Determination of the phytotoxicity of barium in leach-field disposal of gas well brines

M. L. CIPOLLINI* and J. L. PICKERING
Department of Biology, Indiana University of Pennsylvania, Indiana, PA 15705, USA

Received 13 February 1985, Revised August 1985

Key words Barium Biogeochemical cycle Brine Gas wells Phytotoxicity Sodium/potassium ratio

Summary A study was conducted to determine the effect of barium on yield and elemental composition of plants growing near natural gas wells. Brines containing potentially phytotoxic concentrations of barium are periodically released into leach-fields at these wells. Data on plant yield, soil and plant Ba, Ca, Mg, Na, and K concentrations, and soil pH were collected from high-barium well sites, and from greenhouse experiments using simulated brines. Barium had no detectable effect upon plant yield, and contributed only to variations in its own concentration in plants studied. Barium also exhibited biodiminution, in contrast to all other elements studied. Sodium was implicated at the major cause of phytotoxicity at gas well leach-fields. Due to interference of potassium uptake by sodium, the soil sodium/potassium ratio was found to be closely correlated with plant yield fluctuations.

Introduction

The eastern United States has recently experienced a large increase in natural gas well drilling. An environmental problem associated with new wells is the on-site disposal of brines high in sodium, chloride, calcium, magnesium, potassium, and barium. Brines are usually stored at each well site until they are released into shallow "blow-boxes", or leach-pits. Blow-boxes are often inadequate to contain brine output, therefore, much overflow and subsequent surface leaching of brines occurs (personal observation). Resultant denuded areas range from less than 1 m² to over 1000 m². Several other environmental hazards have been postulated to arise from this method of disposal including accumulation of toxic elements in plant tissue, toxic effects to animals using leach-fields as salt licks, and human health risks via contamination of water supplies. Due to the unusually high level of barium in some brines (1000–2000 ppm), this element has been a focal point of concern.

Barium is a member of the alkaline-earth elements, and has chemical and physical properties similar to calcium and magnesium. In nature, barium occurs as divalent cation which are readily precipitated by sulfate- and carbon-ions to form highly insoluble salts. Barium is present in brines, however, as barium chloride, a highly soluble salt. The

*Present address Department of Biological Sciences, Rutgers University, Busch Campus, Piscataway, NJ 08854, USA.
element has no known plant or animal physiological functions, and usually undergoes biodiminution as it is transferred along natural food chains\(^9,21\). However, in the ionic form, barium is considered to be toxic to humans, animals, and plants at moderate concentrations\(^4,21\). Only in rare circumstances of geochemical pollution have barium-ion levels risen to potentially toxic concentrations\(^16,17,21\). The release of barium-ion via gas well brines is a prime example of this type of pollution. It was the objective of this study to determine the degree to which barium contributes to phytotoxicity and elemental imbalances in plants growing near these sites.

Barium-ion toxicity has been reported for *Phaseolus vulgaris* and *Hordeum vulgare* at soil levels of 2000 ppm, and plant foliar levels of 10,000–20,000 ppm\(^4\). These levels were attained by mixing barium nitrate with dry soil prior to planting. Plant yield depression and phytotoxic effects were linked to suppression of potassium uptake by barium-ion. Other researchers report a similar mode of toxicity in *Oryza sativa*\(^6\). Barium is often rapidly fixed when contacting soil particles, therefore, differences in cation-exchange capacities of soils may result in differences in the availability of barium to plants\(^6,11\). Researchers often report very low exchangeable-barium levels in soils (0.0–185 ppm) despite rather high total barium levels (50–3000 ppm\(^6,12,21\). Variation between plant species in the uptake of barium from similar soils is probably due to differences in root cation-exchange potential. Plants with high cation-exchange potentials may accumulate barium-ion to a greater degree than other species\(^23\). Normal plant foliar levels are reported to be 10–150 ppm\(^5,21\). Other than this somewhat limited information, little is known about the absorption, translocation, and accumulation of barium by plants.

Since sodium is the major cation in gas well brines (averaging 60,000 ppm), its potential for phytotoxicity must also be considered. Sodium is known to reduce plant growth by an osmotic effect, which induces a physiological drought in the plant, and by ionic effects, which ultimately reduce the uptake of potassium\(^8,22\). Soil potassium levels have been reported to be critical for plants in highly saline soils\(^8\). In glycophytes, reduction of plant yield by sodium becomes evident at levels around 150–550 ppm, and growth is severely depressed at levels exceeding 2000 ppm\(^2,13\).

**Methods and materials**

*Greenhouse procedure*

Bean (*Phaseolus vulgaris*) and barley (*Hordeum vulgare*) seeds were germinated between layers of cheesecloth that were soaked with distilled water. Fully germinated seeds were