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Selenium concentrations in water and plant tissues of a newly formed arid wetland in Las Vegas, Nevada

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Abstract There is concern that elevated levels of selenium found in the source water of a newly formed wetland park in Las Vegas, Nevada, may have detrimental effects on local wildlife. In this study, we collected and analyzed water samples monthly for a three year period from the inflow and outflow of the system. We also gathered dominant aquatic plants and selected terrestrial plants and analyzed the water and plant tissues (root, shoot, leaf and flower) for selenium by high resolution Inductively Coupled Plasma Mass Spectrometer. Except for storm events and the introduction of an alternative low selenium content source water during summer low-flow conditions, selenium in the water was relatively stable. The concentration in the outflow tended to be slightly lower than the inflow. Concentrations of selenium in the dominant plant taxa in this wetlands were typical of ecosystems in the western United States and varied by taxa, tissue type, localized conditions (e.g., contact with selenium-laden water), and to a lesser extent, seasons. Selenium in the aquatic plant spiny naiad (*Najas marina*) was relatively high and may pose an ecological risk to wildlife during the late spring and summer. Additional work is underway investigating aquatic food chain accumulations of selenium as well as mass balance of selenium in the system.

Keywords Selenium · Toxicity · Wildlife
Aquatic plants · Environmental assessment
Las Vegas · Ecological risk · Arid wetlands

Introduction

It is well known that selenium (Se) has the potential to accumulate to toxic levels in plants in aquatic ecosystems and subsequently impact wildlife (Lemly 2002). Following the discovery of detrimental effects of Se on wildlife in the Kesterson Reservoir in the San Joaquin Valley, California, (USFWS 1990) a survey of wetlands in the western United States indicated most of them were contaminated with elevated levels of Se (Presser et al. 1994; Wu 2004). This study concerns a newly constructed 130-acre wetland in the Las Vegas, Nevada metropolitan area. The constructed wetland, called the Clark County Wetlands Park Nature Preserve (NP), is adjacent to the main channel of the Las Vegas Wash in Southern

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Nevada (Fig. 1). Construction of the Nature Preserve wetland system was completed in April 2001.

Las Vegas Wash is a natural drainage system for the ~4,100 km^2 Las Vegas Valley watershed and is the primary site for discharge of tertiary treated wastewater. The Wash is the only major drainage for the Las Vegas valley, currently populated by ~1.8 million residents. It empties into Las Vegas Bay in Lake Mead, the largest man-made reservoir in the United States. Concentrations of Se in the mainstream of the Wash are relatively low (~2–3 μg/l), whereas concentrations in some tributaries, which consist primarily of runoff and surfacing groundwater, are significantly higher (~10–20 μg/l) (Cizdziel and Zhou 2005). Waterborne selenium at these elevated concentrations is of concern for the health of wildlife, particularly birds and fish. The current EPA guidance for aquatic life Se exposure is 5 μg/l for chronic exposure and 20 μg/l for acute exposure (USEPA 1987). This guidance is in the process of being re-evaluated and will probably be lowered as a result of new data on Se effects (USEPA (U. S. Environmental Protection Agency) 2004). The main water supply for the NP is one of these tributaries to the Wash with high selenium concentrations. Consequently there was, and continues to be, considerable concern that the NP wetlands could be a serious threat to wildlife due to Se toxicity.

A variety of emergent vegetation species were planted following construction of the NP, most of which have thrived in the system, forming a well developed wetland ecosystem. It is known that wetlands serve an important role in the biogeochemical cycling of Se, with some having been shown to volatize Se (e.g.: Hansen et al. 1998; Ansede et al. 1999; De Souza et al. 2000). Thus, it was of interest to determine if the plants of the NP were removing Se from the water via absorption and volatilization or if Se was accumulating in the system, causing an associated increased ecological risk to wildlife. To address these issues, Se concentrations were measured on a monthly basis in water collected at strategic locations in the system. In addition, dominant aquatic and terrestrial plant taxa were collected during periods of relative senescence (fall/winter) and rapid growth (spring/summer) and analyzed for selenium concentrations. This paper reports the waterborne concentrations of Se in the inflow and outflow from the system over a three year period (2001–2003). In addition, the distribution of Se in the plants by species, tissue-type, and season are reported from collections during 2002 and 2003.

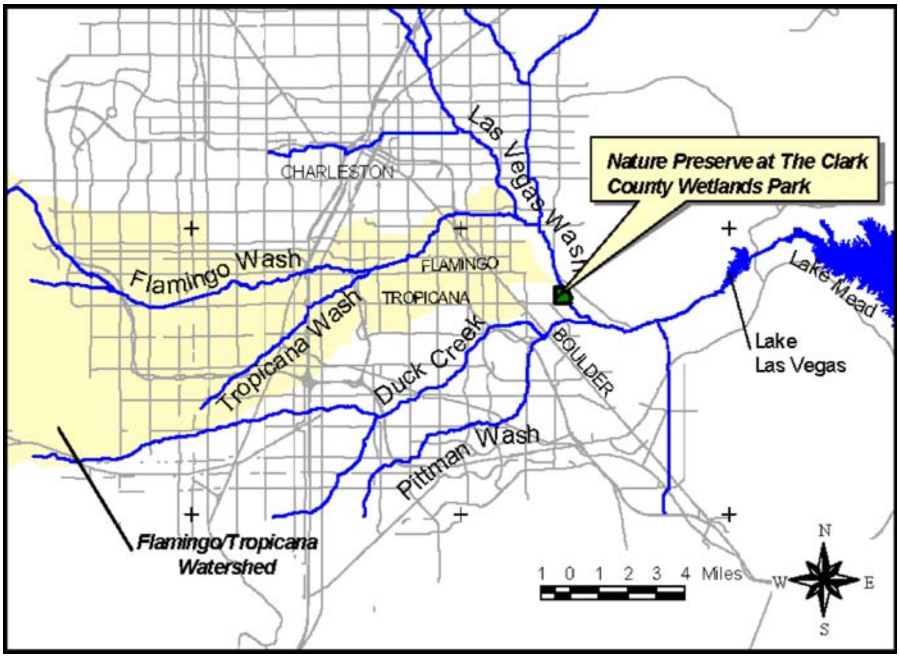


Fig. 1 The Las Vegas Wash and Nature Preserve in relation to major tributaries and Lake Mead

Materials and methods

Study area

The Nature Preserve is part of the 2,500 acre Clark County Wetlands Park and is located within the vicinity of the Las Vegas Wash (Fig. 1). The ponds and streams of the NP were designed to be supplied with water primarily from the nearby Monson Drain, a tributary to the Wash. It was known prior to construction that the Monson Drain had Se concentrations of >20 μg/l during some seasons and flow conditions. During the process of performing a National Environmental Protection Act Environmental Assessment (RECLAMATION 1999), and collection of baseline information for water quality and biological conditions at the NP (Pollard et al. 2002), a monitoring program was established to collect water quality data as the wetlands developed.

Water quality sampling sites and plant collection areas with designated station numbers were established within the NP (Fig. 2). NP-1 is the inflow from the Monson Drain and NP-8 is the outflow from the system. NP-2, NP-3, NP-4, and NP-5 are located at the outflows of individual ponds within the system from upstream to downstream respectively. In this report, we focus primarily on water collected from NP-1 and NP-8. Plant samples were collected from around the upper pond (near NP-2), middle ponds (near NP-3, NP-4 and NP-5), and lower pond (near NP-8).

Fig. 2 Map of the Nature Preserve showing general layout with ponds, trails and monitoring sites. Created from Clark County Aerial Photo taken in Spring, 2001

General water quality characteristics of the system

A complete reporting of the extensive three year water quality monitoring program can be found elsewhere (Pollard et al. 2004). In summary, with few exceptions (storm events and introduction of Las Vegas Wash water) the system can be characterized as highly saline (specific conductance ~4,800 μS/cm), relatively clear (turbidity <30 NTU), slightly alkaline (pH 7.7), with moderate acid-neutralizing capacity (alkalinity ~200 mg/l). Temperature, dissolved oxygen (DO) and flow varied by season. Temperature ranged from ~7°C (Feb.) to ~27°C (July), DO generally averaged around 10 mg/l during the winter and dropped to lows of about 3 mg/l in the summer. Flow rates also decreased from highs of around 2.5 cubic feet per second (cfs) in the winter to 0.2 cfs or less during the summer. Before the addition of a pipeline in April, 2004, allowing introduction of treated effluent from the nearby Clark County Water Reclamation District, low flow conditions and bacterial loads from stormflows during the southwestern monsoon season resulted in stagnation of the system, oxygen deficiencies, and fish kills. Overall, inflows were slightly lower in specific conductance than outflows indicating water loss through seepage, evaporation and plant mediated evapo-transpiration.

Plant species, tissues, and collection periods

Dominant aquatic taxa were selected, including bulrush (*Scirpus californicus*), cattail (*Typha* spp.), alkali bulrush (*Scirpus maritimus*), spiny naiad (*Najas marina*), and stonewart (*Chara vulgaris*). Four co-dominant terrestrial taxa were also studied because they were in close proximity to the wetland ponds and they provide large quantities of seed and significant forage for resident wetland wildlife. These include common reed (*Phragmites communis*), quail bush (*Atriplex lentiformes*), salt cedar (*Tamarix chinensis*), and salt grass (*Distichlis stricta*). Roots, vegetative segments, and flowers were chosen to reflect areas of physiological uptake, potential accumulation and volatilization, and wildlife consumption. Samples were collected during two main sampling periods: fall/winter 2002 and spring/summer 2003. These periods were chosen to represent periods of relative senescence (fall/winter, but mostly fall) and rapid growth (spring/summer) in the wetland plant populations. In summary, water samples were collected at the inflow and outflow of the park monthly for three years (2001–2003) and plant tissues samples were collected from various portions of aquatic and terrestrial plant taxa surrounding the aquatic systems during two seasonal periods in 2002 and 2003.

Field procedures

Water samples were collected into acid-washed Nalgene bottles and preserved with high purity HNO_3 to 1% acid. Samples were kept in a cooler with ice until storage at ~4°C at the laboratory. Plant tissues were selected from healthy appearing sections of mature specimens. Vegetative sections ~15 cm in length were cut from areas near, but not including the growing ends of the plants. Roots were removed from the same plant groups as the vegetative material and washed in the field with NP water to remove all visible sediment. A final rinse in the field with de-ionized water was performed to remove any residual NP water from the sample. Flowering portions of the plants were removed from the same or nearby groups of plants as the vegetative and root portions. The samples were bagged, labeled in the field and transported to the laboratory for storage in a freezer until processing and analysis.

The same basic field procedures were used to collect the fall/winter and spring/summer samples with the following exception. Based on the results of the fall/winter analyses it was noted that individual plants tended to have high field variability. It was decided to composite individual plants at each of the collection stations to allow us to obtain a complete spatially representative data set within the project budget. Therefore the mean concentrations presented for the spring/summer samples are based on fewer samples, but these samples are composites of approximately the same number of plants that were collected in the fall/winter collections and are therefore representative of the same areas.

Sample preparation

Because of the relatively high salt content of the water, typically >3,000 mg/l total dissolved solids, water samples were diluted (gravimetrically) several-fold with 1% HNO_3 prior to analyses, then run directly as described below. Plant samples were processed by placing a sample in a 250 ml Nalgene beaker, pouring approximately 50 ml of liquid nitrogen over the sample and grinding the sample with a ceramic mortar and pestle. If the sample was not sufficiently pulverized, the sample was then re-frozen in liquid nitrogen and blended in a commercial laboratory blender. The goal was for the sample to be of visually uniform composition. After homogenization samples were placed in labeled plastic bags and returned to the freezer until digestion.

Individual plant samples and composites were analyzed for moisture content by drying the sample at 85°C to a constant weight (typically 24 h). This was performed to allow conversion of selenium concentrations to a dry weight basis

Plant samples were digested based on a procedure by Zhang and Combs (1996). Briefly, ~0.5 g of air-dried sample was weighed in 50 ml polypropylene centrifuge tubes. Five ml of concentrated ultra-pure HNO_3 (SeaStar, Seattle WA) was added and the vials were transferred to a ModBlock™ Digestion System (CPI International, Santa Rosa, CA). The vials were loosely capped and the block brought to 80°C for 2 h followed by 100°C for another 2 h. Samples were then allowed to cool and 2 ml of concentrated ultra-pure H_2O_2 (JT Baker, Phillipsburg, NJ) was slowly added. The vials were again loosely capped and the block heater re-heated to 100°C for 2 h. The caps were removed and the samples were allowed to evaporate to a volume of approximately 0.5 ml. After cooling, de-ionized water was added to fill the vials to ~50 ml. The final digestate samples were weighed to the nearest 0.1 mg to determine the total weight of the final sample.

Sample analysis and quality assurance

Diluted water samples and plant digests were analyzed using a method based on U.S. EPA Method

200.8 (USEPA 1991). The instrument employed was the Axiom (Thermo Finnigan, San Jose, CA, USA), a magnetic sector-field Inductively Coupled Plasma Mass Spectrometer (ICP-MS) capable of high resolution and separation of the argon-dimer (^{38}Ar–^{40}Ar) interference peak from the ^{78}Se peak. Analysis of blanks indicated that the interference from ^{78}Kr, which can't be resolved by high resolution, was negligible. Yttrium was added to each sample to 1 ppb as an internal standard. Linear calibration curves had correlation coefficients greater than 0.99. For quality control, each set of samples was accompanied by a blank and a standard reference material (SRM) from the National Institute of Technology, to verify that the procedure was yielding valid results, ±15% of certified values. For water, SRM 1643d and/or 1640 were used. For plants, wheat flour (SRM 1567a) was digested and analyzed (blind) along with other samples within an analysis batch. The results fell within the target range of expected values 10 out of 11 times. The mean result was 1.05±0.08 (certified 1.1±0.2 μg/g), indicating good recoveries. Method blanks showed contamination was negligible relative to concentrations found in the samples. Recoveries from spikes of samples were within 20% of the expected value and showed there were no anomalous matrix effects. In addition, field duplicates were collected for both water and plant samples to determine the variability at a given site. The field variability was higher for plants, with relative percent differences (rpd) ranging from 30–90%, compared to the water (<10%). The precision for laboratory duplicates of plant homogenates was <10% (*n*=16; seven taxa), suggesting that the variability observed for Se between plants of the same species was real and perhaps site specific.

Results and discussion

Selenium in the water

With few exceptions (described later) data from water samples collected over a three year period following wetland construction indicated that Se concentrations in the inflow and outflow were similar and reasonably consistent (Fig. 3). Not including the anomalous data, the mean concentration at the inflow was 19.6±4.0 μg/l (range 8.6–27.0) and at the outflow was 17.6±4.4 μg/l (range 9.9–24.7). If Se was effectively being removed from the source water, mitigating the relatively high concentrations, one would expect to see outflows with consistently lower concentrations than the inflows. We found lower Se concentrations in the outflow compared with the inflow for 17 out of 24 analyses. There were 6 months (Dec. 01, Jan. 02, Oct. 03, Nov. 03, Feb. 03, and May '03) when Se concentrations were more than 5 μg/l lower in the outflow than the inflow and only 2 months (May '01 and Mar. '02) when the opposite was true. While it is likely that Se is being retained and accumulated in the system (to some extent), a more thorough investigation of mass balance would be necessary to quantify the amounts and resolve the issue.

The exceptions mentioned above are of interest and serve to aid in understanding the dynamics of the system. In March of 2001 we observed very high Se concentrations throughout the system. This followed a flood event which left large quantities of pooled water over the entire NP. We hypothesized that slow surface seepage from these pools into the upper pond carried a large loading of re-dissolved surface salts containing high Se concentration into the system which took approximately a month to finish seeping into the upper pond and moving through the system. We intended to test this hypothesis during later storm events, but no comparable events occurred during the remainder of the study.

The other obvious anomaly resulted from the introduction of Las Vegas Wash water into the system to mitigate degrading water quality due to low inflow

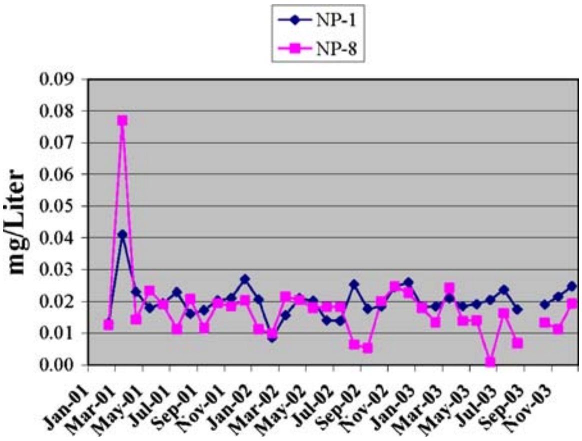


Fig. 3 Selenium concentrations (mg/l) in the inflow (NP-1) and outflow (NP-8) of the Nature Preserve for Feb. 2001 through Dec. 2003. Data is missing in 2003 for June (NP-8) and Sept. (both sites)

to the system and stagnation during the hot summer months (July, August and September 2002 and 2003). LVW water, which contained relatively low concentrations of Se (~2–3 μg/l), was pumped in near NP-2 or NP-4 which essentially diluted the Se in the middle and lower ponds. The Monson Drain inflow (NP-1) and the upper pond (NP2) did not receive input from LVW and did not show anomalous patterns. However, levels at the outflow decreased below that typically found in the system during base flow conditions due to the diluting effect of the added LVW water into the system (Fig. 3).

Overall, these data clearly show that the water borne Se concentrations in the NP, using the Monson Drain as the primary water source, were chronically above the current estimates of 1–2 μg/l for toxic effects on wildlife (Lemly 2002) as well as the EPA Criterion of 5 μg/l for protection of wildlife (USEPA 1987). These data were used by Clark County Parks and Community Services to initiate the construction of a pipeline connecting the NP inflow (NP-1) with treated effluent from the Clark County Water Reclamation District. This pipeline is capable of delivering 8 cfs to the inflow of the park and will allowed park operations to maintain adequate flow (~2.5 cfs) to avoid stagnation in the system as well as dilution of selenium input to the system. Monitoring of Se in the system is continuing past the conclusion of this study to develop a new baseline for water borne Se concentrations with the modified inflow parameters. Future studies are planned to observe the effects of reduced selenium concentrations on the aquatic food chain of the system.

Selenium in the plants

Submergent taxa had high moisture content as did most of the root samples for emergent taxa. Flowers typically had the lowest percent moistures, while the vegetative portions of the plants were typically in an intermediate range between flowers and roots

Table 1 Mean dry weight selenium data (μg/g) for fall/winter sampling[a]

	Part	n	Mean Se	SD	CV	% M
Emergent Taxa						
Bulrush	F	7	0.67	0.21	42.0	24.3
Bulrush	R	5	0.74	0.04	28.6	83.3
Bulrush	V	6	1.17	0.23	48.8	59.9
Cattails	F	8	1.57	0.39	34.2	27.7
Cattails	R	7	1.49	0.37	113.5	78.2
Cattails	V	11	2.81	0.53	59.1	68.3
Alkali Bulrush	F	6	1.05	0.70	91.3	26.6
Alkali Bulrush	R	7	1.50	0.41	103.2	73.6
Alkali Bulrush	V	4	1.51	0.35	49.1	53.0
Submergent Taxa						
Chara	All	1	0.85	–	–	85.0
UD Pond Weed	All	1	0.79	–	–	92.1
Spiny Naiad	All	5	1.51	0.04	40.5	93.3
Terrestrial Taxa						
Common Reed	F	5	1.59	1.20	106.7	29.4
Common Reed	R	4	1.54	0.55	88.5	59.6
Common Reed	V	10	2.03	0.55	52.4	48.4
Quail Bush	F	7	0.37	0.18	122.7	59.9
Quail Bush	V	11	0.54	0.11	69.6	71.2
Tamarisk	F	3	0.30	0.17	75.0	24.7
Tamarisk	V	3	0.87	0.01	2.2	67.0

[a] The portion of plant analyzed (*F* flower, *R* Root, *V* Vegetative Material) is presented along with the sample size (*n*), Standard Deviation (SD), Coefficient of Variation (CV), and Percent Moisture (%M) for all analyses.

Table 2 Mean dry weight selenium data (µg/g) for spring/summer sampling[a]

	Part	n	Mean Se	SD	CV	% M
Emergent Taxa						
Bulrush	F	3	0.78	0.26	33.2	32.4
Bulrush	R	3	0.93	0.34	36.7	85.8
Bulrush	V	3	1.16	0.52	44.7	73.5
Cattails	F	5	1.40	1.05	75.4	71.2
Cattails	R	4	2.08	1.71	82.3	91.5
Cattails	V	5	1.95	1.68	86.3	74.6
Cattails	Sprout	3	1.08	0.73	67.6	81.2
Akali Bulrush	F	5	0.36	0.09	25.5	39.2
Akali Bulrush	R	4	2.11	2.04	96.5	85.0
Akali Bulrush	V	5	1.04	0.42	40.5	71.3
Akali Bulrush	Sprout	2	0.81	0.40	49.0	69.4
Submergent Taxa						
Spiny Naiad	All	3	4.70	2.11	44.8	92.6
Terrestrial Taxa						
Common Reed	F	4	1.27	0.41	31.8	10.6
Common Reed	V	4	1.33	0.69	52.0	65.5
Quail Bush	V	4	0.47	0.34	72.4	69.1
Quail Bush	Sprout	3	0.34	0.12	35.9	76.7
Tamarisk	F	4	1.38	0.34	24.6	56.6
Tamarisk	V	4	2.11	1.96	92.7	61.2
Salt Grass	All	2	0.71	0.69	97.2	46.0

[a] The portion of plant analyzed (*F* flower, *R* Root, *V* Vegetative Material, *Sprout* very young vegetative material) is presented along with the sample size (*n*), Standard Deviation (SD), Coefficient of Variation (CV), and Percent Moisture (%M) for all analyses.

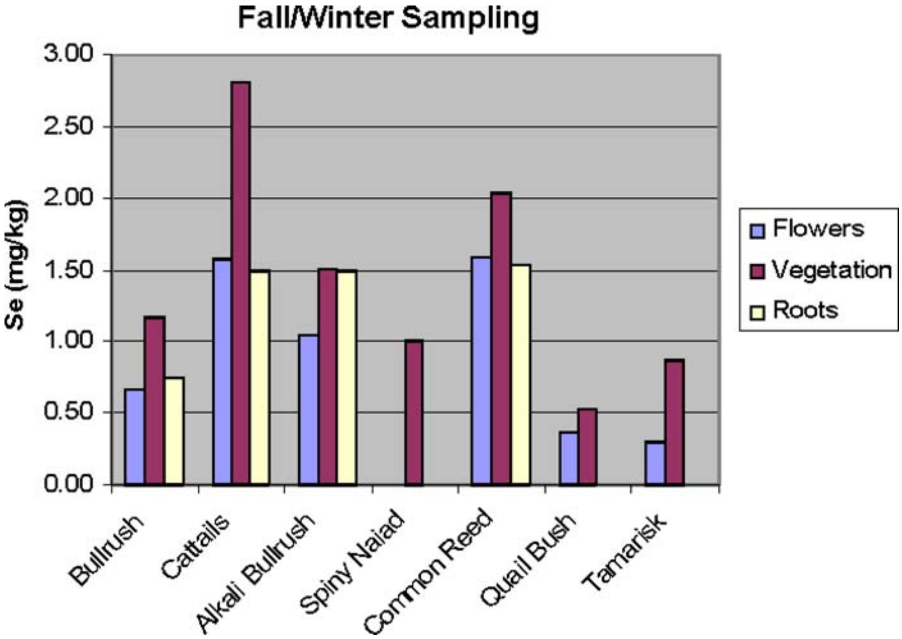
(Tables 1 and 2). Data are presented on a dry-weight basis to normalize Se concentrations to the different water contents between individual tissues and among species.

In this study, cattails, alkali bulrush, common reed and spiny naiad had the highest Se content and quail bush and bulrush had the lowest Se content within the NP (Table 1). This was fairly consistent seasonally, although there was considerable spatial and plant portion variation as has been noted above. Concentrations of Se in the plants varied by tissue, species and season (Tables 1 and 2). For those species and plant tissues that we were able to collect samples in both seasons we were able to make a direct comparison of tissue Se content. The fall samples generally had concentrations highest in the vegetative portions, followed by the roots and flower segments (Table 1, Fig. 4). The distribution was somewhat different for the spring/summer samples, which typically had the highest concentrations in the roots, followed by vegetative segments and flowers (Table 2, Fig. 5), although this pattern was not entirely consistent (see Bulrush in Fig. 5). Concentrations of Se in the vegetative segments were consistently lower in the spring/summer (five out of six species) compared with the fall. The opposite was true for roots which had higher concentrations in the spring/summer (three out of three species). There was no apparent trend for the flowers, which tended to have similar concentrations by season.

Selenium volatilization

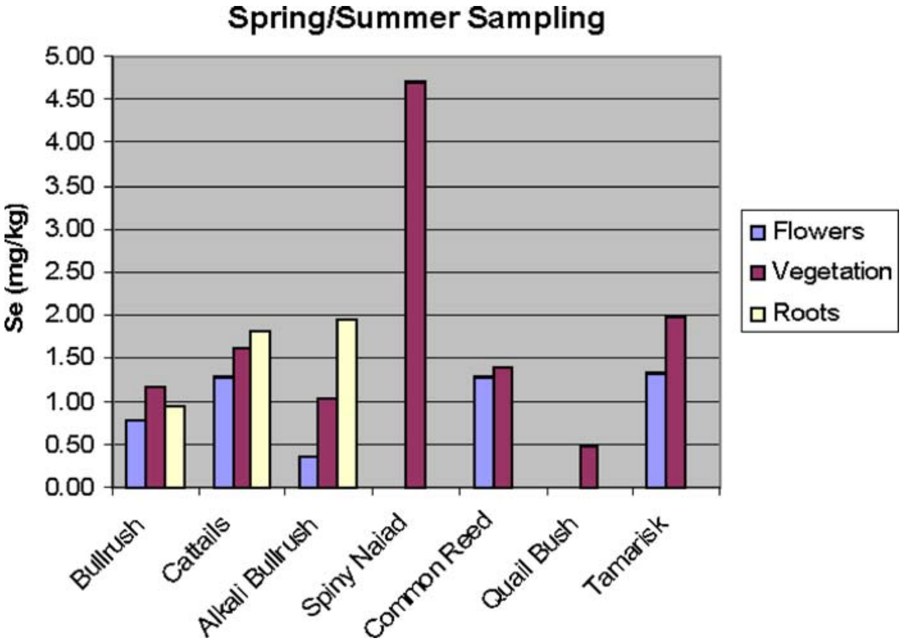
Volatilization of Se from wetlands occurs primarily through plants, and microorganisms associated with plants, and can be affected by not only the various species present but by a number of physical and chemical parameters, e.g. soil nutrients, pH, temperature, sulfate concentrations, aeration (redox conditions), and nitrate/nitrite levels (Wu 2004). Measurements of most of these parameters were beyond the scope of this work. However, we can compare our

Fig. 4 Mean selenium concentrations (μg/g dry weight) in plant tissue samples collected from the Nature Preserve in fall/winter, 2001



plant tissue concentrations to those found in other studies which have demonstrated phytoremediation of Se. Hansen et al. (1998) demonstrated that similar wetland plant species had consistently higher concentrations of Se in the root than in the leaves or shoot portions of the plants. They attributed as much as 30% of the reduction in waterborne Se concentrations exiting a constructed wetland to biological volatilization processes. We assumed that a similar distribution of Se in plant parts in our study would be evidence for volatilization of this element. For example, if the concentrations of Se were lowest in the respiring shoot or leaf portion of a plant, it would be an indication that Se was being volatilized via biological conversions and removed from the system. On the other hand, if Se were highest in the leaves or flowers it would be an indication of bioaccumulation which would tend to increase Se retention in the system over time. Applied

Fig. 5 Mean selenium concentrations (μg/g dry weight) in plant tissue samples collected from the Nature Preserve in spring/summer, 2002



to our data it appears that some plants are accumulating Se during the fall/winter (e.g., bulrush, cattails, and common reed) and removing it (respiring Se compounds) from the system during the spring/summer (e.g., alkali bulrush and cattails). However, the true picture is likely more complicated. It is known that different parts of plants tend to have different molecular forms of Se in different concentrations, each with its own volatilization properties (De Souza et al. 2000). Because of variability within and among species we are unable to conclude whether the wetlands as a whole have a net loss of Se through volatilization.

Ecological risk and comparison to literature data

Plant taxa with relatively high flower or seed Se concentrations could pose an elevated risk for birds and other wildlife via ingestion of these parts. Consequently, it was of interest to find which plants currently inhabiting the wetlands have the highest overall concentrations of Se in their tissues and therefore represent the greatest ecological risk due to Se. Moreover, comparison to other studies with the same or similar plant species would allow us to interpret our data in a broader perspective.

The majority of literature on environmental levels of Se refers to water, sediments, fish, invertebrates, and birds (see Hamilton 2004; Lemly 2002; and Wu 2004 for extensive reviews). The interest in Se in plant tissues has tended to focus on the potential for various plant taxa to concentrate Se, particularly when the plants are a food source for agricultural forage animals (e.g.: Wilbur 1983; Izbiki and Harms 1986; Harms 1995). More recently, comprehensive survey data have been compiled which document the levels of Se in various agricultural plants as well as native plant species (Seiler et al. 2003).

Studies of wetlands in the literature included a constructed wetland in the San Francisco Bay (Hansen et al. 1998) where Se ranged from 5 to 20 μg/g for shoot and root material. This was much higher than our observations, where the highest values were less than 4 μg/g and many observations were less than 1 μg/g. In an area of the lower Colorado River with similar characteristics to our wetlands, the maximum concentration of Se in cattail tissues was less than 0.2 μg/g (Garcia-Hernandez 2000). This was considerably less than the observed concentrations of Se in cattails that we found in the NP during fall or spring sampling (Tables 1 and 2). In both the Hansen and Garcia-Hernandez studies, Se in the source waters were similar to the NP (~20 ppb), although in one case the plants were deemed to be concentrating the Se (Hansen et al. 1998) and in the other they were not (Garcia-Hernandez 2000).

Data for three of the plant taxa studied in the NP (bulrush, cattails, and Quail bush) can be found in Harms (1995), which is a comprehensive statistical summary of all Se vegetation data collected by the US Geological Survey for a 22 year period prior to 1995. Bulrush and cattail data in the NP overlap those in the Harms report. However, these taxa are represented in the report by single samples from Merced County, California and therefore have limited comparative value. Quail bush leaf values presented in Harms (1995) had a much larger range of observed values (0.08–7.5 μg/g) than in our study (0.15–1.4 μg/g). However, the geometric mean presented in Harms (0.43 μg/g) is similar to our average value (0.46±0.09), indicating that the concentrations found here were probably in the typical range for this salt tolerant species.

Seiler et al. (2003) presents data on irrigation induced Se contamination for 26 areas in the Western United States. Median plant Se concentrations found in that report can be compared to our data if grand means are calculated for all plants and plant parts in the NP. The resulting estimate of total plant Se in NP was approximately 1.3 μg/g for spring samples and 1.2 μg/g for fall samples. These values correspond with the following areas presented in Seiler et al. (2003): Lower Colorado River Valley, California–Arizona; Riverton Reclamation Project, Wyoming; San Juan River area, New Mexico; and the Sun River area, Montana. These areas tend to have surface water concentrations that are much lower than the NP. This would tend to indicate that the plants in the Nature Preserve wetlands are not generally accumulating selenium, even though the water concentrations are well above levels of concern.

Seiler et al. (2003) also shows typical background levels for plant tissues to be near 1.5 μg/g and dietary effect levels in these tissues to be near 3 μg/g Se. A majority of the data presented in our study were below these levels and samples that exceeded this guidance typically were isolated samples which were not concentrated in any one area. However, concentrations of Se in the spiny naiad from the spring/

summer (mean 4.71 μg/g, dw) were consistently near or above the dietary effect level, which could pose a problem for birds and fish that feed on this submergent plant species. This was not as evident in fall samples and therefore may be a seasonal effect which might be coupled with reductions in dissolved oxygen and pH levels created by anoxic conditions as the system stagnates in the hot summer months. Among the plants studied, only the spiny naiad appears to be a potential problem and should be monitored and discouraged if the high levels persist.

Conclusions

Measurements of Se in the Clark County Wetlands Park Nature Preserve pointed out the critical importance of flow management to the ecology of the system. Prior to April of 2004, Se concentrations in the NP source water were generally high (~20 μg/l) and may have posed a risk to fish and other wildlife. During the study period, disturbances from storm events and low flow conditions interrupted this generally stable system. Selenium concentrations in the majority of plant tissues analyzed from the NP area appear to be near or below typical levels found in the Western United States. However, tissue concentrations in one aquatic plant taxa (spiny naiad) may pose an ecological risk to wildlife, particularly during the summer months. Additional studies of food chain effects would be necessary to determine the extent of this ecological risk and to formulate possible mitigation measures. We recommend continuing monitoring efforts and studies on the health and status of this unique wetland as the system evolves and matures.

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