

**Lead-free Solder LCA Project
Heavy Metal Leaching from Printed Wire Boards:
Evaluation of Solder Type**

Experimental Methodology

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1.0 Project Overview

Printed wire boards (PWBs) containing different solder types will be processed and leached using standardized US EPA leaching protocols. The solder types to be investigated include:

~~99.3% Sn-Pb~~

~~99.3% Sn / 0.7% Cu~~

~~95.5% Sn / 4.0% Ag / 0.5% Cu~~

~~92.3% Sn / 3.4% Ag / 1.0% Cu / 3.3 % Bi~~

The PWBs will be provided by Abt Associates or directly by the manufacturers. The boards will be processed according to the leaching protocol requirements.

2.0 Sample Description

The PWBs provided will consist of unpopulated boards. As previously stated, 4 solder formulations will be tested. Ideally, one board architecture (referred to here as board type) will be used for all samples.

Multiple boards for each solder type should be provided. Each individual leaching test requires 100 grams of material. To minimize sample variability, distinct board areas that are 100 g in weight will be identified and cut from the main boards. Three distinct 100 g areas will be identified. Thus, each board should weigh at least 300 grams. This concept is illustrated in Figure 1 and is discussed in more detail in "4.0 Sample Processing." This ideal scenario is referred to here as *Scenario 1*. The following table summarizes the requirements. Since TCLP and SPLP will be tested in duplicate, a total of 4 boards of each solder type are needed. Ten boards for each solder type are requested so that additional testing can be performed if needed.

Scenario 1 Requirements¹	
Solder Type	PWB Type 1
Sn-Pb	10 boards
Sn-Cu	10 boards
Sn-Ag-Cu	10 boards
Sn-Ag-Cu-Bi	10 boards
Total Sample	40 boards

¹Assuming boards are greater than 300 g in weight

If the boards weigh less than 300 grams, additional boards will need to be provided.

It is recognized that it may not be possible to have the same board type for every solder type. Thus an alternative scenario is proposed as a backup, and is referred to here as *Scenario 2*. In this scenario, three different board types will be used. They will still be unpopulated boards. Since the Sn-Pb solder is the major material in use today, each of the three board types will have some Sn-Pb boards and some boards with an alternative solder. The requirements for this scenario are illustrated in the following table.

Scenario 1 Requirements			
Solder Type	PWB Type 1	PWB Type 2	PWB Type 3
Sn-Pb	10 boards	10 boards	10 boards
kgSn-Cu	10 boards		
Sn-Ag-Cu		10 boards	
Sn-Ag-Cu-Bi			10 boards
<i>Total Sample</i>		<i>60 boards</i>	

A similar approach will be followed as was in scenario 1. See Figure 2 at the end of this document for a graphical illustration of this approach.

3.0 Leaching Tests to be Employed

Two different US EPA leaching tests will be used.

1. The toxicity characteristic leaching procedure (TCLP)
2. The synthetic precipitation leaching procedure (SPLP)

Each leaching procedure was developed by the EPA. They are used frequently for making decisions based on the potential risk of waste materials leaching to the environment. The procedures are similar with the exception of the leaching fluid used. The TCLP uses an acetic-acid solution to simulate conditions in a municipal waste landfill where organic acids are produced as a result of waste decomposition. Two different TCLP fluids are identified in the testing methods: pH = 2.88 and pH = 4.93. The choice of fluid depends on the buffering ability of the material tested. Based on previous testing of PWBs, it is anticipated the higher pH fluid will be used. The SPLP was designed to simulate acid rainfall. It contains trace amounts of nitric and sulfuric acids and has a pH of 4.2. The TCLP is used to make hazardous waste determinations. The SPLP is frequently used to assess risk from environments where large amounts of organic acids are not expected to be produced.

The TCLP and SPLP each require 100 g of material for the test and the material must be processed prior to leaching (see next section). Leaching takes place at a 20:1 liquid to solid ratio in a rotary extractor at 30 rpm for 18 hours. The leachates are then filtered and analyzed for the chemicals of concern.

4.0 Sample Processing

The TCLP and SPLP require that samples be size-reduced to less 0.95 cm. The PWBs will be processed by cutting them by hand into pieces that will pass the appropriate sieve. One hundred grams of material are needed for each sample. To minimize variability associated with different solder amounts encountered on different areas of a given board (or series of boards), distinct 100-g pieces of board will be identified. These pieces will be cut from the board and then size-reduced for leaching. For each solder type, four identical 100-g pieces will be cut from identical board types (2 for TCLP and 2 for SPLP). A total of three of these distinct 100-g areas will be identified in tested. This results in a total 48 samples being tested if scenario 1 is followed and a total of 72 samples being tested if scenario 2 is followed. Both scenarios are graphically illustrated at the end of this document.

5.0 Analytical Methods

Samples will be processed, leached, and the leachates analyzed in the University of Florida Department of Environmental Engineering Science's analytical laboratory facility. A quality assurance plane will be developed and approved by US EPA before work is conducted. The following metals will be analyzed in all samples: Sn, Pb, Cu, Ag, Bi. Approved EPA analytical methods will be used. Sample concentrations will be measured using either an Inductively Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES) or a Graphite Furnace Atomic Absorption Spectrophotometer (GFAA). Concentrations will be measured to drinking water standard concentrations where appropriate.

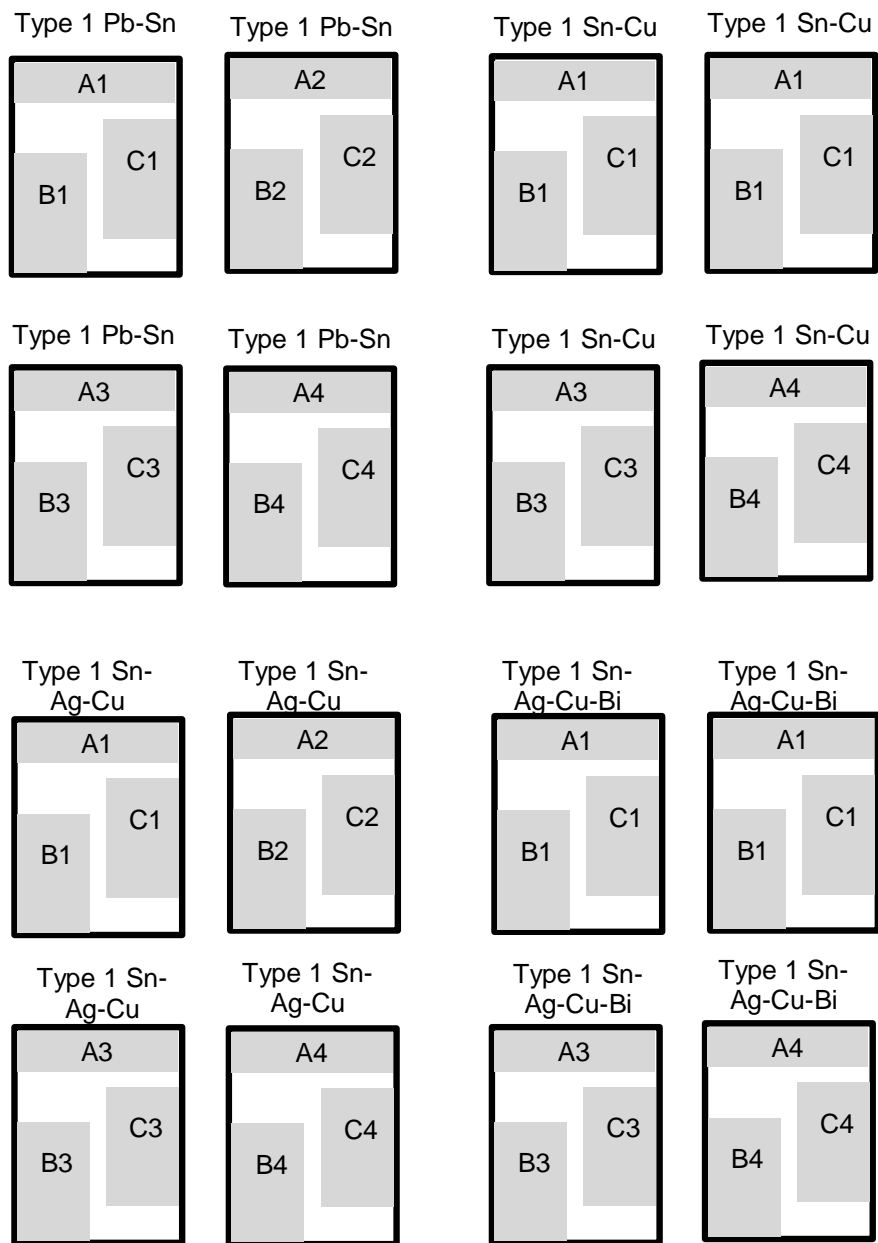
6.0 Final Report

A report describing the results of the work will be prepared. The implications with respect to environmental leaching as well as limitations in the testing procedures will be discussed.

Please submit any comments you may have about this methodology to:

Jack Geibig, University of Tennessee

Jgeibig@utk.edu or 865-974-6513



Samples A1, A3, B1, B3, C1, C3 leached using TCLP
 Samples A2, A4, B2, B4, C2, C4 leached using SPLP

Figure 1: Scenario 1. One Unpopulated Board Type Used
(Note: While figures illustrate all three samples coming from same board, board size and weight may dictate that different boards of same type be used)

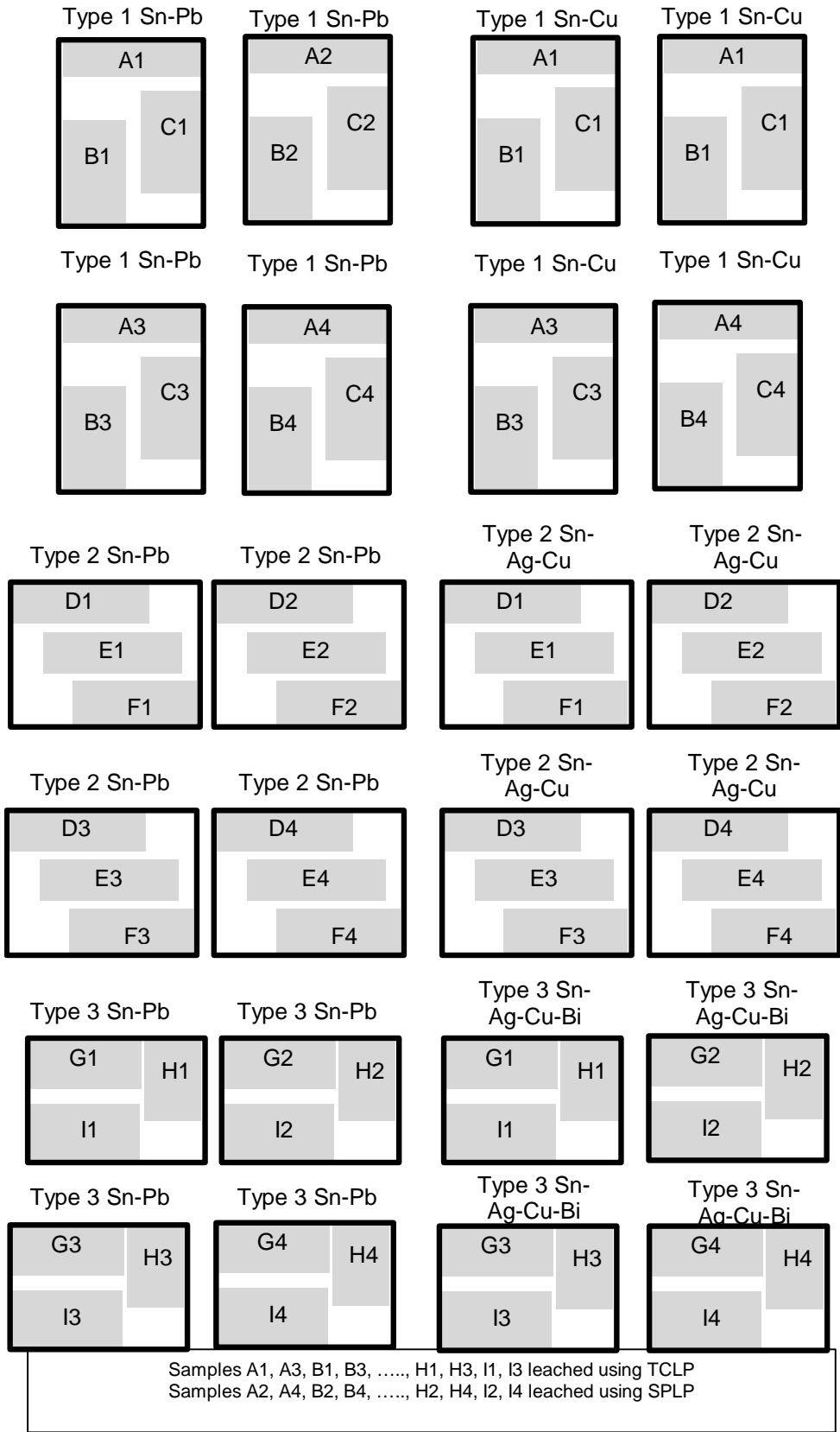


Figure 2: Scenario 2. Three Unpopulated Board Types Used