UPTAKE AND SPECIATION OF MERCURY AND SELENIUM IN VEGETABLE CROPS GROWN ON COMPOST-TREATED SOIL

CHRIS J. CAPPON

Environmental Health Sciences Center, Division of Toxicology, Department of Biophysics, University of Rochester Medical Center, Rochester, NY 14642, U.S.A.

(Received August 25, 1986; revised November 3, 1986)

Abstract. The uptake and speciation of Hg and Se were assessed for the edible portion of 16 different vegetable crops grown on a garden plot which had been exclusively treated with residential compost for 6 yr. This study was conducted under actual field conditions typical of residential gardening and utilized organic gardening techniques. Crops had methylmercury levels averaging 12.8% of the total edible tissue Hg content, divalent inorganic Hg being the only other element form identified. An average of 20.0% of the total Se content was present as hexavalent Se, the remainder being divalent and tetravalent Se forms. In terms of plant/soil concentration factors, Se was more readily assimilated by crops than Hg.

1. Introduction

In the United States and other major industrialized nations, there is much current active interest and research involved with organic methods of farming and residential gardening which stress the exclusive use of composted organic refuse materials in place of commercial fertilizers to better maintain soil fertility and productivity. Large-scale agricultural operations have experimented mostly with stabilized wastewater sewage sludge (digested and composted) and fly ash (coal and sludge) materials, while smaller-scale commercial and residential gardeners have used mostly materials consisting of animal manure, composted municipal refuse and residential (leaf, grass, and bark) compost.

Toxic trace element content is the major concern and drawback to extensive agricultural use of these organic waste materials, and can result in a long-term human health hazard because of element uptake by food and forage crops and subsequent entry into the food chain. Available research – greenhouse and field investigations – into this potential hazard has focused primarily on sewage sludge (Hinesly et al., 1972; Chaney, 1973; Page, 1974; Dick, 1977; Garcia et al., 1981) and coal fly ash (Gutenmann et al., 1979; Furr et al., 1976; Combs et al., 1980) application with particular emphasis on Cd and other toxic heavy metals – Cu, Pb, Ni, and Zn. No information is available concerning potential crop element uptake associated with the use of compost materials.

In contrast to the above toxic trace elements, Hg and Se have received very little attention concerning the existence and nature of specific chemical forms which can influence their soil chemistry and subsequent plant uptake. Both elements are also important because of their environmental ubiquity and existence in specific chemical forms of varying toxicity. In addition, Se exhibits nutritional essentiality and antagonism against heavy metal toxicity in several animal species (Zingaro and Cooper, 1974).
Recent investigations indicate that Hg (Van Loon, 1973, 1974; Cappon, 1981) and Se (Furr et al., 1976; Cappon, 1981) are readily incorporated into vegetation grown on sewage sludge-amended soils usually containing less than 10 ppm (dry weight) of either element.

The present study was conducted to provide similar information on the uptake and, more importantly, the specific chemical forms of Hg and Se in a variety of vegetable crops grown on soil with a known history of compost treatment under field conditions typical of residential gardening.

2. Experimental

2.1. Garden Plot and Soil Treatment

In April 1979, a residential garden plot (9.1 m long x 3.6 m wide) was prepared in Henrietta, NY, a suburb 10 km south of Rochester, NY. This plot was cropped for six consecutive growing seasons (1979–1984), the selected crop varieties being sampled during the last season. The soil was clay loam and had an average pH of 6.5 at the beginning of the sixth growing season. During each year, two uniform applications of residential compost (the first in late April and the second in mid-November) were made, each at a rate of 0.07 to 0.08 kg dry matter/kg soil. For each application, the composted material was thoroughly mixed into the upper 30 cm soil layer by rotary cultivation. The soil surface was carefully harrowed before planting. No additional commercial fertilization or pesticide application was made during the entire growing season.

The residential compost consisted of a mixture of shredded leaves, pine needles, bark, wood chips and sandy loam soil, which had been composted in windrows for up to 3 yr by the Pittsford, NY, recycling center.

2.2. Sampling and Sample Preparation

In 1984, immediately before planting and three weeks after compost application, surface soil samples – 20 cm in length – were taken from 25 randomly-selected sites of the garden plot using a cylindrical soil sampler. The soil samples were combined and thoroughly mixed in a metal container. A 100 g portion of the soil composite was dried for 24 hr at 50 °C and finely ground with a mortar and pestle. The compost material was sampled, composited and dried in a similar manner. The dried samples were stored in glass vials and subsampled for analysis. Soil pH was determined for a 1:1 (w/w) sample-water suspension.

2.3. Crop Growth and Sampling

The crops planted during the 1984 growing season are listed in Table I. Each crop was planted from seed according to the seed supplier’s instructions. In mid-March, the head lettuce, onion, pepper, and tomato plants were started indoors in individual peat plots using an organic potting soil; the plants were transplanted outdoors in mid-May. To conserve available garden space, the tomato, cucumber, and squash plants were staked...