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Comparison of arsenic content in pelletized poultry house waste and biosolids fertilizer

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Abstract

Managers of human biosolids have been incorporating the practice of waste pelletization for use as fertilizer since the mid 1920s, and waste pelletization has recently been embraced by some poultry producers as a way to move nutrients away from saturated agricultural land. However, the presence of arsenic in pelletized poultry house waste (PPHW) resulting from the use of organoarsenical antimicrobial drugs in poultry production raises concerns regarding additional incremental population exposures. Arsenic concentrations were determined in PPHW and pelletized biosolids fertilizer (PBF) samples. Pellets were processed using strong acid microwave digestion and analyzed by graphite furnace atomic absorption spectroscopy. The mean arsenic concentration in PPHW (20.1 ppm) fell within the lower part of the range of previously report arsenic concentrations in unpelletized poultry house waste. Arsenic concentrations in PBF, the source of which is less clear than for PPHW, were approximately a factor of 5 times lower than those in PPHW, with a mean concentration of 4.1 ppm. The pelletization and sale of these biological waste fertilizers present new pathways of exposure to arsenic in consumer populations who would otherwise not come into contact with these wastes. Arsenic exposures in humans resulting from use of these fertilizer pellets should be quantified to avoid potential unintended negative consequences of managing wastes through pelletization.

Keywords: Roxarsone; Biosolids; Animal waste; Poultry; Arsenic

1. Introduction

Arsenic has been characterized as a known human carcinogen by the International Agency for Research on Cancer (IARC) and the US Environmental Protection Agency (USEPA) (International Agency for Research on Cancer, 1987; United States Environmental Protection Agency, 2002), and exposures to high levels of arsenic in drinking water have been linked to cancers of the bladder, lung and skin, as well as non-cancer health effects including cardiovascular disease, diabetes, keratosis and other skin disorders (Agency for Toxic Substances and Disease Registry, 2005). Recent reviews of the arsenic epidemiologic literature by the National Research Council (National Research Council, 1999, 2001) and concerns over lower level exposures have resulted in the USEPA lowering the maximum contaminant level in drinking water from 50 $\mu g\,l^{-1}$ to 10 $\mu g\,l^{-1}$ and convening a committee of the USEPA Scientific Advisory Board to examine the latest research on arsenic toxicity (United States Environmental Protection Agency, 2001, 2005). These new developments

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and the continued interest in chronic low level arsenic exposures highlight the need for the understanding of the contribution of a range of exposure sources.

The arsenic-containing compound roxarsone (3-nitro-4-hydroxyphenylarsonic acid) was introduced into poultry feed in the late 1940s for the purpose of growth promotion, improved feed conversion (ratio of feed ingested to broiler weight at slaughter) and pigmentation, and combating intestinal parasites (Kowalski and Reid, 1972). It has been estimated that approximately 70% of domestically raised broiler chickens receive roxarsone (Chapman and Johnson, 2002), totaling between 1.7 and 2.2 million pounds of the drug added to poultry feed per each year (Wallinga, 2006). It is not certain how much of the ingested roxarsone is retained in the edible tissue of the broilers, but a recent market basket study of uncooked and prepared chicken tissue by the Institute for Agriculture and Trade Policy found detectable levels of arsenic in a variety of poultry products (Wallinga, 2006). While some roxarsone remains in chicken tissue, much of the drug has been shown to be excreted in the waste (Rutherford et al., 2003).

A growing body of evidence for the environmental conversion of roxarsone to the more toxic inorganic arsenic has emerged. Research by the US Geological Survey (USGS) has shown that the majority of arsenic in post-excretion waste is rapidly converted once in the environment through both biotic and abiotic processes into more leachable inorganic forms (Garbarino et al., 2003). In the absence of oxygen, roxarsone is rapidly converted to 4-hydroxy-3-aminophenylarsonic acid and 4-aminopheynlarsonic acid, which further degrade via biological processes almost completely over time in the presence of methane and sulfate-reducing conditions to arsenite and arsenate (Cortinas et al., 2006). It has also been determined that clostridia, the dominant microbial species of the chicken cecum, is responsible for transformation of roxarsone into inorganic arsenic at much faster rates than previously reported (Stolz et al., 2007).

The United States produced 8.87 billion broiler chickens in 2005 (United States Department of Agriculture, 2006), and broiler production is projected to increase by 1% in 2007 (United States Department of Agriculture, 2007). A single broiler excretes approximately 4.9 kg of waste in a typical 48-day lifetime (American Society of Agricultural Engineers, 2005), 150 mg of which is assumed to be roxarsone or its metabolites (Rutherford et al., 2003). As domestic broiler production increases and broiler operations continue to concentrate regionally, the management of poultry house waste (PHW) remains a critical public health issue, and concerns about the potential health effects of arsenic increase these management concerns. Published estimates of arsenic concentrations in PHW range from 14 to 76 ppm (Jackson and Bertsch, 2001; Arai et al., 2003; Garbarino et al., 2003; Jackson et al., 2003).

Application of PHW to farmland has been traditionally viewed as the preferred management strategy, though concerns of nutrient overloading and the resultant eutrophication from loss of nutrients to surface waters (Horrigan et al., 2002) have forced managers of PHW to search out and implement other disposal strategies. A recently developed management option is the pelletization and sale of PHW as fertilizer (Nachman et al., 2005). The pelletization process involves dehydration, heating and crushing, and finally the cooling and formation of the litter into pellets. In the pelletized form, PHW can be more easily transported away from poultry producing regions, and used as fertilizer in residential and commercial settings. Despite the potential for different, non-agricultural populations to be exposed to the waste through use of pellets, arsenic concentrations in pelletized PHW fertilizer (PPHW) have not been addressed in the literature.

Another potential source of arsenic-containing biological waste is pelletized fertilizer produced from Class A biosolids, or treated human sewage sludge. It is estimated that of the 5.6 million dry tons of biosolids produced annually, approximately 3.4 million dry tons are land-applied as fertilizer or soil amendments (National Research Council, 2002). Of the biosolids that are land-applied, approximately one million dry tons are considered acceptable for use at public contact sites or distribution in bags (National Research Council, 2002). Little information is available to suggest the degree of arsenic contamination of processed human biosolids or pelletized biosolids fertilizer (PBF), as waste streams at sewage sludge treatment facilities vary depending on the nature of waste inputs. Indirect arsenic inputs into biosolids would include any arsenic-contaminated media entering into the wastewater stream, including excreted arsenic originating from human exposures (from environmental and dietary sources) and household or commercial wastewater.

Determination of arsenic content in PPHW and PBF will fill a critical information gap regarding poultry and human waste management practices and the subsequent potential for human exposures. The purpose of this paper is to characterize arsenic concentrations in PPHW and PBF. In addition, these arsenic concentrations will be compared with those in raw PHW and background soils.

2. Experimental section

2.1. Pelletized poultry house waste sample collection

PPHW is produced by a variety of companies and is sold under multiple brand names which are distributed throughout the country. For this study, PPHW was purchased from commercial vendors. To obtain as representative a sample as possible, bags of PPHW under four different brand names were purchased from five commercial vendors in the Baltimore metropolitan area in Maryland and one commercial vendor in Asheville, North Carolina. Bags were placed into sealed plastic tubs where they were stored until needed for sample preparation and analysis.