fine particles of lead, having diameter less than 5 nm are directly absorbed by lungs. Inorganic lead is absorbed by the gastrointestinal tract, and organic lead is absorbed by the skin. Lead has long been known to be a toxic heavy metal and exposure is associated with many deleterious health effects. Still, lead remains a popular ingredient in products ranging from paint to batteries. The lead content in any given material is estimated using various methods. The least cumbersome method is found to be X-Ray Fluorescence technique (XRF). A portable XRF device was used in the present study. *Aim:* The main aim of this study to investigate whether lead is present in various commonly used plumbing materials. *Material and Methods:* All types of branded and commonly used pipes were gathered from a market in Bangalore and tested using the XRF machine. In order to evaluate to what extent lead from the pipes could leach into water, seven pipes were randomly selected and filled with Aquafina water (having undetectable level of lead) for a 24 hour period. This water was tested at an NABL accredited laboratory in Bangalore, India for lead content. *Result:* It was determined that lead was present in many of the samples, at an unacceptable levels ranging from, well above the globally accepted level of 0.01 mg/L proof that lead was able to leach from the samples into water. *Conclusions:* As lead in drinking water represents a direct pathway for human exposure, the authors recommend that significant measures be taken to prevent use of lead in the plumbing industry for prevention of it's deleterious effects. Authors have also recommended non expensive solution to prevent the lead from water getting in to biological or environmental system.

Keywords: Drinking water, Galvonized Iron, Health hazards, Plumbing materials, PVC, UPVC, CPVC, Leaching Lead

Introduction:

Lead has long been regarded as a useful metal due to its density, malleability and especially its corrosion resistance and easy workability as it has a low melting point and it easily blends with other metals. When used as an ingredient, it gives more vibrant colors to paints, a higher tensile strength to the pipes, and renders the ability for structures to resist weathering. Rather than being added by itself, the lead is commonly added in its "2+" form as part of a compound such as Lead Oxide. In spite of its usefulness though, it is now recognized that lead is a dangerously toxic metal and a great deal of evidence connects lead with numerous harmful biological effects.

Historically, lead was popular with the ancient Egyptians for its use in cosmetics. Dense and resistant to water, the Egyptians also used lead to make weights and sinkers because of its non-corrosive properties. Eventually, lead reached the Roman Empire where it was widely used as an ingredient in a wide variety of products from water pipes to cooking utensils and storage vessels.

In modern times, lead has been used extensively in lead-acid batteries, water pipes, paints, ammunition, cosmetics, alternate and folk medicines and even some low-cost toys. Eventually, the lead in these products disassociates and is able to enter the environment where it has dire consequences.

It is thought and even established that drinking water provides a significant pathway for biological lead exposure. Since lead seldom occurs naturally in water supplies like lakes and rivers, contamination is often associated with the presence of lead in service pipes, solders, pipe-fittings and galvanized iron (GI) pipes. Previous research has already confirmed GI pipes as a source of lead contamination [1]. However, research on other water pipes, such as the varying types of Polyvinyl chloride (PVC) based pipes, is not as well documented.

In order to further address lead's current presence in plumbing materials, this study posed two questions:

1) Is lead present in plumbing pipes sold in today's market?

2) If so, are these pipes a source of contamination in drinking water?

A detailed survey was taken.

Biologically, lead holds no purpose, and in fact has been found to cause many adverse health effects. According to the World Health Organization, it is estimated that at least 15 to 18 million children in developing countries suffer permanent brain damage due to lead poisoning. It is well known that children consume more water to their body weight and hence are more susceptible to water lead.

Since the preindustrial days, blood lead levels have risen 50 to 200 fold in even the lowest ends of the spectrum [2]. These blood lead levels increase dramatically in industrialized areas and, when correlated with the noticeable biological effects depict the grim reality of lead poisoning.

On the cellular level, lead causes a buildup and then release of calcium in the mitochondria, which when sustained for a long enough time leads to apoptosis, or programmed cell death [3]. Lead has the ability to substitute calcium, a common ion in bodily functions like muscle contraction and nerve interaction. Under this guise, lead readily crosses the blood brain barrier where it accumulates to a high degree. Possibly in an effort to prevent the neuronal mitochondria from exposure, the lead is sequestered in the non-mitochondrial areas of the astroglia [3]. In effect, these areas of high lead content become reservoirs- areas of continuous exposure. Lead in the brain has been associated with deleterious effects regarding neurotransmitter storage, release and receptors [3].

In the blood, lead has a half-life of 35 days, however during this short period it can be absorbed into any bodily tissues it comes in contact with. Along with the brain, another vast reservoir for lead in the body is the bones. In fact, in children 70% of the body's lead exists there. This number increases to 95% in adults (a clear indicator that children's organs are more susceptible to lead absorption as will be discussed later) [3]. In the bones, lead has a half-life of 17-20 years, a far greater number than the 2 year half-life in the brain. Children during their growth and developmental stage are most vulnerable to lead as there is no blood brain barrier and the lead once enters the brain cannot come out.

Once ingested, lead proceeds to the gut, where it is absorbed. In adults, only 5-15% of the ingested lead gets absorbed, but in children this increases to 30-40% [4]. At this stage, lead decreases iron absorption thus disrupting heme development. The inhibited production of heme may eventually lead to anemia, and because the body's tissues are deprived of an adequate oxygen supply hypertension may also result.

The latter effect may only be observed at high blood lead levels, whereas even leading up to this lead can have significant subclinical effects. In children especially these subclinical effects have profound implications on their development. Prior to birth lead can be transferred via the placenta (as there is no placental barrier for lead) [3]. If an inadequate calcium intake exists, then lead will be released from the bones and transported to the developing child. Lead exposure at this stage can cause severe mental defects.

Even after birth, lead still poses a significant threat to a child's cognitive development. Numerous studies correlate increased lead levels with lowered IQs and abnormal social habits. It is widely accepted that, even at low doses, lead can affect a child's IQ [5]. In a study performed by HL Needleman, increased lead levels in children's teeth were shown to correlate with decreased IQ levels [5]. By the numbers, researchers estimate that even at lead levels of 10ìg/dL a child's IQ is reduced by up to 6 points [6]. Further exposure can have even greater effects. As previously stated, abnormal social habits including aggression, impulsiveness and lethargy occur at greater rates among children exposed to lead. Studies done by Needleman, Jama and Hou give similar evidence to this conclusion [6-8]. In Hou's study 27.7% of lead exposed children showed abnormal behavior, versus 11.7% of those of low lead exposure. As put by the Hou study, "Blood lead levels [have] an obvious negative correlation with the development quotients of child adaptive behaviour, gross motor performance, fine motor movements, language development and individual social behaviour"[6].

It is clear that no lead exposure level is safe, and at increasing amounts the effects of lead poisoning become more obvious. Eventually clinical effects such as wrist drop, anemia and hypertension occur, however these only usually become evident at blood lead levels at or above 60ìg/dL. By then, especially in children, a great amount of damage has already been done.

Material and Methods:

The branded pipes included in the study were selected from retailers in KR Market in Bangalore on a random basis. This market is a very popular location for plumbing materials, and so the samples are all indicative of commonly used plumbing materials. The most popular branded pipes fell under one of four categories:

1. Polyvinyl Chloride (PVC)*
2. Chlorinated Polyvinyl Chloride (CPVC)
3. Unplasticized Polyvinyl Chloride (UPVC)
4. Galvanized Iron (GI)

*PVC pipes are primarily recommended for use as sanitation pipes.

Once obtained, dust was cleared from sample's surface and lead content analysis was conducted on location. X-Ray Fluorescence by an Innov-X model á-2000S hand held device (obtained with the help of Scott Clark of the University of Cincinnati USA) was chosen as the appropriate technique due to both its accuracy and availability. X-Ray Fluorescence is conducted by bombarding samples with X-rays, ejecting an inner orbital electron from the metals within the sample. A higher level electron then fills this vacant energy state which results in the release of a photon composed of the difference in energy between the initial and final orbital state. Because there are finite amounts of ways this can occur, the sample data can be compared to known values. This process identifies the concentration of various metals contained within a sample.

Utilizing the machine as a point and shoot device in its soil mode, the average lead content value from three tests were obtained and recorded in parts per million (ppm).

Of these material samples, 2 PVC, 2 UPVC, 2 GI and 1 CPVC pipe were randomly selected for further testing regarding the contained lead's ability to leach into water. The selected pipes were reanalyzed with XRF, as were the end caps used to secure water. The pipes were filled with Aquafina brand water and left for a 24 hour period. These water samples were collected in acid washed 30 mL polyethylene containers and transported by the researchers to NABL accredited Aqua diagnostics in Koramangala, Bangalore, India for testing. Along with water from the samples, water from the Aquafina containers was also collected in order to ensure no significant quantities of lead existed prior to testing. Aqueous lead content testing was done at Aqua diagnostics using Flame Atomic Absorption Spectrometry following the criteria detailed in detailed in APHA 22nd ed 3113b and Graphite Furnace Atomic Absorption Spectrometry for samples with low lead concentrations (<5 ppb) using APHA 22nd ed 3111c procedures for lead. Values for these tests were expressed in mg/L. Testing for pH was also done to verify the pH of the water that was first put in the pipes using a pH meter following the procedure listed in APHA 22nd ed 4500 H+ B for pH.

Results:

The data in Table 1 shows a high instance of lead in UPVC, PVC and GI pipes, however little or no lead in CPVC pipes. The amount of lead varies by brand as well as pipe designation. An asterisk (*) denotes that the pipe was used for water sampling. The caps used to secure water within the pipe samples are also present with lead content as well as a note of which pipe they were secured to. It should be recognized that only leaded caps were paired with leaded pipes. Table 3 shows a correlation between lead in pipes and lead in the water samples taken from these pipes. Also present are the pH's of the water that was removed. Water from the Aquafina bottles that originally stored the water used for the sampling was also tested to confirm there was no lead in the water prior to testing and that the pH of the water was within an acceptable range.

Discussion:

This preliminary study indicates that lead is a common ingredient in PVC, UPVC and GI pipes. Furthermore, the ability for lead to leach from these pipes into the water is also apparent.

All but one water sample failed to meet IS 10500's recommendation of no more than 0.01 mg/L Pb in order for the water to be considered safe to drink. All water samples associated with leaded pipes also con-

Table 1: Lead Content of Pipes by X-Ray Fluorescence

UPVC			
Manufacturer	*Standardization Value*	*Pb (ppm)*	*+/-*
Aquachem	218	4434	87
Astral	220	<12	N/A
Supreme*	220	7766	146
Precision	220	<12	N/A
Texmo*	220	6389	135
Average		3718	
CPVC			
Manufacturer	*Standardization Value*	*Pb (ppm)*	*+/-*
Paras	221	<14	N/A
Ashirvad	218	<12	N/A
Sperry	218	<15	N/A
Astral*	220	<12	N/A
Supreme	218	15	4
Supreme (Curved)	218	<15	N/A
Precision	220	<13	N/A
Average		N/A	

GI				
Manufacturer	*Designation**	*Standardization Value*	*Pb (ppm)*	*+/-*
Jindal	B	220	4500	495
Jindal	C	220	5214	603
Tata	Unknown	220	794	105
Kalinga (1)	B	218	1027	117
Apollo*	B	218	7760	845
Surya Prakash	B	218	5597	668
Kalinga (2)*	C	218	5776	640
Average			4381	
PVC				
Manufacturer	*Designation**	*Standardization Value*	*Pb (ppm)*	*+/-*
Ashirvad	Type A	220	4963	97
Shivaplast	Class 3	220	11316	228
Supreme	Class 2	220	6963	130
Prince*	Unknown	220	7495	142
Spectra*	Unknown	220	4502	105
Average			7048	

*Designation refers to a code used to characterize a pipe's outside diameter and wall thickness.

Table 2: Lead Content of Caps by X-Ray Fluorescence

Manufacturer	*Type*	*Standardization Value*	*Pb (ppm)*	*+/-*
RA *Cap used on Apollo and Kalinga Pipes*	GI	220	1157	101
Aquachem *1st Cap used for Texmo and Supreme*	UPVC	220	<12	N/A
Kissan *2nd Cap used for Texmo*	UPVC	220	<12	N/A
Supreme *Cap used for Astral*	UPVC	220	<10	N/A
Prince *Cap used for Prince and Spectra*	PVC	220	13739	271

tained lead. The sample that did not contain any lead was obtained from a CPVC pipe which similarly had no lead (the only unleaded pipe of all samples). This suggests a direct link between lead content in the pipes and lead content in the water.

Interestingly, lead was not a significant ingredient in all CPVC and some UPVC samples, which infers that lead is not necessary in the production of these pipes. This also suggests that an alternative unleaded method of production exists. The same should be expected of PVC pipes since they are composed of a similar compound.

Table 3: Lead Concentration in Water Samples

Brand	Type	Pb in Water Sample (mg/L)	pH	Water Bottle Used
Apollo	GI	0.233	9.59	1
Kalinga	GI	0.249	9.65	1
Texmo	UPVC	0.537	7.33	1
Astral	CPVC	<0.005	8.09	2
Supreme	UPVC	0.906	7.64	2
Prince	PVC	0.307	7.03	2
Spectra	PVC	0.447	8.99	2
Aquafina *Water (1)*	N/A	<0.005	7.42	N/A
Aquafina *Water (2)*	N/A	<0.005	7.02	N/A

All GI pipes contained some amount of lead; however this amount varied implying that the amount of lead used can be minimized.

These initial findings lead us to believe that existing concentrations of lead in pipes may be a major source of lead contamination for drinking water. Although we acknowledge that PVC pipes are primarily used for sanitation and not drinking water, they also represent a pathway for lead to reach the environment, and thus along with pipes involved in drinking water transportation, also present a significant risk to society.

Although lead treatments are available, they are both costly and unable to fully reverse the effects of lead poisoning. In an Australian study, IQs were seen to slightly increase once treatment was administered; however these numbers did not fully reach those of the non-exposed control group [9]. Another study showed conflicting evidence in which even after treatment, no such recovery in tested values occurred at all [10].

Currently, no standard exists in India to limit the lead content in plumbing fixtures. It is, however mentioned in IS 4985, that the World Health Organization's (WHO) Guidelines for Drinking Water: Recommendations should be referred to regarding lead content in the water. In this publication the WHO recommends that the amount of lead contained in potable water should be no more than 0.01 mg/l. This amount is reiterated in IS 10500: Drinking Water-Specification. These standards, though, only represent a voluntary standard to obtain ISI certification for a product and currently no public standard implemented and regulated by the governement of India exists. In India, most of the standards are voluntary.

In the US, the Lead and Copper Rule (LCR) of 1991 specifies that if lead reaches 15 ppb in 10% of the water supply then significant measures shall occur to correct the lead levels. Section 1417 of the Safe Drinking Water Act also takes the step to define "lead free" plumbing fixtures as any product containing less than 0.25% lead by weight.

The use of lead in plumbing material is an alarming trend especially in the developing countries, which presents a serious threat to many who receive their water through these pipes. This danger is amplified in children, born and unborn, who absorb lead at a much higher rate, 30-40%, versus 5-10% in adults [4]. It is especially daunting when we recognize lead's adverse health effects regarding cognitive development, which infer a reduced earning potential, and thus a loss to the nation's economy [11].

As for the manufacturers of these plumbing materials, the authors of this study believe lead is used out of ignorance rather than arrogance. For this reason, increasing industry wide awareness regarding lead's far reaching negative effects should be made a priority. Institutions such as the National Referral Center for Lead Projects in India (NRCLPI) exist with such a capability. Similarly, the public should also be educated. Educating consumers will drive change in the market simply by their preference to buy 'Lead Free' pipes. Such a trend would significantly motivate brands that desire to stay relevant to invest in lead free manufacturing techniques.

Beyond these measures, it is up to the government to draft and enforce lead content requirements in order to protect both its citizens and its own economic interests. Auditing of these companies should be conducted on a regular basis in order to keep these requirements at the forefront of manufacturers' goals.

Being that pipes such as those tested in this study are present throughout India and quite possibly many other countries, existing leaded pipe infrastructure should be replaced as soon as possible. To do so, the government must offer some monetary incentive for purchasing and replacing these pipes. In the meantime, proper lead filtration should also be incentivized to prevent further exposure.

It is recommended that in areas where lead is suspected to have a presence in drinking water, children especially should have their blood lead levels tested at an accredited facility.

Additional research should be done to determine the pervasiveness of lead in the pipe industry, as well as the amount of leaded pipes laid throughout India. This will serve to better understand the locations and extent to which the problem exists.

Lead is not a necessary evil, and should not be treated as such. For that reason aggressive and immediate action must be taken in order to protect future generations from the irreversible consequences of this toxic metal.

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