Assessing the Release and Transformation of Metal Additives from Consumer Plastics

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1: Motivations

- Consumer plastics span a broad range - electronics, food packing, construction, among others.[1]
- Metals are added to plastics as catalysts and stabilizers to enhance properties; however, they may have toxic repercussions.[2,3]
  - tin, antimony, lead, and zinc
- Most metals are categorized as toxic due to the risk they pose to human health, as well as the environment, should they be released.[3]

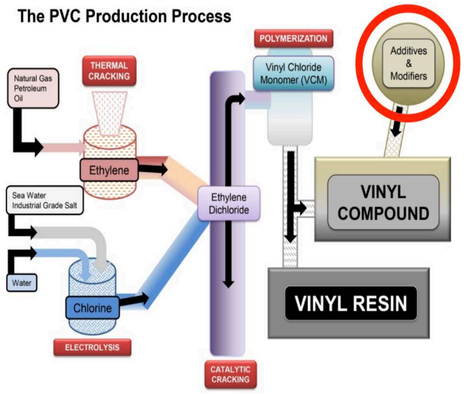

Figure 1. The production of PVC, like other plastics, involves the addition of metal additives to alter physical and chemical properties. Tin, for example, is commonly added to PVC.[4]

2: Previous Research

- A direct application of this can be seen with PVC plastic, commonly used in piping. PVC contains ~0.5-2 wt% of tin to increase durability and lower corrosion rate.
- Many studies have been done to observe the leaching of tin from PVC pipes by running DI water through PVC.
- Organotins (OT); most tin in PVC comes out in the form of organotins, more bioavailable[5]
  - Types: dimethyl tin (DMT), mono-butyl tin (MBT)

Figure 2. The standard format of an organotin compounds.[6]

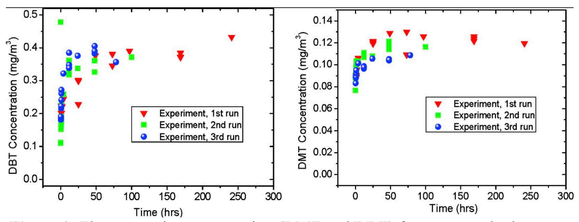

Figure 3. The organotin concentration (DMT and DBT) from one study that ran DI water through PVC piping and measured leaching overtime.[7]

Proposed Research

What concentration of organotins leach from PVC particulates that are of consumable size?

- What effect does particle size have on leaching?

How does the pH of different solutions effect the leaching of organotins from PVC particles?

- Specifically, solutions that model lung and stomach fluids within the human body.

3: Experimentation of PVC Particulates in Synthetic Lung Fluids

3.1 Methodology

Preliminary powder was produced via sanding of PVC piping using an electric hand sander. This powder was then put through a series of sieves to determine particulate size of the powder. The sieves used were for 250 microns, 75 microns, and 25 microns. A lid was placed on the top sieve (250 microns) and a metal dish was put on the bottom to collect particles smaller than 25 microns (Figure 4). Sieving was done in two thirty-minute cycles. Afterwards, the powders were separated into acetylene vials (Figure 5).

Figure 4. Metal sieves for particulate size determination

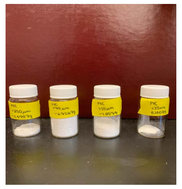

Figure 5. Separated particulates based on sieving fractionation

Figure 6. Incubation Rotator. Continuously mixed samples at 15 rpm in 37˚C

Samples were prepared using ~0.4 g of the respectively sized powder and 40 mL of synthetic biological lung fluid (SBF). Samples were prepared in 50 mL convoluting tubes and continuously mixed for a two-week incubation (Figure 6). Samples were taken at 3 hrs, 6 hrs, 24 hrs, 72 hrs, 1 wk, and 2 wks. Samples were taken in 10 mL aliquots, and 600 µL of HNO_3 and HCl were added, respectively. The sample was then put through syringe filtration using 45-micron filters (Figure 7). Samples were run in triplicate. Size fractions >250 micron and >75 micron were run in Gambles Solution (GS, pH 7.6) and Artificial Lysosomal Fluid (ALF, pH 4.5). The particulates >25 micron were only run in ALF. An ICP-OES was used for sample analysis.

Figure 7. Syringe filter used for sample syringe filtration

3.2 Results

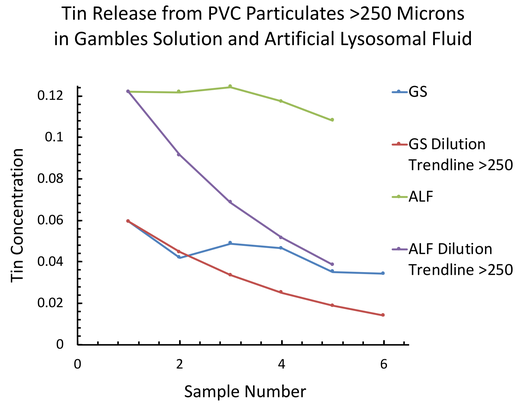

Figure 8. Release of tin from particulates >250 microns in GS and ALF

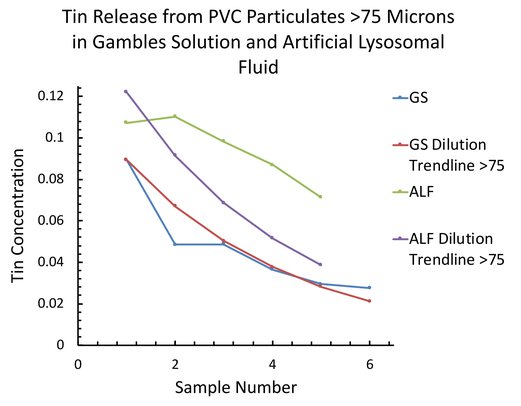

Figure 9. Release of tin from particulates >75 microns in GS and ALF

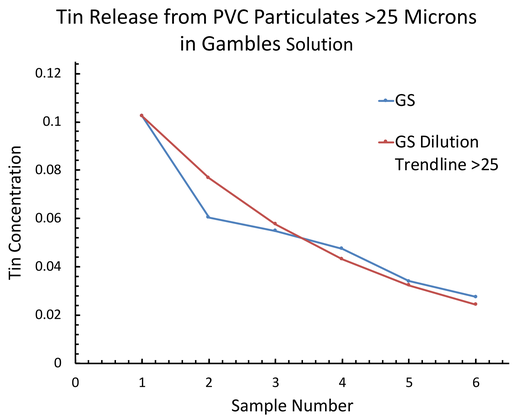

Figure 10. Release of tin from particulates >25 microns in GS.

- The dilution factor trendlines indicate that, in GS, most of the tin is being leached in the initial three hours. Apart from the >250 particulates, the dilution trendline is predicting a greater tin concentration than is present in the sample.
- With the >250 particulates in GS, there is indication that tin is continuously being released over the course of the two weeks. This is counter-intuitive as finer particles tend to have higher leaching concentrations.
- Overall, the particles in the ALF had a much higher tin release than those with the GS. There is also indication, based on the dilution trendlines being lower than the actual tin concentrations, that the tin is being released continuously over the incubation period.

Preliminary Experimentation (SURE 2019)

Figure 11. Preliminary process used to grind up PVC into powder that would be of consumable size. PVC cards (~2x4 in.) were put into a blender, followed by a coffee grinder. The grinding of the PVC particulates generated a powder on the lid of the coffee grinder. A plastic scooper was then used to scrap the powder off the sides of the lid (Figure 12).

Figure 12. PVC powder was collected from the lid of the coffee grinder to be used in experimentation .

- Preliminary methodology (Figure 11) produced approximately 25 grams of PVC
- 2-gram aliquots, of varying size particulates, were put into test tubes and 40 mL of solution was added. Each sample was run in duplicate.
- Solutions utilized: Phosphate Buffered Saline, SPLP, NaOH, Milli-Q water, Gambles Solution, Artificial Lysosomal Fluid

Solution	PBS	GS	ALF	NaOH	SPLP	Milli-Q
pH	7.42	7.64	4.56	9.36	4.21	8.80

- Preliminary samples were sent to the Joint School of Nanoscience and Nanotechnology for analysis
- Results show pH had minimal effect on tin leaching
- Duration of mixing may also play a role in this small difference (samples mixed for 23 days).
- The % tin leached was calculated.

Solution	[Tin] in Sample (mg/L)	Estimated % Tin Leached
GS	0.1406	0.46
ALF	0.2481	0.81
MQ	0.1791	0.58
PBS	0.2483	0.82
NaOH	0.1723	0.57
SPLP	0.1423	0.47

4: What is Next?

- The >25 particulates will need to be run in ALF to see if the results follow current trends.
- Investigating cPVC to see how tin release differs with different types of PVC plastic
- Investigation of other plastic materials and the leaching of metal additives

5: Acknowledgements

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- The Lumen Prize
- Elon University's SURE Program
- Elon College Fellows

6: Selected References

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