WOMBAT TIRE-DERIVED PARTICLES AS A HIGH CARBON SORBENT

David L. Wertz, Richard C. Cummings, Jeff L. Quin, and Steven DuBose
Department of Chemistry & Biochemistry
University of Southern Mississippi
Hattiesburg, MS 39406 USA

INTRODUCTION

More than 250 million scrap tires are added to the national inventory each year. Of these only 20% are recycled, and the remaining 200 million are landfilled -- legally or illegally. Because the scrap tires are not bio-degradable, they clog the landfills. The styrene-butadiene rubber (SBR) in these tires has a high energy value and represents a fuel supply which is replenished each year (i.e., a renewable energy resource. Unfortunately, in the vulcanization of the SBR, sulfur (~ 2% is used to cross-link the SBR fibers, and zinc (~2%) is used to accelerate the vulcanization process(es). These moieties, and others, are retained in the SBR.

When combusted, the scrap tires emit both sulfur oxides and particulate zinc oxide. These combustion species, along with the soot and the toxic oils that are produced, represent serious short-range and long-range pollution problems. In fact, terrorists have recently used scrap tire burnings as a tool for political blackmail in Greece and in Bangladesh.

Even when these air pollution problems are ignored, the combustion of scrap tires is complicated, at a practical level, by the steel belts which have been adhered into the carcass of the tires.

The Wertz group has developed a chemical method for cleaving the steel belts from the SBR carcasses of the tire and then extracting (and recovering) the S, Zn, and other metals from the SBR. As the vulcanized SBR is processed, the carcass is converted into a pulpy solid. This solid may be washed and dried by conventional methods. The dried material may then be easily ground to a powder. Attempts to convert the pulpy solid into pellets are ongoing.

Although originally prepared to be a high fuel value material, the resulting WOMBAT (Wertz Oxidative Molecular Bombardment at Ambient Temperature) powder is also being evaluated as a sequestering agent for extracting divalent metal ions and/or anions from solutions and dispersions.

Shown below are the results of several recent studies conducted by this group on the WOMBAT powder.

EXPERIMENTAL

The WOMBAT powder was dried at 107°C for three hours before using. The resulting powder, with particle diameters ranging from 1μ to 100 μ as measured with an environmental electron microscope, have irregular surfaces. A 1 gram sample of the WOMBAT powder was added to each of several aqueous solutions containing selected divalent cations and/or anions. The resulting dispersion was then filtered, and the resulting solid (WOMBAT powder and any adsorbed or chemically bonded species) was recaptured. This powder was dried for three hours and then examined by wavelength dispersive x-ray fluorescence spectrometer.

In the WDXRS experiment, each subject powder was examined either as a loose powder or as a mechanically pressed pellet.

RESULTS AND DISCUSSION

The x-ray fluorescence method is ideally suited for the analysis of the treated WOMBAT samples because the experiment uses the resulting samples "as is"; i.e., no analysis preparation, which could complicate or even invalidate the results of the sequestering experiments, is needed. The wavelength dispersive method, which is used in our laboratory, offers two additional advantages: (a) the signal-to-noise ratio is very good so that the

WDXRS method has a very low Lower Limit of Detection (LLD) of the subject metal ions deposited onto the WOMBAT powder, and (b) the shapes and locations of the resulting secondary x-ray peaks are sufficiently well known so that computer-synthesized peaks resolution may be readily made.

WDXRS involves the use of both Moseley's and Bragg's laws for the emission of secondary x-ray emissions from an irradiated sample. Thus, secondary K_α X-rays emitted by the de-excitation of the element containing Z electrons is given by:

$$\lambda_j^{-1} = Q \times Z_j^2, \quad (1)$$

for each of the j types of atoms in the condensed phase sample.

The crystal monochromator separates the array of secondary X-rays characteristic of the j types of atoms in the sample by:

$$\Theta_j = (n \times \lambda_j/2 \times d), \quad (2)$$

where d is the inter-planar d-spacing characteristic of the crystal monochromator and n is the order of the diffracting peak from the radiation of wavelength λ_j. Thus, the angle at which a peak occurs in the WDXRS, Θ_j, may be directly related to the element (Z_j) which emits the secondary X-rays.The intensity of the peak at Θ_j, I_j, depends not only on the abundance of analyte j in the sample, but also only several other factors -- including both the absorption and the enhancement effects caused by the sample itself.

The WDXRS of an untreated tire (fig. 1) contains secondary K_α x-ray peaks due to zinc (λ = 1.436 Å) and to sulfur (λ = 5.373 Å) as well as for other moieties contained in the scrap tire. The radiation source, Cr, also produces peaks which appear in the secondary x-ray spectrum. After treatment in the WOMBAT reactor, the zinc and sulfur have been removed from the scrap tire residue, as evidenced by their disappearance in the WDXRS of the powder (fig 2). The WDXRS of the powder recovered after treatment with an aqueous solution of cadmium(II) chloride contains distinct peaks due to the presence of Cd^{+2}(aq) and to Cl^-(aq), as seen in fig. 3. Similar experiments with aqueous copper(II) chloride solutions, exhibit the secondary x-ray peak of Cu^{+2}.

The mechanism(s) by which either of these ions has been retained on the WOMBAT powder is not known and is being investigated at present.

The capability of the WOMBAT powder for extracting other ions will also be discussed.

The group is developing a series of model mixtures in an attempt to make the WDXRS analyses "quantitative" for analytes such as cadmium and copper as each is deposited onto the surface of the WOMBAT powder.