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Effects of Swimming Pool Sanitizing Chemicals on Turf Grass

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Chlorine or bromine-based chemicals are commonly used in swimming pools as sanitizing and oxidizing agents. Chlorine or bromine concentrations of 1.0 to 1.5 ug/mL and pH 7.2 to 7.8 are recommended for swimming pools. Chlorine is a strong oxidizing agent and will react with many different types of inorganic and organic species (Dychdala 1977). Chlorine solutions (hypochlorite ion/hypochlorous acid) inactivate microbes on contact (Dychdala 1977). While trace concentrations of chlorine are essential for plant growth (Broyer et al 1954), higher concentrations have caused injury to plants (Berstein 1975). Other investigators also have reported on chlorine as a phytotoxic pollutant (Brennan et al. 1965; 1969; Hindawi 1968). Kentucky blue grass (*Poa pratensis* L.) was reported to be damaged by accidental release of chlorine gas (Brennan et al. 1969). Plants vary widely in their Cl contents, even in uncontaminated areas (Curtis et al. 1977).

The natural content of bromine in soils and plants is generally less than 50 ug/g, dry weight (Yamada 1968; Wilkins 1978; Maw and Kempton 1982; Dijngova et al. 1986). Bromine occurs in almost all plant tissues but it is not known whether it is essential for plant growth (Martin 1966). Some plant species are known to accumulate more than 640 ug/g dry weight bromine without showing any effects (Paradellis and Panayotakis 1980). Methyl bromide fumigation of soil has been frequently used to destroy various soil-borne organisms and weeds. Residues of this material occasionally cause toxicity to plants but there is a range in tolerance depending upon plant species. Bromine from these residues can be found in the plant tissues. Phytotoxicology problems associated with the use of methyl bromide on the whole are not common and the bromide ion is not regarded as being particularly toxic to plants.

The Phytotoxicology Section of the Ontario Ministry of the Environment regularly receives complaints from the public alleging that turf grass subjected to swimming pool run-off has been injured by the chemicals in the water. Although the potential does exist for the pool chemicals to contact foliage directly through splashing, the area that might reasonably be affected is restricted to a very small band at the perimeter of the pool deck. In our experience, the vast majority of complaint situations are related to conditions wherein water would tend to accumulate such as seepage, water run-off and drainage courses. The present study therefore focused on the uptake of the chemicals from the soil rather than through direct contact with the foliage.

There is limited information on chlorine or bromine absorption by turf grass which can be used that would aid in resolving the cause of the alleged injury. The objective of the present study was to determine if chemicals used to sanitize swimming pool water can indeed be responsible for injury to turf grass.

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MATERIALS AND METHODS

Kentucky blue grass (*Poa pratensis* cv. Baron) seeds were sown in 20 cm diameter pots containing sandy loam soil. The grass plants were kept in the greenhouse throughout the experiment and were grown under fluorescent and incandescent lamps using a 15 hr photoperiod at 22 °C. Chlorine or bromine solutions were prepared by dissolving standard commercial chlorine or bromine (NaOCl or NaOBr) tablets (0.5 %) with tap water at recommended rates for swimming pool use. Recommended free residual chlorine or bromine solutions containing the recommended concentrations of 1.5 ug/mL (pool water) or 150 ug/mL (superchlorination - 100 times the recommended level) were prepared. The pH of the 1.5 ug/g solution was adjusted to 7.4 $\pm$ 0.12 by adding 1N HCl or 0.1N NaOH. The pH of the 150 ug/mL solution was 9.6. The tap water had a pH of 7.4.

Plants at 8 wk of age were subjected to control (tap water only), 1.5 ug/mL or 150 ug/mL chlorine or bromine solutions applied either immediately after preparation or after the solutions were allowed to stand for 7 days. There were 7 pots for each treatment. Each pot received 400 mL of tap water (for control) or 400 mL of solution each time. The treatments were repeated three times, at two wk intervals. Three pots were selected randomly from each treatment for yield determination and these same plants were later chemically analyzed for their Cl, Br and Na content. Plant heights were measured, after which the tops were separated and washed free of soil, blotted dry, and weighed. The average fresh and dry top weights and heights were calculated. One composite sample of surface soil (0-15 cm) was collected from each of the treatment pots for chemical analysis of the same elements listed above. Soil samples free of roots were air-dried for 48 hr, crushed to pass through a 45-mesh sieve and stored in screw-topped glass jars prior to chemical analysis. Chemical analysis was performed on oven-dried tops. The processing of vegetation is described elsewhere (Bisessar et al.1983). Chemical analysis of Cl in vegetation was done by X-ray fluorescence spectrophotometry. Analytical methods for Cl, Br and Na are described elsewhere (Ontario Ministry of the Environment 1983). Bromine analysis was performed by McMaster University, Nuclear Reactor Laboratory, Hamilton, Ontario. About 100-500 mg of powdered sample was sealed in a polyethylene vial and together with standards NBS-1572 and chemical standards and blank vials was irradiated at an epithermal flux of ~ 2 x 10^{11} cm^2 sec^{-1} for 1 hr. Samples and standards were counted for 500 sec on a germanium coaxial detector (ORTEC) with energy resolution of >1.75 KeV (FWHM) at 1332.5 KeV (relative efficiency of greater than 10 % and peak to compton ratio of 41:1). The decay period for vegetation and soil samples was 2 and 3 d, respectively. The bromine was determined by using ^{2}Br (Half life = 35 hr) radionuclide with Gramm Ray energies at 554 KeV and 777 KeV. Analysis of variance and Duncan's Multiple Range Tests were applied to all data.

RESULTS AND DISCUSSION

The analytical results for soil and plant are shown in Tables 1-3. The treatments applied immediately and later are designated (I) and (L), respectively. Table 1 shows the concentrations of some of the various elements in soils at harvest. The concentrations of the elements in control soil follow the pattern Na > Cl > Br. The concentrations of all elements were within the generally accepted range for most uncontaminated soils (Wilkins 1978; Paradellis and Panayotakis 1980). Bromine concentrations present in the treated soils were slightly above the control indicating that some retention of bromine was occurring. Other elements (Cl and Na) were either similar to or slightly lower in the treated soils compared to the control. As chlorine readily leaches from soil, the other elements may also have percolated from the potted soil with the 400 mL solution treatment.

Table 1. Chemical concentrations of soil treated with Cl or Br at 1.5 and 150 ug/mL (I and L denote immediate and later treatments, respectively)

	Chemical concentrations in ug/g, dry wt					
	Chlorine *		Bromine		Sodium	
Treatment	I	L	I	L	I	L
Control	93	93	4.29	4.29	200	200
Chlorine 1.5 ug/mL	50	50	4.65	4.70	170	160
Chlorine 150 ug/mL	51	55	4.65	4.47	180	160
Bromine 1.5 ug/mL	50	84	5.73	6.30	150	190
Bromine 150 ug/mL	55	82	8.10	8.80	190	180

* Water extractable concentration

The average chemical content of grass tops at harvest is shown in Table 2. Grass tops from the respective Cl or Br treatments contained significantly higher Cl or Br than the control indicating that, barring possible vapour loss or foliage contact with the treatment solution, root uptake from the treatment soil had occurred. The only exception was for Cl that was applied immediately following solution preparation.

Table 2. Chemical concentrations of grass tops ** treated with chlorine or bromine at 1.5 and 150 ug/g mL (I and L denote immediate and later treatments, respectively)

	Chemical concentrations in ug/g, dry wt					
Treatment	Chlorine		Bromine		Sodium	
	I	L	I	L	I	L
Control	13800 a	13800 b**	5.63 c	5.63 c	1900 a	1900 a
Chlorine 1.5 mg/mL	16100 a	15700 a	5.85 c	5.84 c	1700 ab	2100 ab
Chlorine 150 ug/mL	14100 a	17300 a	4.41 c	6.96 c	1400 b	2166 b
Bromine 1.5 ug/mL	13700 a	12300 b	53.73 b	39.53 b	1466 b	1566 b
Bromine 150 ug/mL	13900 a	12800 b	262.43 a	314.76 a	1733 ab	1433 c

* Means of 7 replicates

* * a,b,c for a given element (within columns) treatment means followed by the same letter are not significantly different ($p \leq 0.05$)

The other element (Na) was either similar or significantly lower in grass tops from the treated soils compared to the corresponding control samples. Bromine content in grass tops increased significantly with bromine solution treatment and was correlated ($r = 0.95$ $P \leq 0.05$) with increased increments of bromine in the soil. In all cases, the concentrations of sodium in the grass were within the acceptable range (Martin 1966); However, Br, and in some cases, Cl concentrations were elevated in grass tops. The analytical results for both the immediate and delayed treatments of Br solution at 150 ug/mL were significantly higher than Br solutions at 1.5 ug/mL.

Table 3 shows the height, fresh and dry weight of grass tops at harvest. Plant heights and weights were generally, and in some cases significantly, higher in the treated soil compared to the untreated control. The improved yields do not necessarily imply that Br is an essential plant nutrient since Br may be indirectly influencing growth by encouraging or suppressing uptake of other nutrients. Foliar markings or toxicity were not evident in any treatment and the Kentucky blue grass developed normally and did not appear dwarfed or stunted. The chlorine ion appeared to be more mobile than the Br ion and a greater amount was probably lost in leachate from the soil. This loss could account for the reduced plant uptake and lack of observable effects on turf grass.

Table 3. Grass* height, fresh and dry wt when treated with chlorine or bromine at 1.5 and 150 ug/mL (I and L denote Immediate and later treatments, respectively)

	Height (cm)		Fresh wt (g)		Dry wt (g)	
Treatment	I	L	I	L	I	L
Control	9.4 c**	9.4 c	15.8 c	15.8 c	7.9 b	7.9 b
Chlorine 1.5 ug/mL	14.0 ab	13.0 a	15.5 c	20.2 b	10.3 a	8.9 ab
Chlorine 150 ug/mL	13.7 b	13.7 b	24.4 a	24.6 a	10.9 a	9.8 a
Bromine 1.5 ug/mL	14.9 a	12.7 ab	24.4 a	23.7 a	10.3 a	8.9 ab
Bromine 150 ug/mL	13.1 b	11.3 b	18.6 b	16.7 c	10.9 a	8.5 b

* Means of 7 replicates

** a,b,c, Values followed by the same letter (within columns) are significantly different ($p \leq 0.05$)

Kentucky blue grass subjected to 3 applications of chemical solutions to simulate exposure to swimming pool run-off water containing chlorine or bromine did not have any phytotoxic effect despite the fact that the highest concentrations used were about 100 times higher than the recommended rate of 1.0 to 1.5 ug/mL Cl or Br. Poor performance of turf grasses alleged to be associated with swimming pool run-off water appears to be related to factors other than the chemicals used for sanitation purposes.

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