Producing Lead-Free Copper Alloys for Plumbing Fittings; A Case Study of Nigerian Taps

Durowoju M.O, Kolapo O. I
Department of Mechanical Engineering, Ladoke Akintola University of Technology, Ogbomosho

ABSTRACT

Inclusion of lead in pipe fittings brings about good machinability, lubricity and filling of pores created after casting. The leaching of lead into drinkable water exposes people particularly children to harmful effects of lead. In view this, it is necessary to search for other elements that can eventually replace lead and offering the advantages provided by lead.

Nigerian taps (Brass Tap1, Brass Tap 2 and Cast Iron Tap) were considered in the study and it was observed that the lead compositions are 2.14%, ~ 5.81% and 0.011% respectively. The first two taps have percentages of lead which is above the allowable value of 0.25% given by most of the regulatory bodies.

This brings the urgent need to consider alternative elements to replace lead.

Keywords: Brass taps, Cast iron taps, Lead, Leaching, Pipe fittings
*corresponding author

I. INTRODUCTION

Of immense importance are plumbing fittings used either for industrial or domestic purposes. Over the years, several materials have been used to fabricate plumbing fittings ranging from lead fittings used in very old buildings to more recent plastic fittings. Through the ages, brass plumbing fittings have stood the test of time because of their immense benefits like good castability, antimicrobial ability, in built corrosion resistance, cost effectiveness, ease of recycling and enhanced machinability. However, as beneficial as brass fittings are, they have a major drawback of containing lead, which manufacturers add to improve some qualities, but is highly detrimental to health.

Lead (Pb) is commonly added to many cast copper alloys because of the low solubility of Pb in copper, true alloying does not occur to any measurable degree. During the solidification of castings, some constituents in a given alloy form crystals at higher temperatures relative to others, resulting in tree-like structures called dendrites. The small spaces between the dendrites can interconnect to form micropores. This microporosity is a consequence of the solidification process. The role of Pb is to seal these intradendritic pores. This results in a pressure-tight casting, which is important for fluid handling applications [1].

Pb also allows the machining of castings to be performed at higher speeds without the aid of coolants because it acts as a lubricant for cutting tool edges and promotes the formation of small, discontinuous chips that easily can be cleared. This result in improved machined surface finishes. Pb also plays a role in providing lubricity during service, as in cast copper bearings and bushings. Pb does not have an adverse effect on strength unless present in high concentrations, but it does reduce ductility [1].
The pattern Lead globules form on the surface of the brass increases the available lead surface area which in turn affects the degree of leaching. In addition, cutting operations can smear the lead globules over the surface. These effects can lead to significant lead leaching from brasses of comparatively low lead content [2].

Lead does not noticeably alter the taste, colour or smell of water. The effects of low levels of lead toxicity in humans may not be obvious. There may be no symptoms present or symptoms may be mistaken as other illnesses. The only way to know the concentration of lead in water is through sampling and laboratory testing [1, 3].
Today, brass materials are used in nearly 100 percent of all residential, commercial and municipal water distribution systems. Many household faucets, plumbing fittings, check valves and well pumps are manufactured with brass parts [4].
In view of these, this work is set out to establish the need to develop lead-free brass plumbing fittings that will utilize the inherent benefits of brass and at the same time eliminate poisonous lead which is commonly used as alloying element. In place of lead, graphite and silicon can be used separately to cast plumbing fittings. These elements have no record of being toxic to human health.

II. MATERIALS AND METHODS

The materials considered include the common plumbing fittings used in Nigeria. Although they vary in colours and shapes, many are made of brass. What actually distinguishes them is that some have been electroplated into various colours to improve their appearances.

Compositional analysis was performed on three different samples of the fittings (taps) shown in figure 1 below. The analysis was conducted at Grand Foundries and Engineering Works Limited Ikeja, Lagos, Nigeria using optical emission spectrometer shown in figure 2 below.

A: Brass Tap 1

B: Brass Tap 2

C: Cast Iron Tap

Fig 1: Sample taps

Figure 2: Optical Emission Spectrometer

The optical emission spectrometer operates on the principle of separation of light. When a polished metal sample is placed on the machine, it acts as negative electrode and the electrode arrangement inside the machines act as positive, this enables current to pass through the sample for excitation (increase in energy of the sample to charge up the outermost electron of the sample) to take place, also known as sparking. As the sample is heated up, the elements inside it is released as white light. This light is now separated into individual elements present in the metal.

Wavelength, velocity and colour are properties used in separating the elements (white light) because element has unique colour, wavelength and velocity.

For accuracy in percentage of each element, a computer is attached to the machine which communicates with the spectrometer to give result.

III. EXISTING STANDARDS

There have been various regulations throughout the world to control the level of lead in plumbing materials. On January 4th, 2011, President Obama signed Bill S. 3874**,** the reduction of Lead in Drinking water Act legislation into federal law.

This action amends the Safe Drinking Water Act and reduces the maximum allowable percentage of lead from 8.00% to 0.25% (weighted average) as it pertains to “pipe, pipe fittings, plumbing fittings and fixtures” in plumbing faucets and fixtures

California Bill AB 1953 changes the lead free requirements to a weighted average of no more than 0.25% lead content. This is effective January 1st, 2010.

Vermont S.152 clearly states that plumbing products containing lead will be prohibited for sale effective January 1st, 2010 with a lead free requirement (to a weighted average) of no more than 0.25% lead content. This legislation does not require third party certification.

California - AB1953 (approved September 30, 2006 effective January 1st, 2010)

Maryland - HB.372 (approved May 5, 2010 effective January 1st, 2012

Louisiana - H.B. 471/Act No. 362 (approved June 29, 2011) takes effect January 1, 2013

The "Lead and Copper Rule", or LCR, is a United States federal regulation which limits the concentration of lead and copper allowed in public drinking water at the consumer's tap, as well limiting the permissible amount of pipe corrosion occurring due to the water itself. The U.S. Environmental Protection Agency (EPA) first issued the rule in 1991 pursuant to the Safe Drinking Water Act. EPA promulgated the regulations following studies that concluded that copper and lead have an adverse effect on individuals [5].

The LCR sought to therefore limit the levels of these metals in water through improving water treatment centers, determining copper and lead levels for customers who use lead plumbing parts, and eliminating the water source as a source of lead and copper. If the lead and copper levels exceed the "action levels", water suppliers are required to educate their consumers on how to reduce exposure to lead. A 2004-2005 study of the LCR by EPA noted that the system had been effective in 96 percent of systems serving at least 3,300 people [6,7]

EPA has stated that the LCR has reduced exposure to lead "that can cause damage to brain, red blood cells, and kidneys, especially for young children and pregnant women." It also explained that the rule has reduced copper exposure "that can cause stomach and intestinal distress, liver or kidney damage, and complications of Wilson's disease in genetically predisposed people [8, 9].

IV. RESULTS AND DISCUSSION

The results of compositional analysis carried out at Grand Foundry Limited Lagos using spectrometer are shown in tables 1, 2 and 3 below.

Table 1.0: Composition of Brass Tap A

Program: Cu-01-F							
Comment: Orientation Cu-Base 120971							
Average (n=1)							
Elements: Concentration							
Si (%)	**Fe (%)**	**Cu (%)**	**Mn (%)**	**Mg (%)**	**Cr (%)**	**Ni (%)**	**Zn (%)**
0.0023	~1.345	81.510	0.018	0.018	0.056	0.0010	13.50
Ti (%)	**Ag (%)**	**B (%)**	**Be (%)**	**Bi (%)**	**Ca (%)**	**Cd (%)**	**Co (%)**
0.014	0.0360	0.018	0.051	0.053	0.011	0.041	0.096
Li (%)	**Na (%)**	**P (%)**	**Pb (%)**	**Sn (%)**	**Sr (%)**	**V (%)**	**Zr (%)**
0.3033	0.0016	0.012	**2.14**	0.075	0.67	0.0005	0.025
Al (%)							
0.0022							

Table 2: Composition of Brass Tap B

Program: Cu-20-F							
Comment: Cu/Zn-alloy							
Average (n=2)							
Elements: Concentration							
Zn (%)	**Pb (%)**	**Sn (%)**	**P (%)**	**Mn (%)**	**Fe (%)**	**Ni (%)**	**Si (%)**
35.24	**~5.81**	1.35	0.0029	0.0027	0.64	0.425	0.028
Mg (%)	**Cr (%)**	**As (%)**	**Sb (%)**	**Bi (%)**	**Co (%)**	**Al (%)**	**S (%)**
0.0012	0.0062	0.011	0.096	0.0046	<0.0015	0.51	0.0067
Cu (%)							
55.9							

Table 3: Composition of Cast Iron Tap

Program: Fe-20-F									
Comment: Cast iron-F									
Average (n=2)									
Elements: Concentration									
C (%)	**Si (%)**	**Mn (%)**	**P (%)**	**S (%)**	**Cr (%)**	**Ni (%)**	**Mo (%)**	**La (%)**	**Fe(%)**
3.95	2.95	0.59	0.118	0.119	0.039	0.015	<0.0020	0.0046	91.9
Al (%)	**Cu (%)**	**Co (%)**	**Ti (%)**	**Nb (%)**	**V (%)**	**W (%)**	**Pb (%)**		
0.0015	0.143	0.0084	0.066	0.0039	0.020	0.011	**0.011**		
Mg (%)	**B (%)**	**Sn (%)**	**Zn (%)**	**As (%)**	**Bi (%)**	**Ce (%)**	**Zr (%)**		
0.0039	<0.0005	0.017	0.0071	0.013	<0.0015	0.0069	<0.0015		

V. DISCUSSION

Of the three samples examined, two are copper-based alloys while the remaining one is cast iron. The three samples contain lead, two of which go beyond recommended concentration.

Brass A consist 2.14 % wt of Lead, Brass B has 5.81 % wt of Lead and the cast iron, 0.011 % wt of Lead

VI. CONCLUSION

Plumbing fittings made of leaded brasses are in no doubt in circulation. Many use these fittings oblivious of the fact that they are potentially harmful to their health. Regulatory bodies in developing countries like Nigeria have not lived up to expectation in tackling this problem. The work has established the need to try other alloying elements like silicon, bismuth and graphite to observe the extent to which they can fill the gap created by the intended exclusion of lead in plumbing fittings. In particular, it will be necessary to study the effect on porosity, lubricity and the types of chips produced during machining operations

REFERENCES

[1] Scott, S (2011) “Transitioning to no lead copper “ ESI North America Farmingting Hills Michigan

[2] Sharon, O.S (2008): “Drinking Water” University of Nebraska–Lincoln Extension Publications

[3] Steve, D (2008) “Drinking Water: Lead “University of Nebraska–Lincoln Extension Publications Nebraska Department of Health and Human Services

[4] Safe Drinking Water Act Amendments of (1986). "Prohibition on use of lead pipes, solder, and flux." 42 U.S.C. § 300g-6(d). Pub.L. 99-359, approved 1986-06-19.

[5] Faust, S.D.; Aly, O.M (1998). “Chemistry of Water Treatment” (2 ed.). Boca Raton, FL: CRC Press. p. 6. ISBN 978-1-57504-011-0.

[6] Lead and Copper Rule Revisions, (2005): " Journal of Environmental Health 68.5 46. Reference Guide." Document no. EPA-816-F-04-009.

[7] Mcgill, R (1993) "The Influence of an Educational Fact Sheet on Small System Water Supplier Attitudes toward the Lead and Copper Rule," Journal of Environmental Health 56.4

[8] Smith, W F. (1993) “Structure and properties of engineering alloys”second edition Mc Graw-Hill ISB 0-07-59172-5

[9] Vipin B (2005):, "Question & Answer: Lead and Copper Rule Revisions," Journal of Environmental Health 68.5 46.