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# Organic and Trace Element Contaminants in Water, Biota, Sediment, and Semipermeable Membrane Devices at the Tres Rios Treatment Wetlands, Phoenix, Arizona

Water-Resources Investigations Report 03–4129

U.S. Department of the Interior
U.S. Geological Survey

# ORGANIC AND TRACE ELEMENT CONTAMINANTS IN WATER, BIOTA, SEDIMENT, AND SEMIPERMEABLE MEMBRANE DEVICES AT THE TRES RIOS TREATMENT WETLANDS, PHOENIX, ARIZONA

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U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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# CONVERSION FACTORS AND ABBREVIATIONS

| Multiply | By | To obtain |
|---|---|---|
| **Length** | | |
| centimeter (cm) | 0.3937 | inch (in) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| micrometer (µm) | $10^{-6}$ | meter (m) |
| nanometer (nm) | $10^{-9}$ | meter (m) |
| **Area** | | |
| square meter ($m^2$) | 10.76 | square feet ($ft^2$) |
| square meter ($m^2$) | 0.00247 | acre (ac) |
| square meter ($m^2$) | 10000 | hectares (ha) |
| square kilometer ($km^2$) | 0.3861 | square mile ($mi^2$) |
| **Volume** | | |
| liter (L) | 0.2642 | gallon (gal) |
| cubic meter ($m^3$) | 1.308 | cubic yard ($yd^3$) |
| milliliter (mL) | 1000 | liter (L) |
| **Mass** | | |
| gram (g) | 0.03527 | ounce avoirdupois (oz) |
| kilogram (kg) | 2.205 | pounds (lb) |
| milligram (mg) | 1000 | gram (g) |
| **Flow** | | |
| meter per second (m/s) | 3.281 | foot per second (ft/s) |
| cubic meter per second ($m^3/s$) | 35.31 | cubic feet per second ($ft^3/s$) |
| cubic meter per second ($m^3/s$) | 22.82 | million gallons per day (mgd) |
| cubic meter per second ($m^3/s$) | 86400 | cubic meter per day ($m^3/d$) |
| **Concentration** | | |
| milligrams per liter (mg/L) | | parts per million |
| nanogram per liter (ng/L) | | parts per trillion |
| microgram per gram (µg/g) | | parts per million |
| microgram per kilogram (µg/kg) | | parts per billion |
| micrograms per liter (µg/L) | | parts per billion |

**Miscellaneous**

$cm^2/mL$ – square centimeter per milliliter

mS/cm – millisiemens per centimeter

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

°F = 1.8 (°C) + 32

# ABBREVIATIONS

BHT - butylatedhydroxytoluene
BPA - bisphenol A
BOR - Bureau of Reclamation
C1 - Cobble 1 wetland
C2 - Cobble 2 wetland
$C_{18}$ - octadecyl-bonded porous silica
CAFF - caffeine
CAS - Chemical Abstract Services
CHO - cholesterol
CLLE - continuous liquid-liquid extraction
$CO_2$ - carbon dioxide
COP - coprostanol
*o*,*p*'-DDD - 1,1-Dichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethane
*p*,*p*'-DDD - 1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethane
*o*,*p*'-DDE - 1,1-Dichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethylene
*p*,*p*'-DDE - 1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethylene
*o*,*p*'-DDT - 1,1,1-Trichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethane
*p*,*p*'-DDT - 1,1,1-Trichloro-2,2-bis(*p*-chlorophenyl)ethane
DOC - dissolved organic carbon
DO - dissolved oxygen
DUP - duplicate
E - estimated
EDTA - ethylenediaminetetraacetic acid
$d_{12}$-EDTA - ethylenediaminetetraacetic acid with 12 deuterium atoms replacing hydrogen
DOLT-1 - National Research Council of Canada Dogfish muscle standard reference material
DORM-1 - National Research Council of Canada Dogfish liver standard reference material
ESA - ethane sulfonic acid
EST - Environmental Sampling Technologies
GC - gas chromatography
GC/MS - gas chromatography/mass spectrometry
GPC - gel permeation chromatography
H1 - Hayfield 1 wetland
H2 - Hayfield 2 wetland
HOC - hydrophobic organic compounds
ICP/AES - inductively coupled plasma/atomic emission spectrometry
ICP/MS - inductively coupled plasma/mass spectrometry
LRL - laboratory reporting level
MDL - method detection limit
ND - not determined
NA - not available
NAWQA - National Water Quality Assessment
NCI - negative chemical ionization
NIST - National Institute of Standards
NP - nonylphenol

NPEC - nonylphenolethoxycarboxylate
NP1EC - nonylphenolmonoethoxycarboxylate
NP1EO – nonylphenolmonoethoxylate
NP2EC - nonylphenoldiethoxycarboxylate
NP3EC - nonylphenoltriethoxycarboxylate
NP4EC - nonylphenoltetraethoxycarboxylate
NTA - nitrilotriacetic acid
NWQL - National Water Quality Laboratory
OP1EO - octylphenolmonoethoxylate
PCB - polychlorinatedbiphenyl
% REC - percent recovery
PTFE - polytetrafluoroethylene
QA - quality assurance
QA/QC - quality assurance/quality control
RSD - relative standard deviation
SIM - selected ion monitoring
SPE - solid phase extraction
SPMD - semipermeable membrane devices
SRM - standard reference material
SRWS - standard reference water sample
TC - total carbon
TIC - total inorganic carbon
TOC - total organic carbon
TOP - *tert*-octylphenol
TRI - triclosan
USEPA - U.S. Environmental Protection Agency
USGS - U.S. Geological Survey
UV - ultraviolet
UV254 - ultraviolet light adsorption at 254 nm
v/v - volume/volume
VOC - volatile organic compounds
WWTP - wastewater treatment plant
w/w - weight/weight

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## ABSTRACT

The Tres Rios Demonstration Treatment Wetlands located near Phoenix, Arizona are sustained by effluent from the 91st Avenue Wastewater Treatment Plant (WWTP). A series of sampling events were conducted between 1998 and 2000, and the results of organic and inorganic analysis of water, sediment, biota, and semipermeable membrane devices (SPMD) are presented here. The free-water surface wetlands consist of shallow (0.3 meter) zones containing emergent vegetation (softstem bulrush, *Schoenoplectus tabernaemontai*, and Olney's bulrush, *Schoenoplectus americanus*), and deep zones (1.5 m) without vegetation. Conditions ranged from aerobic to anaerobic between the wetland inlet and outlet locations and temperatures were relatively constant, and there was little removal of specific conductance, total and dissolved organic carbon, and major anions and cations. Several pesticides and herbicides were detected in water samples including carbaryl, diazinon, 3,4-dichloroaniline (degradate of linuron and diuron), prometon, and simazine. Volatile organic compounds detected include bromodichloromethane, chloroform, dibromochloromethane, 1,4-dichlorobenzene, methylene chloride, tetrachloroethene, and toluene.

Concentrations of ethylenediaminetetraacetic acid (EDTA), a metal complexing agent and indicator compound of wastewater-impact, were greater than 100 micrograms per liter (μg/L) in the effluent and were reduced 75% between the wetland inlet and outlet. In contrast, concentrations of nitrilotriacetic acid (NTA), a more biodegradable metal complexing agent, were lower (less than 10 μg/L) and remained relatively stable in the wetlands. Downstream of the 91st Avenue WWTP effluent discharge location, the levels of EDTA in the Gila River decreased by 77% after 12 kilometers (km) of transport.

Alkylphenolethoxylate (APE) compounds are potential endocrine disrupting chemicals derived from nonionic surfactant degradation and are commonly detected in wastewater effluents. The most abundant APE-derived compounds were nonylphenolethoxycarboxylic acids (NPEC) which are hydrophilic (water soluble) degradates that occur as ionic species. The combined nonylphenolmonoethoxycarboxylate and nonylphenoldiethoxycarboxylate (NP1EC and NP2EC) levels in the effluent were greater than 100 μg/L and decreased 47% and 36%, respectively, in the treatment wetlands. Concentrations of nonylphenoltriethoxycarboxylate and nonylphenoltetraethoxycarboxylate (NP3EC and NP4EC) were lower and relatively stable at the wetland inlet and outlet locations. Combined NP1EC and NP2EC concentrations greater than 50 μg/L were detected in the Gila River 12 km downstream from the 91st Avenue WWTP discharge. Other NPE-derived compounds that were detected include nonylphenol, octyphenol, nonylphenolmonoethoxylate, nonylphenoldiethoxylate, octylphenolmonoethoxylate, and octylphenoldiethoxylate. A variety of other organic wastewater contaminants also were detected, including caffeine, triclosan, and coprostanol.

In 1998, tilapia (*Tilapia mossambica*) and mosquito fish (*Gambusia affinis)* collected from the wetlands showed accumulation of *p,p'*-DDD, *p,p'*-DDE, and dieldrin. In 2000, *Tilapia* showed accumulation of *p,p'*-DDE and *trans*-nonachlor. *Gambusia* collected in 2000 had elevated concentrations of *cis*- and *trans*-chlordane, *p,p'*-DDE, dieldrin, lindane, *trans*-nonachlor, and polychlorinatedbiphenyls. *Tilapia* appeared to be less susceptible than *Gambusia* to accumulation of hydrophobic organic compounds (HOC) on a mass basis. Although the lipid content of the *Tilapia* liver tissue was equivalent to the whole-body *Gambusia*, concentrations of *p,p'*-DDE and *trans*-nonachlor and were 3 to 5 times higher in the whole-body *Gambusia* than in the *Tilapia* liver. The absence of contaminants in the *Tilapia* filet tissue indicates low risk to human populations that eat the fish. In the 2000 sampling, all of the compounds detected in *Tilapia* were detected in the *Gambusia*, but the *Gambusia* also contained additional compounds.

The SPMD showed elevated concentrations of HOC that potentially can bioconcentrate in the lipid of aquatic organisms. SPMD deployed for 28 days in 1998 accumulated *cis*- and *trans*-chlordane, *p,p'*-DDE, dieldrin, endosulfan I, endosulfan II, heptachlor epoxide, hexachlorobenzene, lindane, *cis*- and *trans*-nonachlor, oxychlordane, and pentachloroanisole. The SPMD outlet concentrations showed a 70% to >99% reduction relative to inlet concentrations. During 1999, a time-series experiment (SPMD were collected 1, 2, 4, 6, and 8 weeks after deployment) was conducted to determine SPMD uptake rate characteristics in the treatment wetlands. The results indicate that *cis*- and *trans*-chlordane, and *trans*-nonachlor achieved steady state within 28 days, and that consistent with the 1998 results, there was >70% removal across the wetland. Dieldrin, lindane, and pentachloroanisole showed linear uptake during the initial part of the exposure (first 4 weeks) followed by clearance in the later part of the study. Dieldrin concentrations decreased 64% between the inlet and outlet, lindane decreased 37%, and pentachloroanisole decreased >90%. Concentrations of *p,p'*-DDE in the SPMD increased over time and demonstrated that both internal loading and removal mechanisms were occurring within the wetland.

Both the *Gambusia* and *Tilapia*, and the SPMD data indicate accumulation of *p,p'*-DDE, dieldrin, and *trans*-nonachlor, whereas the *Gambusia* and SPMD also accumulated *cis*- and *trans*-chlordane, and lindane. The inlet SPMD contained elevated concentrations for each of these compounds relative to the outlet and values measured in the fish tissue. The *Gambusia* concentrations were generally equivalent to those measured in the outlet SPMD.

Although there was a slight increase in the wetland outlet concentrations relative to the inlets, the major-ion chemistry indicated little change during wetland treatment. This is consistent with specific conductance results, which are an indirect measure of total dissolved ions. A large suite of dissolved trace elements were detected, and as would be expected, varied significantly in their behavior in the wetlands. For example, dissolved arsenic concentrations in the wetland outlets were similar to (averaged 9% higher) the inlet concentrations, indicating no removal and the slight concentrating effects of evapotranspiration. In contrast, copper underwent significant removal (>90%) during wetland treatment and lead and zinc were removed to a lesser extent (>50%). Some elements such as cadmium and the rare earth elements, had higher concentrations in the outlets than the inlets indicating internal loading.

The sediment and bulrush vegetation had trace element distributions in general agreement with the water composition, although for many elements, concentrations in the sediment and vegetation were much higher. For example, concentrations of lead, zinc, arsenic, copper, and cadmium were 20, 25, 50, 1000, and 10,000 times higher in the vegetation respectively than in the water.

Trace element distributions in the fish tissue were similar between the *Tilapia* and *Gambusia* whole-body analyses, and were in general agreement with the water composition. The concentrations of most trace elements in the *Tilapia* filet tissue were very low, whereas concentrations in the liver tissue were an order of magnitude higher.

# CHAPTER 1 - INTRODUCTION

Water remains a scarce resource in the Southwestern United States, prompting many cities to reclaim treated wastewater effluent to satisfy growing municipal water demands. Constructed wetlands are increasingly being implemented to provide supplemental treatment to wastewater treatment plant (WWTP) effluents while achieving wildlife habitat goals. Wetlands can maximize biological and vegetative diversity while sequestering, assimilating, and transforming a wide variety of organic compounds and trace elements.

Residual wastewater contaminants can have a profound effect in arid regions due to high evaporation and evapotranspiration rates, which can reduce dilution and assimilation capacity by native stream water. Human, wildlife, and environmental health concerns may exist due to prolonged exposure to trace levels of chemicals in wastewater-dominated systems. Aquatic organisms living in treatment wetlands potentially can accumulate anthropogenic compounds through successive food pathways resulting in acute toxic effects and long-term ecosystem disruption. The potential for hydrophobic organic compounds (HOC) and trace elements to bioaccumulate is an important consideration in design and policy decisions related to constructed wetlands supplied by wastewater effluents.

## PURPOSE AND SCOPE

This research originated from an interagency agreement between the Bureau of Reclamation (BOR), Technical Service Center, Water Resource Services of Denver, Colorado, and the U.S. Geological Survey (USGS) in Boulder, Colorado. The agreement emphasized studies to assess the potential for bioaccumulation and biotoxicity of HOC and trace elements in aquatic organisms inhabiting effluent-dependent wetlands and stream systems. The objective of this report is to present analytical results for water, biota, and sediments for the Tres Rios Demonstration Treatment Wetlands (Tres Rios Wetlands) located near Phoenix, Arizona. Additional goals were:

- Determine HOC and trace elemental contaminant attenuation within the wetland basins.
- Assess mechanisms of bioaccumulation for chemicals present in biota.
- Evaluate analytical methods for determining bioaccumulation.
- Assess wastewater impacts at downstream locations

This report summarizes research on HOC and trace elements conducted from 1998 to 2000. Water, sediment, fish, and semipermeable membrane device (SPMD) samples were collected concurrently to provide an overview of wetland biota and site conditions. The samples were characterized by a variety of analytical methods.

## ACKNOWLEDGEMENTS

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analysis. Thanks to Kate Campbell, Tom Leiker, Steve Zaugg, Donna Rose, Denis Markovcheck, and Gerald Hoffman (USGS) for their field and laboratory contributions.

## BACKGROUND

The BOR in cooperation with the City of Phoenix and the regional cities of Mesa, Tempe, Scottsdale, Youngtown, and Glendale, established the Phoenix Water Reclamation and Reuse Study in 1993 (CH2M Hill, 1995). The primary objective of the study was to identify technologies to reclaim municipal wastewater effluent for beneficial use applications. The Tres Rios Wetlands were evaluated as a means of satisfying water quality and wildlife habitat enhancement goals in the region. The U.S. Army Corps of Engineers initially described the demonstration wetlands concept in an unpublished water resources report for Maricopa County (CH2M Hill, 1995). As a result, the BOR proposed a design for two wetland systems sustained by effluent from the 91st Avenue WWTP and discharging into the Salt River. In October 1993, the BOR released a report on the "Phoenix Water Reclamation and Reuse Study" which included the conceptual design of the Tres Rios Demonstration Wetlands (U.S. Bureau of Reclamation, 1993). The City of Phoenix and BOR amended the original proposal to include research cells in March 1994. The wetland design and construction was finalized in spring 1995 and the initial planting and irrigation began in May 1995. In October 1995, full hydraulic control of the site began (CH2M Hill, 1997).

## SITE DESCRIPTION

The Tres Rios Wetlands are located at the 91st Avenue WWTP near the Salt River in Maricopa County, Arizona. The facilities consist of 12 small-scale research cells and two larger-scale demonstration wetlands systems: the Cobble and Hayfield sites that vary in size, layout, and operational conditions (fig. 1-1). This study was conducted at the two demonstration wetland sites, each consisting of two parallel basins with emergent vegetation and controlled flow conditions. The four wetlands polish nearly 7500 cubic meters per day ($m^3$/day, about 2 million gallons per day) of advanced-secondary, activated-sludge treated, nitrified-denitrified, chlorinated wastewater discharged from the 91st Avenue WWTP. Each wetland has alternating internal shallow zones (emergent vegetation) and deep zones (open water) with the deep zones having a depth one-meter below the emergent marsh elevation. Effluent from the 91st Avenue WWTP is pumped to the Cobble and Hayfield sites and distributed via inlet splitter boxes. Wetland operators control average detention times ranging from three to seven days with depths of 0.1 to 0.5 meters (m). During the course of this investigation the wetlands underwent periodic reconstruction, thus altering configuration, operation, and treatment (City of Phoenix, 1998; Wass, Gerke and Associates, 2001). All of the wetlands can be operated at similar conditions to compare design features on treatment efficiencies.

### HAYFIELD SITE

The Hayfield site (fig. 1-2) consists of two free-water-surface constructed wetlands with each being approximately 228 m long and 60 m wide, and covering 1.4 hectares (ha) (CH2M Hill, 1997; Wass, Gerke and Associates, 2001). The two Hayfield wetlands (H1 and H2) were constructed on a former agricultural field. The H1 wetland has five internal sinusoidal deep zones and the H2 wetland has two interior deep zones. Although configured differently, both wetlands had approximately 20% deep water and 80% shallow emergent marsh zones. Several nesting islands are located in the H2 deep zones. The Hayfield wetlands are operated in parallel, and effluent from the two wetlands is combined and discharged into the Salt River channel.

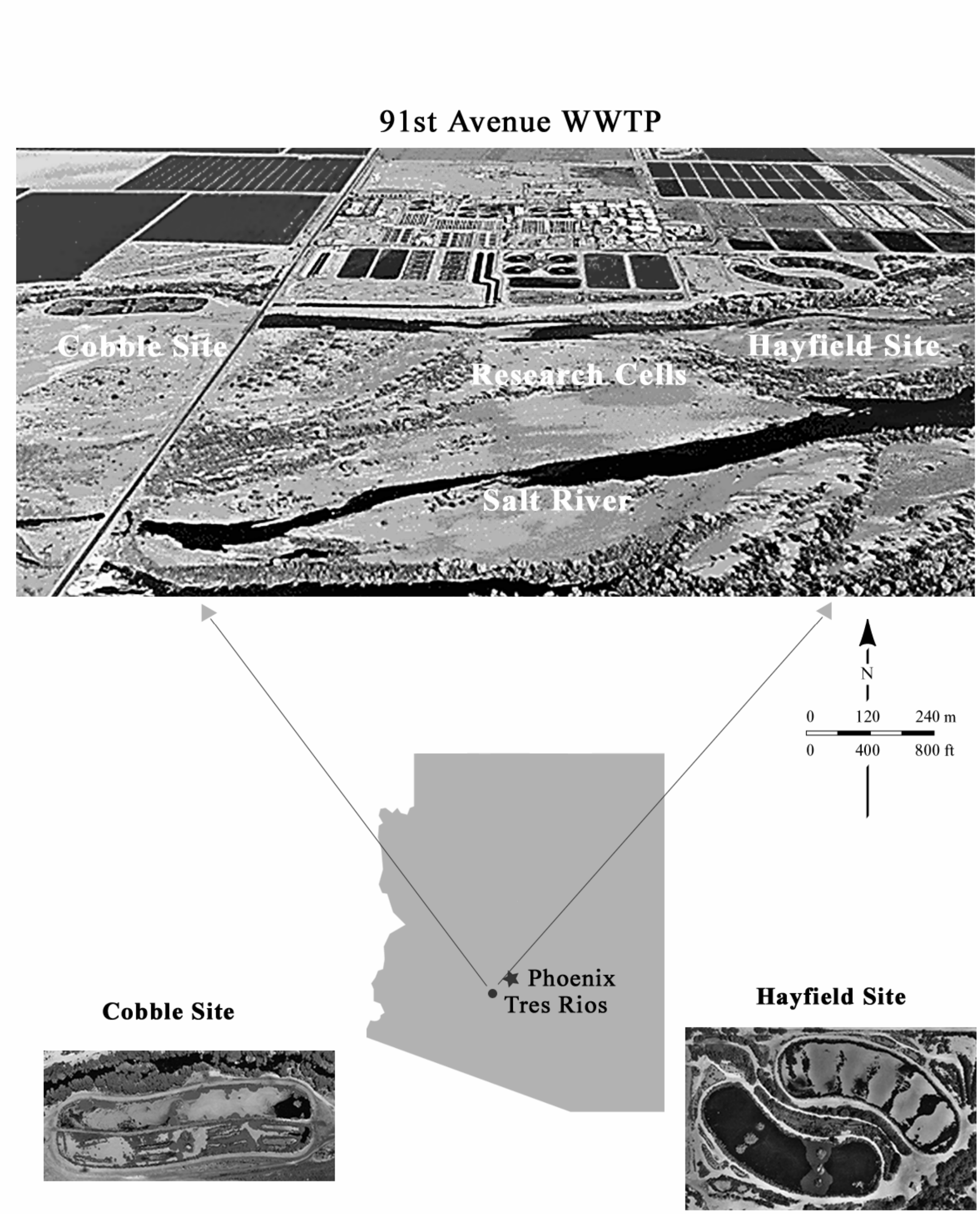

**Figure 1-1**. Site location and aerial photograph of the 91$^{st}$ Avenue Wastewater Treatment Plant and Tres Rios Treatment Wetlands.

## COBBLE SITE

The Cobble Site (fig. 1-3) consists of 2 free-water-surface constructed wetlands with each measuring approximately 275 m long and 35 m wide, and covering 0.96 ha (CH2M Hill, 1997; Wass, Gerke and Associates, 2001). The Cobble wetlands (C1 and C2) are built on the Salt River alluvial channel. The coarse cobble sediments allow significant leakage from the unlined C1 wetland. The C2 wetland is lined with 2 to 4 centimeter (cm) of loamy topsoil from a nearby agricultural field to curtail water losses due to infiltration. During the course of most of this study, the C1 wetland contained mainly open water with little vegetation, whereas the C2 wetland was fully vegetated. Effluent from the Cobble wetlands empties into the 91st Avenue WWTP discharge channel.

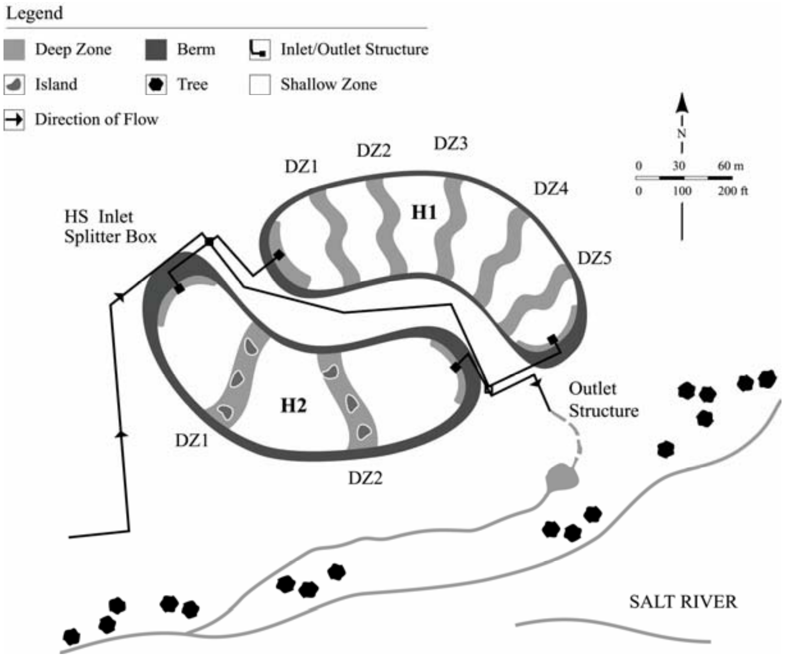

**Figure 1-2**. Hayfield wetlands site map. [HS, Hayfield site; H1, Hayfield 1 wetland; H2, Hayfield 2 wetland; DZ, deep zone]

## ECOSYSTEM

The Tres Rios Wetlands provide habitat for numerous species of indigenous and migratory birds. Shallow open water zones support wading bird and waterfowl habitat while dense vegetation attracts passerine species. Biological diversity of the wetland basins at Tres Rios also includes fish, mammal, and macroinvertebrate species. Tilapia (*Tilapia mossambica*) are large, hardy fish that inhabit deep, open water areas and feed on algae. Mosquito fish (*Gambusia affinis*) are small fish that live in shallow vegetated areas and feed off mosquito larvae and other zooplankton. Mammals such as beaver and muskrats reside in the wetland basins.

Plant species inhabiting the wetland basins include both emergent and floating aquatic vegetation. Emergent plants are rooted, vascular species that grow above the water surface in the shallow zones. The major emergent vegetation species are softstem bulrush (*Schoenoplectus tabernaemontai*) and Olney's (three-square) bulrush (*Schoenoplectus americanus*). Floating aquatic plants occur in the deep zones and include both rooted and non-rooted vascular plants that have some parts, typically chlorophyll-bearing leaves, floating on the surface. Floating aquatic vegetation consisted primarily of duck weed (*Lemna spp.*) and water pennywort (*Hydrocotyle spp.*).

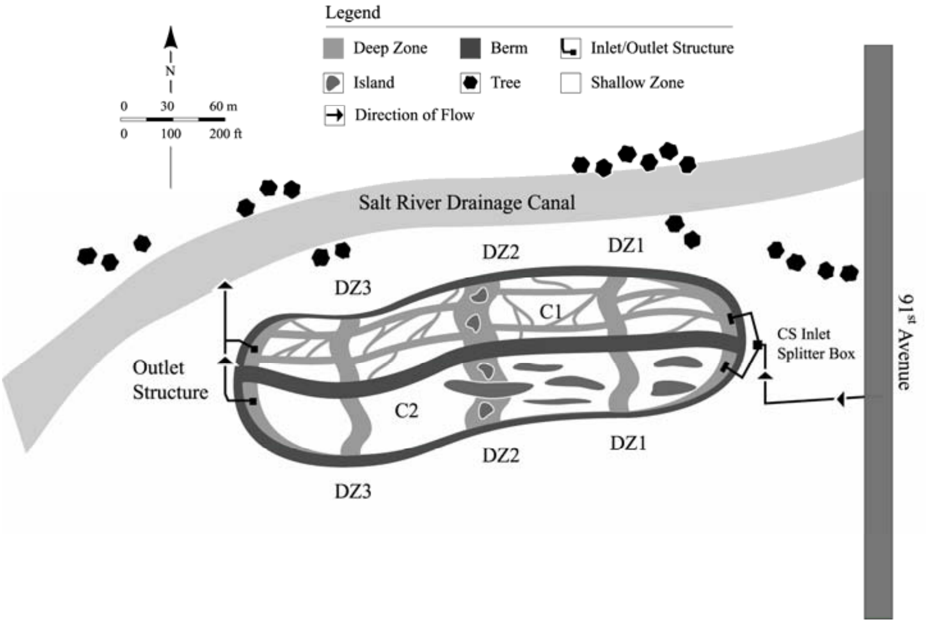

**Figure 1-3**. Cobble wetlands site map. [CS, Cobble site; C1, Cobble 1 wetland; C2, Cobble 2 wetland; DZ, deep zone]

# CHAPTER 2 - SAMPLING APPROACH

Samples were collected over a three-year period (1998 to 2000) at the Tres Rios Wetlands to provide field data on biota contaminant concentrations and wetland removal pathways. Tables 2-1, 2-2, and 2-3 summarize the field sampling efforts. Water analysis provided details on aqueous pollutant levels existing in the wetland habitat. Fish tissue and SPMD samples provide insight into bioconcentration processes occurring within the treatment basins. Sediment and bulrush analysis depict alternate removal processes of HOC and trace elements in the constructed wetlands.

## FIELD SAMPLING METHODS

### WATER

Water samples were collected between 1998 and 2000 at each wetland inlet and outlet structure to detail long-term wastewater profiles. During 1998, Hydrolab MiniSonde 4A data collection platforms were positioned near the H2 inlet and outlet (approximately 0.5 m below water surface) to monitor conductivity, pH, temperature, and dissolved oxygen (DO) levels at one-hour intervals over a one-month period. Additional water samples were collected at the 91st Avenue Outfall, 115th Avenue (5 kilometers, km, downstream), and Bullard Avenue (12 km downstream) along the Salt/Gila River to monitor water quality downstream of the wetlands and at the treatment plant discharge point. The Salt River becomes known as the Gila River immediately downstream of 115th Avenue.

Water samples were collected in cleaned and burned one liter (L) amber glass bottles for analysis of total organic carbon (TOC), dissolved organic carbon (DOC), select pesticides, ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acid (NTA), nonylphenol ethoxycarboxylates (NPEC), and a suite of wastewater-derived compounds including nonylphenol and caffeine. Each bottle was rinsed three times with sample before filling and preserving on ice for shipping. Samples for EDTA, NTA, and NPEC were preserved with 1% (volume/volume, v/v) formalin. In February 2000, samples were collected in each deep zone of the H1 wetlands for analysis of volatile organic compounds (VOC). The samples were collected in pre-cleaned 40 milliliter (mL) amber-glass vials with no headspace to prevent losses from the aqueous phase, and preserved by addition of hydrochloric acid and ascorbic acid. Samples were shipped on ice and stored at 4 degrees Celsius (°C) until analysis.

**Table 2-1**. Tres Rios Wetlands field sampling events, 1998. [H2, Hayfield 2 wetland; SPMD, semipermeable membrane device]

| Date | Location | Field Sampling |
|---|---|---|
| July 23, 1998 | H2 Wetland | *Tilapia* and *Gambusia* Collection |
| July 24, 1998 | H2 Inlet | Sediment samples collected |
| " | H2 Inlet | Hydrolab deployed |
| " | H2 Inlet | SPMD deployed |
| " | H2 Inlet | Water samples collected |
| " | H2 Outlet | Sediment samples collected |
| " | H2 Outlet | Hydrolab deployed |
| " | H2 Outlet | SPMD deployed |
| " | H2 Outlet | Water samples collected |
| " | Bullard Avenue | SPMD deployed |
| " | Bullard Avenue | Water samples collected |
| July 28, 1998 | H2 Inlet | Water samples collected |
| " | H2 Outlet | Water samples collected |
| August 4, 1998 | H2 Inlet | Water samples collected |
| " | H2 Outlet | Water samples collected |
| August 10, 1998 | H2 Inlet | Water samples collected |
| " | H2 Outlet | Water samples collected |
| August 18, 1998 | H2 Inlet | Water samples collected |
| " | H2 Outlet | Water samples collected |
| August 21, 1998 | H2 Inlet | SPMD removed and shipped |
| " | H2 Inlet | Hydrolabs retrieved |
| " | H2 Inlet | Water samples collected |
| " | H2 Outlet | SPMD removed and shipped |
| " | H2 Outlet | Hydrolabs retrieved |
| " | H2 Outlet | Water samples collected |
| " | Bullard Avenue | SPMD removed and shipped |
| " | Bullard Avenue | Water samples collected |

**Table 2-2**. Tres Rios Wetlands field sampling events, 1999. [H1, Hayfield 1 wetland; C2, Cobble 2 wetland; SPMD, semipermeable membrane device]

| Date | Location | Field Sampling |
|---|---|---|
| June 21, 1999 | H1 Inlet | Water samples collected |
| June 22, 1999 | H1 Inlet | Water samples collected |
| " | H1 Outlet | Water samples collected |
| June 23, 1999 | C2 Inlet | Sediment samples collected |
| " | C2 Inlet | *Schoenoplectus* samples collected |
| " | C2 Outlet | Sediment samples collected |
| " | C2 Outlet | *Schoenoplectus* samples collected |
| " | 115th Avenue | Water samples collected |
| " | Bullard Avenue | Water samples collected |
| June 24, 1999 | H1 Inlet | Five duplicate SPMD deployed |
| " | H1 Outlet | Five duplicate SPMD deployed |
| July 1, 1999 | H1 Inlet | Duplicate SPMD set 1 removed and shipped |
| " | H1 Outlet | Duplicate SPMD set 1 removed and shipped |
| July 8, 1999 | H1 Inlet | Duplicate SPMD set 2 removed and shipped |
| " | H1 Outlet | Duplicate SPMD set 2 removed and shipped |
| July 22, 1999 | H1 Inlet | Duplicate SPMD set 3 removed and shipped |
| " | H1 Outlet | Duplicate SPMD set 3 removed and shipped |
| August 5, 1999 | H1 Inlet | Duplicate SPMD set 4 removed and shipped |
| " | H1 Outlet | Duplicate SPMD set 4 removed and shipped |
| August 19, 1999 | H1 Inlet | Duplicate SPMD set 5 removed and shipped |
| " | H1 Outlet | Duplicate SPMD set 5 removed and shipped |

**Table 2-3**. Tres Rios Wetlands field sampling events, 2000. [H1, Hayfield 1 wetland; H2, Hayfield 2 wetland; C1, Cobble 1 wetland; C2, Cobble 2 wetland; VOC, volatile organic compounds]

| Date | Location | Field Sampling |
|---|---|---|
| February 13, 2000 | Bullard Avenue | Water samples collected |
| " | 115th Avenue | Water samples collected |
| February 14, 2000 | Cobble Inlet | Water samples collected |
| " | C1 Outlet | Water samples collected |
| " | C2 Outlet | Water samples collected |
| " | H1 Wetland | *Tilapia* collected |
| " | Cobble Wetlands | *Gambusia* collected |
| February 15, 2000 | Hayfield Inlet | Water samples collected |
| " | H1 Outlet | Water samples collected |
| " | H2 Outlet | Water samples collected |
| February 16, 2000 | 91st Ave Dewatering Well | Water samples collected |
| " | H1 Wetland | VOC water samples collected |

Samples were collected for determination of major ion water chemistry (anions and cations), trace elements (including mercury, Hg), and selected nutrients. A sample from each site was collected in an acid-rinsed Teflon (polytetrafluoroethylene - PTFE) holding bottle and an acid-rinsed glass holding bottle, which were shipped on ice to the USGS laboratory in Boulder, Colorado. Each bottle was rinsed a minimum of three times with sample prior to filling. Upon arrival at the laboratory, metals samples were immediately filtered through 47 millimeter (mm) diameter, 0.4 micrometer (µm) pore size polycarbonate membrane filters (Nuclepore #111107) in a PTFE filter holder under ultraclean conditions (Kelly and Taylor, 1996). Samples were collected in pre-cleaned high-density polyethylene bottles and preserved by the addition of high-purity distilled nitric acid (Kuehner and others, 1972) for trace-metals analysis. A filtered subsample for anion analysis was retained without acidification and preserved by chilling. Samples for Hg analysis were filtered from the glass holding bottle, collected in pre-cleaned borosilicate glass bottles with PTFE lined screw caps, and preserved with a mixture of high-purity nitric acid and high-purity potassium dichromate. Samples for nutrient analysis (nitrate, nitrite, ammonium, and phosphate) were collected in precleaned brown polyethylene bottles and stored at 4 $^{o}$C.

## FISH

*Tilapia* and *Gambusia* were collected in 1998 and 2000 to investigate bioconcentration effects. The fish were caught by throw net (*Tilapia*) or scoop net (*Gambusia*), weighed, measured, examined, and preserved on dry ice. The *Gambusia* and *Tilapia* specimens were stored in aluminum foil for HOC analysis pesticide detection and plastic bags for trace-element analysis. Samples were stored frozen (-20 $^{o}$C) until further processing and analysis.

## SEMIPERMEABLE MEMBRANE DEVICES

Semipermeable membrane devices (SPMD) are *in-situ* samplers that mimic uptake of HOC into the fatty tissues of aquatic organisms by passive diffusion of organic molecules through a synthetic membrane into lipid material (Huckins and others, 1996). Contaminant concentrations in the SPMD represent bioavailable compounds present in aquatic habitats.

Although HOC that rapidly partition into SPMD exhibit similar behavior in aquatic organisms, the SPMD concentrate chemicals that can be metabolized or excreted by fish. As a result, the number of compounds sequestered by SPMD and their concentrations can be larger than those found in native fish tissue. In addition, SPMD provide time-integrated concentrations by sampling large volumes of water over several weeks accounting for hourly and daily fluctuations in flow and composition.

Figure 2-1 shows the design of a typical SPMD and illustrates compound partitioning into the polyethylene tubing and diffusion through transport corridors into the triolein lipid. Local concentration gradients and physicochemical properties govern the rate of uptake into the sampling device. Semipermeable membrane devices primarily sequester dissolved organic molecules with some degree of conformational freedom and not limited by steric or solubility factors. Very large molecules may encounter transport resistance across both synthetic and biological membranes. Each SPMD is coiled across a metal deployment rack and placed inside a metal protective shroud. The containment structure protects the SPMD from damage, and can hold five SPMD deployment racks that can be combined to create a composite sample or analyzed individually. The SPMD used in this study were purchased from Environmental Sampling Technologies (EST, St Joseph, Missouri) in the standard design (Huckins and others, 1996) with a triolein/membrane ratio (weight/weight, w/w) of ≈ 0.2, a low-density polyethylene membrane thickness of 75 to 90 μm, and a membrane surface area/lipid volume ratio of ≈ 450 cubic centimeters per milliliter ($cm^2/mL$).

During the 1998 field study, SPMD were deployed for 28 days at the H2 inlet and outlet to investigate the relative removal of bioavailable compounds through the wetland. Additional samplers were placed in the Salt River at the Bullard Avenue location to evaluate the presence of HOC at a downstream location. At each site, duplicate sets of five SPMD were transferred from sealed metal cans into the containment devices and then submerged at approximately the midpoint of the water column (≈ 0.5 m below water surface). No reference compounds were used in field exposures but similar flow and temperature regimes existed at both inlet and outlet locations allowing for intersite comparisons. At the conclusion of the 28-day deployment, the SPMD were recovered, immediately sealed in the original metal cans, and shipped on ice to EST. A trip blank accompanied the SPMD during shipment, deployment, and recovery. The blank was exposed to the atmosphere during deployment and recovery of the SPMD at each location and then resealed in the metal can and shipped for processing with the field samples.

During 1999, a SPMD time-course study was conducted in the H1 wetland over an eight-week period. Duplicate deployment structures, containing five SPMD each, were placed near the inlet and outlet structures in the wetland. A duplicate set of SPMD was retrieved from each inlet and outlet location after the first week and then approximately every two weeks throughout the field survey. Trip blank SPMD were exposed to the atmosphere during the deployment and retrieval of samplers at each site. The field and trip blank SPMD were sealed in metal cans, preserved in ice, and shipped to EST for processing.

## SEDIMENT

Composite (5 subsamples) sediment samples were collected along transects across the inlets and outlets of the H2 and C2 wetlands during 1998 and 1999 to examine HOC and trace elements associated with the wetland soils. Sediment samples from a depth of 5 to 10 centimeters (cm) were obtained using a polyvinyl chloride coring device, and placed in 500-mL, wide-mouthed amber glass jars. The samples were shipped on ice and frozen until analysis.

## VEGETATION

Composite vegetation samples were collected from near the inlets and outlets of the Hayfield 2 and Cobble 2 wetlands during 1999 for trace element analysis. *Schoenoplectus tabernaemontani* and *Schoenoplectus americanus* samples were collected by hand pulling the whole plants. Samples were placed in plastic bags, shipped on ice, and frozen for trace element analysis.

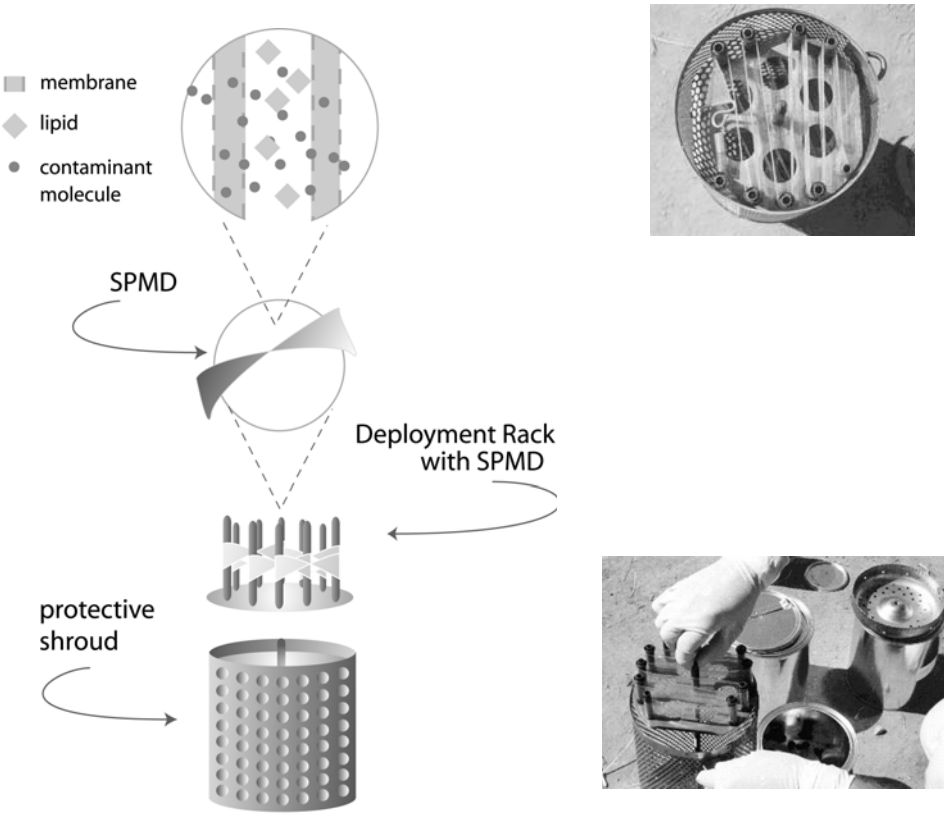

**Figure 2-1**. Semipermeable membrane device partitioning and containment structure (after Huckins and others, 1996).

# ANALYTICAL METHODS

## WATER

### Field Measurements

Temperature, specific conductance, pH, and dissolved oxygen measurements were made at the time of sample collection. Specific conductance was measured using a temperature compensated conductivity meter (Orion 124) calibrated daily against USGS standard reference solutions. Dissolved oxygen was measured using a temperature and pressure compensated DO meter (Orion 820) that was calibrated daily against air. Sample pH was measured using an Orion 250 Meter and 9107 Triode pH electrode. The electrode was calibrated daily using pH 4, 7, and 10 standards.

### Total and Dissolved Organic Carbon

Total and dissolved organic carbon analysis was performed using a Sievers Model 800 Total Organic Carbon Analyzer. The instrument measures total carbon (TC) and total inorganic carbon (TIC), determining TOC by difference. Ammonium persulfate and phosphoric acid are added to the sample. The low pH converts TIC to carbon dioxide ($CO_2$). The TC in the sample is subjected to ultraviolet (UV) radiation that in the presence of the persulfate oxidant breaks down organic carbon in the sample to form $CO_2$. The $CO_2$ partitions across a selectively permeable membrane into deionized water and is measured as bicarbonate ion by conductivity detector.

Ultraviolet light absorbance of the filtered water samples was measured at 254 nanometers (nm) to determine aromaticity, an indication of the humic and fulvic acid contribution to the total DOC (Thurman, 1985; Chin and others, 1994; Sartoris and others, 2000; Barber and others, 2001). Absorbance was measured in a 1-cm quartz cell using a Bausch and Lomb Spectronics Model 710 spectrophotometer. A 5 milligram (mg) carbon per liter Suwannee River Fulvic acid (Averett and others, 1989) solution was used as a reference standard.

### Pesticides

Water samples were analyzed by USGS National Water Quality Laboratory (NWQL) Schedule 2001 for a variety of pesticide compounds (table 2-4) as described by Zaugg and others (1995). Water samples were filtered through 0.7-µm glass-fiber filters, extracted using octadecyl-bonded porous silica ($C_{18}$) solid phase extraction (SPE) cartridges, and eluted with methylene chloride. The SPE extracts were analyzed by electron impact gas chromatography/mass spectrometry (GC/MS) in the selected ion monitoring (SIM) mode. The SPE extracts were analyzed by negative chemical ionization (NCI) GC/MS for organochlorine compounds.

### Herbicides

Water samples were analyzed for herbicides, insecticides, and associated metabolites (tables 2-5, 2-6, and 2-7) as described by Zimmerman and Thurman (1999). Compounds were extracted from filtered water samples by $C_{18}$ SPE followed by elution with ethyl acetate. Target compounds were identified and quantified by SIM-GC/MS. Surrogate and internal standards were used to determine the concentrations and evaluate method performance. The method detection limit was approximately 5 micrograms per liter (μg/L).

### Volatile Organic Compounds

Water samples were analyzed for VOC (table 2-8) by NWQL Schedule 2020 (86 compounds) and Schedule 2022 (35 compounds) as described in Connor and others (1998). Laboratory reporting limits are given for each compound and ranged from 0.03 to 7.1 μg/L. A Tekmar Model LSC 2000 concentrator with a Tekmar Aquatek autosampler purge and trap unit was used to sparge helium gas through a 25-mL aliquot of environmental sample. A VOCARB 3000 trap containing 10 cm of Carbopak B (60/80 mesh), 6 cm of Carboxen (60/80 mesh), and 1 cm of Carboxen 1001 (60/80 mesh) was used to trap the VOC. The compounds were thermally desorbed into a megabore capillary column interfaced with a GC/MS equipped with sub-ambient GC oven-cooling and a jet separator. The VOC concentrations were identified using standard reference materials and comparing retention times and ion ratios of the mass spectra.

### Wastewater-Derived Compounds

Alkylphenols and other wastewater-derived compounds (table 2-9) were determined as described in Barber and others (2000). This method uses continuous liquid-liquid extraction (CLLE) with methylene chloride at pH 2 to continually expose a sample to solvent for an extended period by refluxing the solvent. The solvent is dispersed through a coarse-glass frit resulting in formation of micro-droplets that travel through the sample matrix. After extraction, the solvent is passed through a sodium sulfate drying column and the volume reduced to 500 microliter (μL). The extracts were analyzed by GC/MS in both the full scan and SIM modes. Surrogate standards were added to the sample prior to extraction to evaluate method performance.

### Ethylenediaminetetraacetic, Nitrilotriacetic, and Nonylphenolethoxycarboxylic Acids

Ethylenediaminetetraacetic acid, NTA, and NPEC (table 2-10) were measured as the propyl esters (Barber and others, 2000) using a modification of the method of Schaffner and Giger (1984). Samples were spiked with $d_{12}$-EDTA, evaporated to dryness, acidified with formic acid:distilled water (1:1 v/v), and evaporated to dryness again. Acetyl chloride:propanol (1:10 v/v) was added, the sample heated to 85 $^{o}$C for 1 hour (hr), and the esters extracted into chloroform. The extracts were evaporated and redissolved in toluene. Analysis for the propyl ester derivatives was by GC/MS in the full scan and SIM modes.

**Table 2-4**. Forty-eight pesticide compounds determined by USGS NWQL Schedule 2001. [CAS Number, Chemical Abstract Services registry number; LRL, laboratory reporting level; µg/L, microgram per liter]

| Compound | CAS Number | LRL (µg/L) |
|---|---|---|
| Acetochlor | 34256-82-1 | 0.004 |
| Alachlor | 15972-60-8 | 0.002 |
| Atrazine | 1912-24-9 | 0.007 |
| Azinphos-methyl | 86-50-0 | 0.050 |
| Benfluralin | 1861-40-1 | 0.010 |
| Butylate | 2008-41-5 | 0.002 |
| Carbaryl | 63-25-2 | 0.040 |
| Carbofuran | 1563-66-2 | 0.020 |
| Chlorpyrifos | 2921-88-2 | 0.005 |
| Cyanazine | 21725-46-2 | 0.018 |
| 1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethylene (*p,p'*-DDE) | 72-55-9 | 0.003 |
| Dacthal | 1861-32-1 | 0.003 |
| Deethylatrazine | 6190-65-4 | 0.006 |
| Diazinon | 333-41-5 | 0.005 |
| Dieldrin | 60-57-1 | 0.005 |
| 2,6-Diethylaniline | 579-66-8 | 0.002 |
| Disulfoton | 298-04-4 | 0.020 |
| *S*-Ethyldipropylthiocarbamate | 759-94-4 | 0.002 |
| Ethalfluralin | 55283-68-6 | 0.009 |
| Ethoprophos | 13194-48-4 | 0.005 |
| Fonofos | 944-22-9 | 0.003 |
| *alpha*-Hexachlorohexane | 319-84-6 | 0.005 |
| *gamma*-Hexachlorohexane (lindane) | 58-89-9 | 0.004 |
| Linuron | 330-55-2 | 0.035 |
| Malathion | 121-75-5 | 0.027 |
| Metolachlor | 51218-45-2 | 0.013 |
| Metribuzin | 21087-64-9 | 0.006 |
| Molinate | 2212-67-1 | 0.002 |
| Napropamide | 15299-99-7 | 0.007 |
| Parathion | 56-38-2 | 0.007 |
| Parathion-methyl | 298-00-0 | 0.006 |
| Pebulate | 1114-71-2 | 0.002 |
| Pendimethalin | 40487-42-1 | 0.010 |
| *cis*-Permethrin | 54774-45-7 | 0.006 |
| Phorate | 298-02-2 | 0.011 |
| Prometon | 1610-18-0 | 0.015 |
| Propachlor | 1918-16-7 | 0.010 |
| Propanil | 709-98-8 | 0.011 |
| Propargite | 2312-35-8 | 0.023 |
| Propyzamide | 23950-58-5 | 0.004 |
| Simazine | 122-34-9 | 0.011 |
| Tebuthiuron | 34014-18-1 | 0.016 |
| Terbacil | 5902-51-2 | 0.034 |
| Terbufos | 13071-79-9 | 0.017 |
| Terbuthylazine | 5915-41-3 | 0.100 |
| Thiobencarb | 28249-77-6 | 0.005 |
| Tri-allate | 2303-17-5 | 0.002 |
| Trifluralin | 1582-09-8 | 0.009 |
| **Surrogate Standards** | | |
| Diazinon-$d_{10}$ | 100155-47-3 | 0.100 |
| *alpha*-Hexachlorohexane-$d_6$ | 86194-41-4 | 0.100 |

**Table 2-5**. Twenty-six herbicide compounds measured in water by the USGS Lawrence, Kansas laboratory. [CAS Number, Chemical Abstract Services registry number; MDL, method detection limit; µg/L, microgram per liter; NA, not available]

| Compound | CAS Number | MDL (µg/L) |
|---|---|---|
| Acetochlor | 34256-82-1 | 0.05 |
| Alachor | 15972-60-8 | 0.05 |
| Atrazine | 1912-24-9 | 0.05 |
| Cyanazine | 21725-46-2 | 0.05 |
| Cyanazine-amide | 36576-42-8 | 0.05 |
| Deethylatrazine | 6190-65-4 | 0.05 |
| Deisopropylatrazine | 1007-28-9 | 0.05 |
| Deisopropylprometryn | NA | 0.05 |
| Demethylfluometurn | NA | 0.20 |
| Demethylnorfluorazon | NA | 5 |
| 3,4-Dichloroaniline | 95-76-1 | 5 |
| Diuron | 330-54-1 | 0.20 |
| Fluometuron | 2164-17-2 | 0.20 |
| Linuron | 330-55-2 | 0.20 |
| Metolachlor | 51218-45-2 | 0.05 |
| Metribuzin | 21087-64-9 | 5 |
| Molinate | 2212-67-1 | 5 |
| Norfluorazon | 27314-13-2 | 5 |
| Pendimethalin | 40487-42-1 | 5 |
| Prometryn | 7287-19-6 | 5 |
| Propanil | 709-98-8 | 5 |
| Propazine | 139-40-2 | 0.05 |
| Simazine | 122-34-9 | 0.05 |
| Trifluralin | 1582-09-8 | 5 |
| Trifluromethyl-aniline | 9898-16-8 | 5 |
| Trifluromethyl phenyl urea | 13114-87-9 | 5 |

## Major Cations and Trace Elements

Major ions present at relatively high (milligram per liter, mg/L) concentration levels (including calcium, Ca, magnesium, Mg, sodium, Na, and iron, Fe) were determined by inductively coupled plasma/atomic emission spectrometry (ICP/AES) techniques using a Perkin Elmer Optima 3300, dual view emission spectrometer operating in the radial view mode. A description of the analysis conditions and general procedures for this methodology are reported by Garbarino and Taylor (1979). Potassium was also determined by ICP/AES using the same instrument operating in the axial-view mode. Samples were analyzed in triplicate to provide a measure of the variability of the analysis.

Trace-element determinations (excluding Hg) were performed with a Perkin Elmer Elan Model 6000, inductively coupled plasma/mass spectrometer (ICP/MS). Aerosols of nitric acid acidified aqueous samples were introduced into the spectrometer with a cone-spray pneumatic nebulizer. Multiple internal standards (indium, iridium, and rhodium), covering the entire mass range were used to normalize the system for drift. Details of the analysis are described elsewhere (Garbarino and Taylor, 1995; Taylor, 2001). Samples were analyzed in triplicate to provide a measure of the variability of the analysis. Specific trace elements measured for the individual sample matrices (water, sediment, biota) and their average detection limits are shown in tables 2-11 to 2-14.

**Table 2-6**. Twenty-three insecticide compounds measured in water by the USGS Lawrence, Kansas laboratory. [CAS Number, Chemical Abstract Services registry number; MDL, method detection limit; µg/L, microgram per liter]

| Compound | CAS Number | MDL (µg/L) |
|---|---|---|
| Aldrin | 309-00-2 | 0.05 |
| Azinphos-methyl | 85-50-0 | 0.05 |
| Bifinthrin | 82657-04-03 | 0.05 |
| Chlordane | 57-74-9 | 0.05 |
| Chlorpyriphos | 2921-88-2 | 0.05 |
| Cyfluthrin | 68359-37-5 | 0.05 |
| L-Cyhalothrin | 68085-85-8 | 0.05 |
| Cypermethrin | 52315-07-8 | 0.05 |
| 1,1-Dichloro-2,2-bis(*p*-chlorophenyl)ethane (*p,p'*-DDD) | 72-54-8 | 0.05 |
| *p,p'*-DDE | 72-55-9 | 0.05 |
| 1,1,1-Trichloro-2,2-bis(*p*-chlorophenyl)ethane (*p,p'*-DDT) | 50-29-3 | 0.05 |
| Dicrotophos | 141-66-2 | 0.05 |
| Dieldrin | 60-57-1 | 0.05 |
| Endosulfan | 115-29-7 | 0.05 |
| Endrin | 72-20-8 | 0.05 |
| Fonofos | 944-22-9 | 0.05 |
| Heptachlor | 76-44-8 | 0.05 |
| Malathion | 121-75-5 | 0.05 |
| Methyl parathion | 298-00-0 | 0.05 |
| Permethrin | 52645-53-1 | 0.05 |
| Profenos (Profenofos) | 41198-08-7 | 0.05 |
| Sulprofos | 35400-43-2 | 0.05 |
| Terbufos | 13071-79-9 | 0.05 |

**Table 2-7**. Seven herbicide metabolites measured in water by the USGS Lawrence, Kansas laboratory. [CAS Number, Chemical Abstract Services registry number; MDL, method detection limit; µg/L, microgram per liter; ESA, ethane sulfonic acid; NA, not available]

| Compound | CAS Number | MDL (µg/L) |
|---|---|---|
| Acetochlor ESA | NA | 0.05 |
| Acetochlor oxanilic acid | NA | 0.05 |
| Alachlor ESA | NA | 0.05 |
| Alachlor oxanilic acid | NA | 0.05 |
| Hydroxyatrazine | 2163-68-0 | 0.05 |
| Metolachlor ESA | NA | 0.05 |
| Metolachlor oxanilic acid | NA | 0.05 |

**Table 2-8**. Eighty-six volatile organic compounds measured in water by USGS NWQL Schedule 2020 and 35 compounds measured by Schedule 2022. [CAS Number, Chemical Abstract Services registry number; LRL, laboratory reporting level; µg/L, microgram per liter; NA, not available]

| Compound | CAS Number | LRL (µg/L) |
|---|---|---|
| Acetone | 67-64-1 | 7.10 |
| Acrylonitrile | 107-13-1 | 1.20 |
| Benzene[a] | 71-43-2 | 0.04 |
| Bromobenzene | 108-86-1 | 0.04 |
| Bromochloromethane | 74-97-5 | 0.04 |
| Bromodichloromethane[a] | 75-27-4 | 0.05 |
| Bromoform[a] | 75-25-2 | 0.06 |
| Bromomethane | 74-83-9 | 0.26 |
| 2-Butanone | 78-93-3 | 1.60 |
| *normal*-Butylbenzene | 104-51-8 | 0.19 |
| *sec*-Butylbenzene | 135-98-8 | 0.03 |
| *tert*-Butylbenzene | 98-06-6 | 0.06 |
| *tert*-Butyl ethyl ether[a] | 637-92-3 | 0.05 |
| *tert*-Butyl methyl ether (MTBE) [a] | 1634-04-4 | 0.17 |
| Carbon disulfide | 75-15-0 | 0.07 |
| Chlorobenzene[a] | 108-90-7 | 0.03 |
| Chloroethane | 75-00-3 | 0.12 |
| Chloroform[a] | 67-66-3 | 0.05 |
| Chloromethane | 74-87-3 | 0.50 |
| 3-Chloropropene | 107-05-1 | 0.20 |
| 2-Chlorotoluene | 95-49-8 | 0.04 |
| 4-Chlorotoluene | 106-43-4 | 0.06 |
| Dibromochloromethane[a] | 124-48-1 | 0.18 |
| 1,2-Dibromo-3-chloropropane | 96-12-8 | 0.21 |
| 1,2-Dibromoethane | 106-93-4 | 0.04 |
| Dibromomethane | 74-95-3 | 0.05 |
| 1,2-Dichlorobenzene[a] | 95-50-1 | 0.05 |
| 1,3-Dichlorobenzene[a] | 541-73-1 | 0.05 |
| 1,4-Dichlorobenzene[a] | 106-46-7 | 0.05 |
| *trans*-1,4-Dichloro-2-butene | 110-57-6 | 0.70 |
| Dichlorodifluoromethane[a] | 75-71-8 | 0.27 |
| 1,1-Dichloroethane[a] | 75-34-3 | 0.07 |
| 1,2-Dichloroethane[a] | 107-06-2 | 0.13 |
| 1,1-Dichloroethene[a] | 75-35-4 | 0.04 |
| *cis*-1,2-Dichloroethene[a] | 156-59-2 | 0.04 |
| *trans*-1,2-Dichloroethene[a] | 156-60-5 | 0.03 |
| 1,2-Dichloropropane[a] | 78-87-5 | 0.07 |
| 1,3-Dichloropropane | 142-28-9 | 0.12 |
| 2,2-Dichloropropane | 594-20-7 | 0.05 |
| 1,1-Dichloropropene | 563-58-6 | 0.03 |
| *cis*-1,3-Dichloropropene | 10061-01-5 | 0.09 |
| *trans*-1,3-Dichloropropene | 10061-02-6 | 0.09 |
| Diethyl ether[a] | 60-29-7 | 0.17 |
| Diisopropyl ether[a] | 108-20-3 | 0.10 |
| Ethylbenzene[a] | 100-41-4 | 0.03 |
| Ethyl methacrylate | 97-63-2 | 0.18 |
| 1,2-Ethyltoluene | 611-14-3 | 0.06 |
| Hexachlorobutadiene | 87-68-3 | 0.14 |
| Hexachloroethane | 67-72-1 | 0.19 |
| 2-Hexanone | 591-78-6 | 0.70 |

**Table 2-8**. Continued.

| Compound | CAS Number | LRL (µg/L) |
|---|---|---|
| Isopropylbenzene | 98-82-8 | 0.03 |
| 1,4-Isopropyltoluene | 99-87-6 | 0.07 |
| Methyl acrylate | 96-33-3 | 1.40 |
| Methyl acrylonitrile | 126-98-7 | 0.60 |
| Methylene chloride[a] | 75-09-2 | 0.38 |
| Methyl iodide | 74-88-4 | 0.12 |
| Methyl methacrylate | 80-62-6 | 0.35 |
| 4-Methyl-2-pentanone | 108-10-1 | 0.37 |
| Naphthalene | 91-20-3 | 0.25 |
| *tert*-Pentylmethyl ether | 994-05-8 | 0.11 |
| *normal*-Propylbenzene | 103-65-1 | 0.04 |
| Styrene[a] | 100-42-5 | 0.04 |
| 1,1,1,2-Tetrachloroethane | 630-20-6 | 0.03 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 0.09 |
| Tetrachloroethene[a] | 127-18-4 | 0.10 |
| Tetrachloromethane[a] | 56-23-5 | 0.06 |
| Tetrahydrofuran | 109-99-9 | 2.20 |
| 1,2,3,4-Tetramethylbenzene | 488-23-3 | 0.23 |
| 1,2,3,5-Tetramethylbenzene | 527-53-7 | 0.20 |
| Toluene[a] | 108-88-3 | 0.05 |
| 1,2,3-Trichlorobenzene | 87-61-6 | 0.27 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 0.19 |
| 1,1,1-Trichloroethane[a] | 71-55-6 | 0.03 |
| 1,1,2-Trichloroethane | 79-00-5 | 0.06 |
| Trichloroethene[a] | 79-01-6 | 0.04 |
| Trichlorofluoromethane[a] | 75-69-4 | 0.09 |
| 1,2,3-Trichloropropane | 96-18-4 | 0.16 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane[a] | 76-13-1 | 0.06 |
| 1,2,3-Trimethylbenzene | 526-73-8 | 0.12 |
| 1,2,4-Trimethylbenzene | 95-63-6 | 0.06 |
| 1,3,5-Trimethylbenzene | 108-67-8 | 0.04 |
| Vinyl bromide | 593-60-2 | 0.10 |
| Vinyl chloride[a] | 75-01-4 | 0.11 |
| 1,3- and 1,4-Xylene[a] | 108-38-3 and 106-42-3 | 0.06 |
| 1,2-Xylene[a] | 95-47-6 | 0.04 |
| **Surrogate Standards** | | |
| 1,4-Bromofluorobenzene[a] | 460-00-4 | NA |
| 1,2-Dichloroethane $d_4$[a] | 17060-07-0 | NA |
| Toluene $d_8$[a] | 2037-26-5 | NA |

[a]. VOC measured in both USGS NWQL Schedule 2020 and 2022.

**Table 2-9**. Forty wastewater-derived compounds measured in water by USGS Boulder, Colorado Laboratory. [CAS Number, Chemical Abstract Services registry number; MDL, method detection limit; µg/L, microgram per liter; NA, not available]

| Compound | CAS Number | MDL (µg/L) |
|---|---|---|
| *cis*-Androsterone | 53-41-8 | 0.01 |
| Bisphenol A | 80-05-7 | 0.01 |
| 2[3]-*tert*-Butyl-4-methoxyphenol | 25013-16-5 | 0.01 |
| 4-*tert*-Butylphenol | 98-54-4 | 0.01 |
| Caffeine | 58-08-2 | 0.01 |
| Cholesterol | 57-88-5 | 0.01 |
| 3-*beta*-Coprostanol | 360-68-9 | 0.01 |
| 2,6-Di-*tert*-butyl-1,4-benzoquinone | 719-22-2 | 0.01 |
| 2,6-Di-*tert*-butyl-4-methylphenol | 128-37-0 | 0.01 |
| 2,6-Di-*tert*-butylphenol | 128-39-2 | 0.01 |
| 1,2-Dichlorobenzene | 95-50-1 | 0.01 |
| 1,3-Dichlorobenzene | 541-73-1 | 0.01 |
| 1,4-Dichlorobenzene | 106-46-7 | 0.01 |
| Equilenin | 517-09-9 | 0.01 |
| Equilin | 474-86-2 | 0.01 |
| 17-*alpha*-Estradiol | 57-91-0 | 0.01 |
| 17-*beta*-Estradiol | 50-28-2 | 0.01 |
| Estriol | 50-27-1 | 0.01 |
| Estrone | 53-16-7 | 0.01 |
| 4-Ethylphenol | 123-07-9 | 0.01 |
| 17-*alpha*-Ethynylestradiol | 57-63-6 | 0.01 |
| Mestranol | 72-33-3 | 0.01 |
| 4-Methylphenol | 106-44-5 | 0.01 |
| 4-Nonylphenol | 25154-52-3 | 0.01 |
| 4-Nonylphenolmonoethoxylate | 9016-45-9 | 0.01 |
| 4-Nonylphenoldiethoxylate | NA | 0.01 |
| 4-Nonylphenoltriethoxylate | NA | 0.01 |
| 4-Nonylphenoltetraethoxylate | NA | 0.01 |
| 19-Norethisterone | 68-22-4 | 0.01 |
| 4-*normal*-Octylphenol | 1806-26-4 | 0.01 |
| 4-*tert*-Octylphenol | 140-66-9 | 0.01 |
| 4-*tert*-Octylphenolmonoethoxylate | 9036-19-5 | 0.01 |
| 4-*tert*-Octylphenoldiethoxylate | NA | 0.01 |
| 4-*tert*-Octylphenoltriethoxylate | NA | 0.01 |
| 4-*tert*-Octylphenoltetraethoxylate | NA | 0.01 |
| 4-*tert*-Pentylphenol | 80-46-6 | 0.01 |
| Progesterone | 57-83-0 | 0.01 |
| 4-Propylphenol | 645-56-7 | 0.01 |
| Testosterone | 58-22-0 | 0.01 |
| Triclosan | 3380-34-5 | 0.01 |
| **Surrogate Standards** | | |
| Bisphenol A $d_6$ | 86588-58-1 | 0.01 |
| Cholesterol $d_7$ | NA | 0.01 |
| 2,6-Di-*tert*-butyl-4-methylphenol $d_{21}$ | 64502-99-4 | 0.01 |
| 17-*beta*-Estradiol $d_4$ | 66789-03-5 | 0.01 |
| 4-*normal*-Nonylphenol | 104-40-5 | 0.01 |
| 4-*normal*-Nonylphenolmonoethoxylate | NA | 0.01 |
| 4-*normal*-Nonylphenoldiethoxylate | NA | 0.01 |

**Table 2-10**. Ethylenediaminetetraacetic acid, nitrilotriacetic acid, and nonylphenolethoxycarboxylic acid measured in water by USGS Boulder, Colorado Laboratory. [CAS Number, Chemical Abstract Services registry number; MDL, method detection limit; µg/L, microgram per liter; NA, not available]

| Compound | CAS Number | MDL (µg/L) |
|---|---|---|
| Ethylenediaminetetraacetic acid | 60-00-4 | 0.5 |
| Nitrilotriacetic acid | 139-13-9 | 0.5 |
| 4-Nonylphenolmonoethoxycarboxylate | NA | 0.5 |
| 4-Nonylphenoldiethoxycarboxylate | 106807-78-7 | 0.5 |
| 4-Nonylphenoltriethoxycarboxylate | NA | 0.5 |
| 4-Nonylphenoltetraethoxycarboxylate | NA | 0.5 |
| 4-Nonylphenolpentaethoxycarboxylate | NA | 0.5 |
| **Surrogate Standards** | | |
| Ethylenediaminetetraacetic acid $d_{12}$ | 203806-08-0 | 0.5 |
| 4-*normal*-Nonylphenoldiethoxycarboxylate | NA | 0.5 |

**Table 2-11**. Major ions and trace elements measured in water, their atomic symbols, and method detection limits (MDL). [µg/L, microgram per liter]

| Element | MDL (µg/L) | Element | MDL (µg/L) |
|---|---|---|---|
| Aluminum (Al) | 0.05 | Magnesium (Mg) | 15 |
| Arsenic (As) | 0.04 | Manganese (Mn) | 0.02 |
| Boron (B) | 4 | Molybdenum (Mo) | 0.03 |
| Barium (Ba) | 0.01 | Sodium (Na) | 70 |
| Beryllium (Be) | 0.02 | Neodymium (Nd) | 0.003 |
| Bismuth (Bi) | 0.01 | Nickel (Ni) | 0.02 |
| Calcium (Ca) | 20 | Lead (Pb) | 0.006 |
| Cadmium (Cd) | 0.006 | Praseodymium (Pr) | 0.0005 |
| Cerium (Ce) | 0.001 | Rubidium (Rb) | 0.002 |
| Cobalt (Co) | 0.01 | Rhenium (Re) | 0.0013 |
| Chromium (Cr) | 0.2 | Antimony (Sb) | 0.02 |
| Cesium (Cs) | 0.06 | Selenium (Se) | 0.2 |
| Copper (Cu) | 0.02 | Silica ($SiO_2$) | 50 |
| Dysprosium (Dy) | 0.002 | Samarium (Sm) | 0.003 |
| Erbium (Er) | 0.002 | Strontium (Sr) | 0.02 |
| Europium (Eu) | 0.001 | Terbium (Tb) | 0.0007 |
| Iron (Fe) | 0.7 | Thallium (Tl) | 0.005 |
| Gadolinium (Gd) | 0.003 | Thulium (Tm) | 0.0005 |
| Mercury (Hg) | 0.0004 | Uranium (U) | 0.002 |
| Holmium (Ho) | 0.0005 | Vanadium (V) | 0.05 |
| Potassium (K) | 10 | Yttrium (Y) | 0.0004 |
| Lanthanum (La) | 0.0005 | Ytterbium (Yb) | 0.0014 |
| Lithium (Li) | 0.1 | Zinc (Zn) | 0.08 |
| Lutetium (Lu) | 0.0005 | Zirconium (Zr) | 0.01 |

**Table 2-12**. Major ions and trace elements measured in fish tissue (dry weight basis) and method detection limits (MDL). [µg/g, microgram per gram]

| Element | MDL (µg/g) | Element | MDL (µg/g) |
|---|---|---|---|
| Al | 0.5 | Mg | 20 |
| As | 0.05 | Mn | 0.2 |
| B | 9 | Mo | 0.1 |
| Ba | 0.07 | Na | 70 |
| Be | 0.2 | Nd | 0.008 |
| Bi | 0.005 | Ni | 0.2 |
| Ca | 10 | Pb | 0.04 |
| Cd | 0.07 | Pr | 0.003 |
| Ce | 0.003 | Rb | 0.1 |
| Co | 0.02 | Re | 0.004 |
| Cr | 1 | Sb | 0.03 |
| Cs | 1 | Se | 0.2 |
| Cu | 0.01 | $SiO_2$ | 100 |
| Dy | 0.002 | Sm | 0.005 |
| Er | 0.008 | Sr | 0.1 |
| Eu | 0.001 | Tb | 0.002 |
| Fe | 5 | Tl | 0.05 |
| Gd | 0.003 | Tm | 0.002 |
| Hg | 0.006 | U | 0.006 |
| Ho | 0.0005 | V | 0.5 |
| K | 50 | Y | 0.003 |
| La | 0.003 | Yb | 0.006 |
| Li | 0.1 | Zn | 0.8 |
| Lu | 0.001 | Zr | 0.01 |

Mercury stock and standard solutions were made from Puratronic grade (99.9995%) mercuric chloride (Johnson Mathey), and preserved in a solution of high-purity nitric acid and primary-standard grade potassium dichromate (4% v/v and 0.04% weight/volume, w/v, respectively). Deionized water (18 megaohm/cm) was used for preparing all standards and reagent solutions. A 2% w/v stannous chloride solution in 3% v/v trace-metal grade hydrochloric acid purged for 15 minutes with argon was used for the reduction of Hg to its elemental form in the cold-vapor reactor. Concentrations of Hg were measured using an automated, cold-vapor atomic fluorescence spectrometer (PS Analytical). Details of the method are described in Roth (1994) and Roth and others (2001). Elemental Hg vapor from the sample produced by chemically reducing Hg with excess stannous chloride was transported to the atomic-fluorescence detector with a stream of argon gas. Peak height intensities of unknown samples were compared to a six-point calibration curve prepared from aqueous standards ranging in concentration from 0 to 50 nanograms per liter (ng/L).

## Anions

The determination of major anions including chloride and sulfate was completed on filtered samples by ion-exchange chromatography utilizing a Dionex model 2002i ion chromatograph. Detailed procedures are described in Brinton and others (1996).

**Table 2-13.** Major ions and trace elements measured in vegetation tissue (dry weight basis) and method detection limits (MDL). [µg/g, microgram per gram; --, major constituent and therefore MDL not determined]

| Element | MDL (µg/g) | Element | MDL (µg/g) |
|---|---|---|---|
| Al | 0.5 | Mg | -- |
| As | 0.05 | Mn | 0.1 |
| B | 5 | Mo | 0.2 |
| Ba | 0.1 | Na | -- |
| Be | 0.08 | Nd | 0.003 |
| Bi | 0.01 | Ni | 0.03 |
| Ca | -- | Pb | 0.02 |
| Cd | 0.009 | Pr | 0.0004 |
| Ce | 0.001 | Rb | 0.1 |
| Co | 0.01 | Re | 0.001 |
| Cr | 2 | Sb | 0.008 |
| Cs | 0.3 | Se | 0.3 |
| Cu | 0.01 | $SiO_2$ | -- |
| Dy | 0.003 | Sm | 0.003 |
| Er | 0.003 | Sr | 0.1 |
| Eu | 0.001 | Tb | 0.0006 |
| Fe | -- | Tl | 0.01 |
| Gd | 0.002 | Tm | 0.0004 |
| Hg | 0.005 | U | 0.003 |
| Ho | 0.0004 | V | 0.3 |
| K | -- | Y | 0.001 |
| La | 0.0005 | Yb | 0.002 |
| Li | 0.1 | Zn | 0.5 |
| Lu | 0.0007 | Zr | 0.03 |

## Nutrients

Filtered water samples were analyzed for nitrite, nitrate plus nitrite, ammonium, and orthophosphate using an air-segmented continuous flow analyzer (Alpkem RFA 300). Nitrate plus nitrite was determined colorimetrically at 543 nm by diazotization with sulfanilamide and reaction with N-(1-naphthyl)-ethylenediamine (Greiss reaction) after reduction of nitrate to nitrite with cadmium metal. Nitrite was determined by the same technique without cadmium reduction. Ammonium was determined colorimetrically at 660 nm by the salicylic acid analog of the indophenol blue method. Orthophosphate was determined colorimetrically at 880 nm by the phosphoantomonyl molybdenum blue method. Further details are available in Antweiler and others (1996).

**Table 2-14.** Major ions and trace elements measured in sediment samples (dry weight basis) and method detection limits (MDL). [µg/g, microgram per gram; --, major constituent and therefore MDL not determined]

| Element | MDL (µg/g) | Element | MDL (µg/g) |
|---|---|---|---|
| | | Mg | -- |
| As | 20 | Mn | 0.1 |
| Ba | 1 | Mo | 0.1 |
| Be | 0.09 | Na | -- |
| Bi | 0.01 | Nd | 0.1 |
| Ca | -- | Ni | 0.1 |
| Cd | 0.01 | Pb | 0.1 |
| Ce | 0.1 | Pr | 0.1 |
| Co | 0.11 | Rb | 0.1 |
| Cr | 1 | Re | 0.002 |
| Cs | 1 | Sb | 0.1 |
| Cu | 0.1 | Se | 0.1 |
| Dy | 0.1 | Sm | 0.1 |
| Er | 0.1 | Sr | 0.1 |
| Eu | 0.1 | Tb | 0.01 |
| Fe | -- | Tl | 0.1 |
| Gd | 0.1 | Tm | 0.01 |
| Hg | 0.003 | U | 0.01 |
| Ho | 0.01 | V | 0.1 |
| K | -- | Y | 0.1 |
| La | 0.1 | Yb | 0.01 |
| Li | 0.1 | Zn | 0.5 |
| Lu | 0.01 | Zr | 0.1 |

## FISH TISSUE AND SEMIPERMEABLE MEMBRANE DEVICES

### Tissue Processing

Fish specimens were collected in 1998 (table 2-15) for whole-body, filet, liver, and other (bones, skin, organs other than liver) tissue analysis to obtain preliminary data on HOC and trace element concentrations. Individual *Tilapia* whole-body fish were dissected using stainless steel tools in a clean room environment to obtain the various fractions. Composite *Gambusia* whole-body and *Tilapia* whole-body, filet, and other tissue were homogenized for approximately three minutes using a stainless-steel blade in a tissue blender. *Tilapia* livers were homogenized by stirring with a Teflon probe for three minutes. The homogenized fish tissue samples were dried at 65 °C until a constant weight was achieved.

Additional *Gambusia* and *Tilapia* specimens were collected in 2000 for more detailed analysis of HOC and trace elements. Figure 2-2 shows a typical *Tilapia* specimen. Individual *Tilapia* were dissected in a laminar-flow hood using PTFE coated labware and ceramic knives and scissors (fig. 2-3). The filet tissue was separated from the skin and the bones were removed. The filet tissue was minced with the ceramic knife and homogenized. Livers from each specimen were removed using ceramic scissors. A portion of both the homogenized filet and liver tissue was oven-dried to determine percent moisture. After analysis, the percent moisture was used to compute trace-element concentrations on a dry-weight basis. Because of their small size *Gambusia* were treated as whole organisms (fig. 2-4).

**Figure 2-2**. Typical *Tilapia* specimen.

**Figure 2-3**. *Tilapia* dissected with a ceramic knife.

**Table 2-15.** Data on fish tissue samples collected in 1998 and 2000 and analyzed for organochlorine compounds and trace elements. [--, not determined; ++, tissue sample collected but mass not determined]

| Sample Type | Collection Date | Length (mm) | Height (mm) | Whole Body (g) | Filet (g) | Liver (g) | Other (g) |
|---|---|---|---|---|---|---|---|
| **Organic Analysis** | | | | | | | |
| *Tilapia* Whole-Body1[a] | 1998 | 162 | -- | 77.5 | -- | -- | -- |
| “ | 1998 | 176 | -- | 96.5 | -- | -- | -- |
| “ | 1998 | 148 | -- | 60.0 | -- | -- | -- |
| “ | 1998 | 166 | -- | 80.0 | -- | -- | -- |
| “ | 1998 | 147 | -- | 61.0 | -- | -- | -- |
| *Tilapia* Dissection[a] | 1998 | 145 | -- | 56.0 | ++ | ++ | ++ |
| “ | 1998 | 137 | -- | 44.5 | ++ | ++ | ++ |
| “ | 1998 | 165 | -- | 80.0 | ++ | ++ | ++ |
| “ | 1998 | 148 | -- | 57.0 | ++ | ++ | ++ |
| “ | 1998 | 162 | -- | 75.5 | ++ | ++ | ++ |
| *Gambusia* Whole-Body[a] | 1998 | -- | -- | 118.5 | -- | -- | -- |
| **Trace Element Analysis** | | | | | | | |
| *Tilapia* Whole-Body #1[a] | 1998 | 285 | -- | 410.0 | -- | -- | -- |
| “ | 1998 | 274 | -- | 356.0 | -- | -- | -- |
| “ | 1998 | 177 | -- | 104.0 | -- | -- | -- |
| *Tilapia* Dissection #1[a] | 1998 | 175 | -- | 89.0 | ++ | ++ | ++ |
| “ | 1998 | 151 | -- | 66.0 | ++ | ++ | ++ |
| *Tilapia* Whole-Body #2[a] | 1998 | 138 | -- | 52.0 | -- | -- | -- |
| “ | 1998 | 141 | -- | 53.5 | -- | -- | -- |
| “ | 1998 | 138 | -- | 49.0 | -- | -- | -- |
| *Tilapia* Dissection #2[a] | 1998 | 160 | -- | 75.5 | ++ | ++ | ++ |
| “ | 1998 | 139 | -- | 47.5 | ++ | ++ | ++ |
| *Gambusia* Whole-Body[a] | 1998 | -- | -- | 44.5 | -- | -- | -- |
| | | | | | | | |
| **Organic Analysis** | | | | | | | |
| *Tilapia* Whole-Body[a] | 2000 | 210 | 73 | 150.8 | -- | -- | -- |
| “ | 2000 | 180 | 57 | 96.7 | -- | -- | -- |
| “ | 2000 | 209 | 68 | 140.7 | -- | -- | -- |
| “ | 2000 | 205 | 68 | 148.1 | -- | -- | -- |
| “ | 2000 | 210 | 67 | 102.6 | -- | -- | -- |
| *Tilapia* Dissection[a] | 2000 | 201 | 72 | 169.1 | 25.0 | 1.6 | 129.5 |
| “ | 2000 | 220 | 73 | 167.7 | 32.7 | 4.8 | 117.2 |
| “ | 2000 | 210 | 69 | 115.5 | 12.5 | 1.4 | 93.7 |
| “ | 2000 | 165 | 50 | 59.8 | 9.7 | 0.4 | 47.2 |
| “ | 2000 | 230 | 79 | 180.5 | 36.7 | 3.0 | 132.3 |
| *Gambusia* Whole-Body[a] | 2000 | -- | -- | 59.2 | -- | -- | -- |
| **Trace Element Analysis** | | | | | | | |
| *Tilapia* Dissection[a] | 2000 | 183 | 57 | 97.9 | 20.1 | 1.2 | 76.6[b] |
| “ | 2000 | 171 | 54 | 88.0 | 20.2 | 1.4 | 66.4[b] |
| “ | 2000 | 174 | 61 | 100.9 | 15.6 | 0.4 | 84.9[b] |
| “ | 2000 | 197 | 64 | 119.1 | 21.2 | 1.6 | 96.3[b] |
| “ | 2000 | 220 | 74 | 164.2 | 30.3 | 1.8 | 132.1[b] |
| “ | 2000 | 156 | 54 | 59.2 | 6.5 | 0.6 | 52.1[b] |
| “ | 2000 | 177 | 58 | 90.1 | 15.4 | 0.4 | 74.3[b] |
| “ | 2000 | 172 | 58 | 82.9 | 12.8 | 0.7 | 69.4[b] |
| *Gambusia* Whole-Body[a] | 2000 | -- | -- | 97.0 | -- | -- | -- |

[a]. Composite sample.

[b]. Value calculated by difference.

**Figure 2-4**. Numerous *Gambusia* specimens in holding jar.

## Organic Contaminants

### *Fish Tissue*

Whole-body and filet tissue samples collected in 1998 (table 2-15) were prepared for HOC analysis by USGS NWQL Schedule 2101 (table 2-16) as described in Leiker and others (1995). A subset of five *Tilapia* collected in 2000 were dissected into filet, liver, and other parts, weighed, and frozen in amber glass jars. Well-mixed composite samples of homogenized whole body, filet, liver, and other fish tissues were mixed with granular anhydrous sodium sulfate. Aliquots of the homogenized tissue were Soxhlet extracted overnight with methylene chloride. The extract volume was reduced and a subsample removed to determine percent lipid concentration. The remaining extract was injected into a Waters Envirogel gel permeation chromatography (GPC) column to isolate target compounds from lipid material. The GPC extracts were fractionated into polar and nonpolar portions using alumina/silica adsorption chromatography. Each fraction was concentrated and analyzed by dual capillary-column gas chromatography with electron-capture detection. The method detection limits were approximately 5 micrograms per kilogram (μg/kg).

### *Semipermeable Membrane Devices*

The SPMD were stored in sealed metal cans in a freezer until processed by EST in a clean room where the exterior periphyton and algal biomass was removed by scrubbing with a nylon brush followed by an acid rinse. HOC residues were recovered by dialysis in hexane and further enriched by GPC. The GPC fractionated hexane extracts were reduced in volume to approximately 4 mL and ampulated. The SPMD extracts were further concentrated and analyzed for the same compounds as the fish tissue (table 2-16) by dual capillary-column gas chromatography with electron capture detection (Leiker and others, 1995), with additional analysis by NCI GC/MS for confirmation of compound identities.

## Trace Elements

### *Fish Tissue*

Fish specimens were collected in 1998 (table 2-15) for trace element analysis (Hoffman, 1996). Tissue samples were digested using concentrated nitric acid and 30% hydrogen peroxide. The digested samples were evaporated to near dryness and reconstituted with nitric acid, and insoluble material removed by filtration. Duplicate blank samples, each consisting of three Whatman filters wetted with 30 mL of deionized water, were homogenized and digested similarly to the fish samples to determine contaminants introduced by the homogenization process. Two additional blank filter samples were digested but not homogenized to identify contaminants in the filters. Two reagent blanks were taken through the digestion process for use as reference standards.

Additional fish specimens were collected in 2000 for trace-element analysis. Samples were digested in closed PTFE vessels in a laboratory microwave oven using high purity nitric acid (Milestone, 1994). After digestion, samples were diluted to volume with 1% high-purity nitric acid. Blanks were processed using the same procedure. Samples were analyzed by the appropriate instrumental method (as described above) in triplicate and reported with an error term representing the standard deviation of replicate measurements. Accuracy was established using certified standard reference materials (SRM) from the National Research Council of Canada (NRC), and included SRM DORM-1 (Dogfish Muscle) and SRM DOLT-1 (Dogfish Liver). Detection limits for fish tissue determinations are reported in table 2-12.

### *Vegetation Tissue*

Two species of rooted emergent plants were sampled; (1) softstem bulrush (*Schoenoplectus tabernaemontani*), and (2) Olney's (three-square) bulrush (*Schoenoplectus americanus*). Whole plants were sampled in the field and transported to the laboratory. In the laboratory, culms from the bulrush specimens were dissected using a ceramic knife into subsamples along the entire length of the culm. The subsamples were composited and freeze-dried to remove moisture, followed by grinding with acrylic balls to insure homogeneity.

Portions of the freeze-dried sample were digested as described above with high purity nitric acid using a closed-vessel microwave oven procedure. Samples were analyzed by the appropriate instrumental method (described above) in triplicate and reported with an error term representing the standard deviation of replicate measurements. Accuracy of these analyses was established using National Institute of Standards and Technology (NIST) SRM Apple Leaves (SRM 1515). Digestion blanks also were analyzed. Analyses are reported on a dry-weight basis. Detection limits for the plant tissue determinations are reported in table 2-13.

## SEDIMENT

### Organic Contaminants

Hydrophobic organic compounds in bottom sediment were determined by NWQL Schedule 2501 (table 2-16) as described in Furlong and others (1996). Wet sediment samples were weighed, centrifuged, and mixed with sodium sulfate to remove excess water. The sediment sample was then Soxhlet extracted overnight with methanol followed by methylene chloride, and the combined extracts dried over sodium sulfate. The extract volume was reduced and an aliquot was injected into a styrene-divinylbenzene GPC column and eluted with methylene chloride. Separate fractions were collected for organochlorine compounds and semi-volatile compounds. The semi-volatile fraction was exchanged into ethyl acetate and reduced in volume. Target analytes were identified by GC/MS, and quantitation was performed using internal standards and a multiple-point calibration curve.

### Trace Elements

Sediment samples were thawed and homogenized prior to subsampling wet. Subsamples were removed for both digestion and percent moisture determinations. Total digestions were performed using a microwave oven-process as described elsewhere (Roth and others, 1997; Hayes, 1993). Concentrations were determined by the appropriate analytical method in triplicate and reported with an error term representing the standard deviation of replicate measurements. Accuracy of these analyses was established using NIST SRM Buffalo River Sediment (SRM 2704). Digestion blanks also were analyzed. Analyses are reported on a dry-weight basis. Detection limits for the sediment determinations are reported in table 2-14.

**Table 2-16.** Twenty-eight organochlorine compounds measured in fish tissue, semipermeable membrane devices, and sediment samples by USGS NWQL Schedule 2101. [CAS Number, Chemical Abstract Services registry number; LRL, laboratory reporting level; µg/kg, microgram per kilogram; NA, not available]

| Compound | CAS Number | LRL (µg/kg) |
|---|---|---|
| Aldrin | 309-00-2 | 5.0 |
| *cis*-Chlordane | 5103-71-9 | 5.0 |
| *trans*-Chlordane | 5103-74-2 | 5.0 |
| 1,1-Dichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethane (*o,p'*-DDD) | 53-19-0 | 5.0 |
| *p,p'*-DDD | 72-54-8 | 5.0 |
| 1,1-Dichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethylene (*o,p'*-DDE) | 3424-82-6 | 5.0 |
| *p,p'*-DDE | 72-55-9 | 5.0 |
| 1,1,1-Trichloro-2-(*o*-chlorophenyl)-2-(*p*-chlorophenyl)ethane (*o,p'*-DDT) | 789-02-6 | 5.0 |
| *p,p'*-DDT | 50-29-3 | 5.0 |
| Dacthal | 1861-32-1 | 5.0 |
| Dieldrin | 60-57-1 | 5.0 |
| Endrin | 72-20-8 | 5.0 |
| Endosulfan I | 959-98-8 | NA |
| Endosulfan II | 33213-65-9 | NA |
| *alpha*-Hexachlorohexane | 319-84-6 | 5.0 |
| *beta*-Hexachlorohexane | 319-85-7 | 5.0 |
| *delta*-Hexachlorohexane | 319-86-8 | 5.0 |
| *gamma*-Hexachlorohexane (lindane) | 58-89-9 | 5.0 |
| Heptachlor | 76-44-8 | 5.0 |
| Heptachlor epoxide | 1024-57-3 | 5.0 |
| Hexachlorobenzene | 118-74-1 | 5.0 |
| *o,p'*-Methoxychlor | 30667-99-3 | 5.0 |
| *p,p'*-Methoxychlor | 72-43-5 | 5.0 |
| Mirex | 2385-85-5 | 5.0 |
| *cis*-Nonachlor | 5103-73-1 | 5.0 |
| *trans*-Nonachlor | 39765-80-5 | 5.0 |
| Oxychlordane | 27304-13-8 | 5.0 |
| Pentachloroanisole | 1825-21-4 | 5.0 |
| Polychlorinated biphenyls | 1336-36-3 | 50 |
| Toxaphene | 8001-35-2 | 200 |
| Lipid | NA | 0.5% |
| **Surrogate Standards** | | |
| 3,5-Dichlorobiphenyl | 34883-41-5 | 0.1 |
| *alpha*-Hexachlorohexane-$d_6$ | 86194-41-4 | 0.1 |
| 2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl | 52663-79-3 | 0.1 |
| 2,4,6-Trichlorobiphenyl | 35693-92-6 | 0.1 |

# CHAPTER 3 - ORGANIC COMPOUNDS IN WATER, BIOTA, SEMIPERMEABLE MEMBRANE DEVICES, AND SEDIMENT

Water samples collected from wetland sites and downstream Salt/Gila River locations were analyzed for a variety of parameters including field measurements (temperature, DO, pH, specific conductance), TOC, DOC, UV254, pesticides, herbicides, insecticides, VOC, EDTA, NTA, and NPEC. Biota, SPMD, and sediment were collected and analyzed for HOC. Although over 200 specific compounds were measured (see Chapter 2), only compounds that were detected are reported in this chapter.

## WATER

### FIELD MEASUREMENTS

Table 3-1 summarizes the field and bulk organic measurements for samples collected from the wetlands and the Salt/Gila River system. Two Hydrolabs were deployed for one month (July 24 to August 21, 1998) in the inlet and outlet of the H2 wetland, to continuously monitor (at one hour intervals) temperature, DO, pH, and conductivity (fig. 3-1). The Hydrolab temperature profiles indicated a diurnal fluctuation of nearly 5 °C at both the inlet and outlet sites (fig. 3-1a). The inlet temperature averaged 33 °C while the outlet averaged 31 °C.

Figure 3-1b shows DO levels during the field survey. Although the influent DO probe failed several days after the experiment began, early readings indicated an average of 94% saturation at the wetland inlet. Both inlet and outlet results indicate a diurnal DO variation of 14 to 47%. The outlet DO measurements remained primarily in the 0 to 20% saturation range but approached 40% saturation twice near the end of the study. Dissolved oxygen conditions ranged from aerobic to anaerobic from the inlet to the outlet location.

The pH values averaged 7.3 (ranged from 7.1 to 7.4) at the wetland inlet and 6.7 (ranged from 6.5 to 7.3) at the outlet (fig. 3-1c). The pH measurements displayed a minor daily fluctuation that was more pronounced at the inlet. As the study concluded (August 16 to August 21), the outlet pH levels had large daily values that occurred at 9:00 am.

Specific conductance showed considerable variation over the 30-day study (fig. 3-1d). The inlet specific conductance ranged from 1.6 to 1.9 millisiemens per centimeter (mS/cm) while the outlet ranged from 1.5 to 1.8 mS/cm. The inlet experienced an average 0.1 mS/cm diurnal fluctuation whereas the outlet had only minor daily changes in specific conductance. Overall, the inlet and outlet specific conductance followed similar trends throughout the study. The outlet experienced a 0.2 mS/cm decrease near the end of the study, an anomaly that occurred several days before the significant pH and temperature deviations.

**Table 3-1**. Summary of specific sampling information, field measurements, and organic carbon analysis for 1998 to 2000 water sampling events. [Temp, water temperature in degrees Celsius, °C; DO, dissolved oxygen; mg/L, milligrams per liter; SC, specific conductance; mS/cm, millisiemens per centimeter; TOC, total organic carbon; DOC, dissolved organic carbon; UV254, ultraviolet light absorbance at 254 nanometers; cm, centimeter; ND, not determined]

| Date | Time | Location | pH | Temp °C | DO mg/L | SC mS/cm | TOC mg/L | DOC mg/L | TOC UV254 cm | DOC UV254 cm |
|---|---|---|---|---|---|---|---|---|---|---|
| 7/24/98 | 0830 | Hayfield Inlet | 7.41 | 32.4 | 5.1 | 1.71 | 8.5 | 8.3 | 0.142 | 0.130 |
| 7/24/98 | 0900 | Hayfield 2 Outlet | 7.13 | 29.8 | 0.6 | 1.67 | 8.4 | 8.6 | 0.156 | 0.160 |
| 7/24/98 | 1200 | Bullard Avenue | 7.70 | 32.6 | 7.6 | 1.97 | 6.5 | 6.4 | 0.111 | 0.108 |
| 7/28/98 | ND | Hayfield Inlet | 7.29 | 33.2 | 2.1 | 1.83 | 8.3 | 8.2 | 0.152 | 0.141 |
| 7/28/98 | ND | Hayfield 2 Outlet | 7.19 | 30.8 | 0.5 | 1.67 | 8.3 | 8.3 | 0.190 | 0.191 |
| 8/4/98 | 1000 | Hayfield Inlet | 7.24 | 33.4 | 3.8 | 1.71 | 9.1 | 8.9 | 0.160 | 0.137 |
| 8/4/98 | 1015 | Hayfield 2 Outlet | 7.07 | 32.6 | 2.3 | 1.73 | 9.2 | 9.2 | 0.183 | 0.182 |
| 8/10/98 | ND | Hayfield Inlet | 7.14 | 31.9 | 4.4 | 1.66 | 7.5 | 7.2 | 0.138 | 0.127 |
| 8/10/98 | ND | Hayfield 2 Outlet | 7.23 | 28.8 | 1.2 | 1.75 | 7.6 | 7.7 | 0.158 | 0.155 |
| 8/18/98 | ND | Hayfield Inlet | 6.73 | 32.0 | 4.4 | 1.70 | 7.7 | 7.5 | 0.147 | 0.133 |
| 8/18/98 | ND | Hayfield 2 Outlet | 6.71 | 28.8 | 1.0 | 1.69 | 8.4 | 8.4 | 0.175 | 0.175 |
| 6/22/99 | 1715 | Hayfield Inlet | ND | 30.6 | ND | 1.70 | 7.6 | 5.4 | 0.146 | 0.119 |
| 6/22/99 | 1730 | Hayfield 1 Outlet | ND | 27.8 | ND | 1.72 | 7.9 | 8.0 | 0.154 | 0.156 |
| 2/14/00 | 1345 | Bullard Avenue | 7.51 | 19.4 | 5.6 | 2.35 | 5.7 | 5.7 | 0.117 | 0.118 |
| 2/14/00 | 1630 | 115th Avenue | 7.04 | 22.6 | 3.9 | 2.10 | 6.0 | 6.0 | 0.113 | 0.110 |
| 2/14/00 | 0830 | Cobble Inlet | 6.97 | 24.6 | 3.5 | 1.35 | 9.7 | 9.3 | 0.172 | 0.155 |
| 2/14/00 | 0915 | Cobble 1 Outlet | 7.26 | 16.7 | 6.6 | 1.38 | 8.5 | 8.7 | 0.142 | 0.145 |
| 2/14/00 | 0900 | Cobble 2 Outlet | 7.21 | 14.7 | 2.5 | 1.32 | 8.3 | 8.2 | 0.147 | 0.147 |
| 2/14/00 | 0745 | Hayfield Inlet | 6.90 | 24.6 | 3.2 | 1.36 | 9.6 | 9.4 | 0.168 | 0.154 |
| 2/14/00 | 0800 | Hayfield 1 Outlet | 7.31 | 14.6 | 2.8 | 1.39 | 8.3 | 8.4 | 0.153 | 0.151 |
| 2/14/00 | 0815 | Hayfield 2 Outlet | 7.31 | 14.5 | 4.9 | 1.37 | 8.3 | 8.3 | 0.157 | 0.143 |

## TOTAL AND DISSOLVED ORGANIC CARBON

Total and dissolved organic carbon were measured at the Hayfield and Cobble wetlands inlets and outlets, as well as a number of other sites (table 3-1). Concentrations of TOC were monitored weekly at the H2 wetland during July and August 1998, and averaged 8.2 mg/L (ranged from 7.5 to 9.1 mg/L) in the inlet and 8.4 mg/L (ranged from 7.6 to 9.2 mg/L) in the outlet, an increase of about 2%. Similar results were observed for DOC which averaged 8.0 mg/L in the inlet and 8.4 mg/L in the outlet. Samples collected at other times during the study also indicated internal loading of carbon by the wetlands, which is consistent with previous studies on treatment wetlands (Barber and others, 1999; Sartoris and others, 2000; Rostad and others, 2000; Barber and others, 2001). The internal loading also is reflected by a slight increase in the specific absorbance (DOC/UV254) between the wetland inlets and outlets, which indicates an increase in aromaticity due to plant derived dissolved organic matter (Barber and others, 2001).

## PESTICIDES, HERBICIDES AND INSECTICIDES

Pesticide analysis of the H2 wetland water samples collected during July and August 1998 detected 7 of the 48 (15%) compounds measured (table 3-2). Diazinon, prometon, and simazine were detected in most samples, and atrazine, carbaryl, chloropyrifos, and S-ethyldipropylthiocarbamate were identified in some samples. Additional non-target compounds detected in the August 21, 1998 H2 outlet sample include the ethyl ester of butenoic acid, ethylbenzene isomers, dimethylbenzene isomers, benzyl alcohol, 2-(methylthio)-benziathiazole, and phenylisoquinoline.

Only one of the 26 (4%) herbicides measured by the Kansas laboratory was detected in water samples from the H2 wetland and Bullard Avenue sites during August 1998 (table 3-3). This compound, 3,4-dichloroaniline, is a degradate of the herbicides linuron and diuron and was detected in all samples. Concentrations in the wetland outlet were 57 to 127% greater than in the inlet indicating internal loading of the herbicide as water traveled through the wetland. Specific conductance measurements (table 3-1) indicate that concentration effects due to evapotranspiration were minor. A possible source of internal loading to the wetlands is aerial deposition from applications to the surrounding farmlands. Samples collected at the downstream Bullard Avenue site had 3,4-dichloroaniline concentrations similar to those determined in the wetlands. Only one of the 23 (4%) insecticides measured (chlorpyriphos) was detected in the H2 wetland and Bullard Avenue samples (table 3-3). No herbicide metabolites were detected in water samples analyzed during the field study.

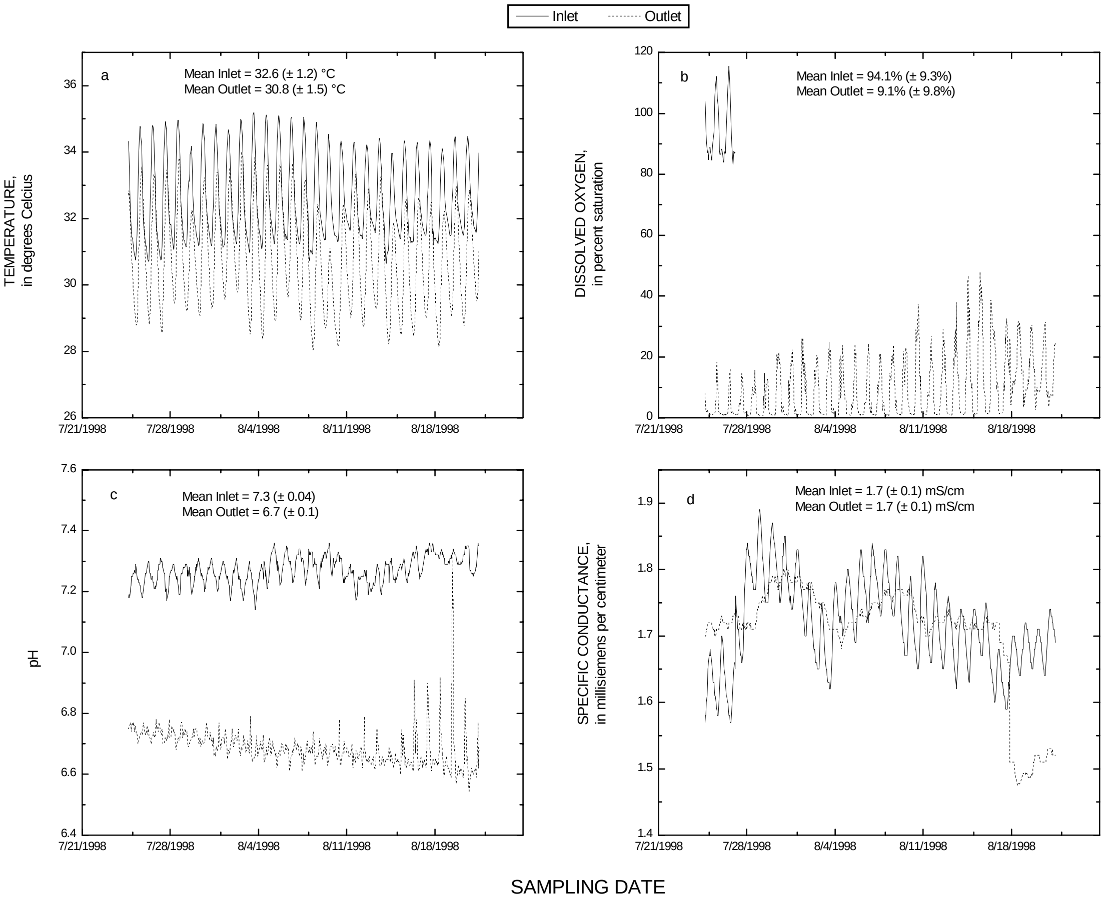

**Figure 3-1**. Hydrolab profiles of (a) temperature, (b) dissolved oxygen, (c) pH, and (d) specific conductance at the Hayfield 2 wetland inlet and outlet, July 24 to August 21, 1998.

## VOLATILE ORGANIC COMPOUNDS

The 91st Avenue WWTP effluent and the H1 wetland contained a variety of VOC including methylene chloride, chloroform, tetrachloroethene, 1,4-dichlorobenzene, bromodichloromethane, dibromochloromethane, and toluene (tables 3-4 and 3-5). Twenty-seven (31%) of the 86 Schedule 2020 target compounds were detected in the Hayfield inlet splitter box, and 18 (51%) of the 35 Schedule 2022 target compounds were detected in the H1 wetland inlet. Chloroform, bromodichloromethane, and dibromochloromethane were detected at the highest concentrations in the inlet structure, followed by a large initial decrease, and then approaching a plateau through the rest of the H1 wetland (fig. 3-2a). Methylene chloride, 1,4-dichlorobenzene, tetrachloroethene, and toluene were present at order-of-magnitude lower levels, and demonstrated steady decreases in concentrations during travel through the wetland (fig. 3-2b). Acetone, 2-butanone, bromochloromethane, carbon disulfide, chloromethane, chloroethane, dibromomethane, hexachloroethane, 1,4-isopropyltoluene, 4-methyl-2-pentanone, 1,2,4-trichlorobenzene, and 1,2,3-trichloropropane were detected in the inlet splitter box; benzene, diethylether, *tert*-butyl methyl ester, and trichloroethene were present throughout the wetland; and bromoform, carbon tetrachloride, chlorobenzene, ethylbenzene, 1,3- 1,4-, and 1,2-xylene were present in the wetland inlet and the first part of the wetland. All of these compounds were at concentrations near their detection limits (tables 3-4 and 3-5).

## WASTEWATER-DERIVED COMPOUNDS

Concentrations of wastewater-derived compounds were monitored in the wetland basins and at several downstream locations from 1998 to 2000 (table 3-6). Twenty six (65%) of the 40 wastewater compounds were detected in one or more sample during the study. The compounds most frequently detected include bisphenol A (BPA), caffeine (CAFF), cholesterol (CHO), coprostanol (COP), 2,6-di-*tert*-butyl-1,4-benzoquinone (DTBB), 1,4-dichlorobenzene (DCB), nonylphenol (NP), nonylphenolmonoethoxylate (NP1EO), *tert*-octylphenol (TOP), octylphenolmonoethoxylate (OP1EO), and triclosan (TRI). Figure 3-3 shows the relative removal of BPA, CAFF, DTBB, DCB, NP, NP1EO, and TRI in the Hayfield and Cobble wetlands during February 2000. The NP concentrations averaged 0.65 μg/L at the inlets and 0.39 μg/L at the outlets, an average removal of 40%. The NP1EO concentrations averaged 0.27 μg/L at the inlets and 0.007 μg/L at the outlets, with an average removal of 98%. Caffeine, TRI and BPA had removal rates of 76%, 16%, and 44%. Concentrations also decreased in the downstream Salt River sites: NP, NP1EO, CAFF, and BPA levels at 115th Avenue were 9%, 81%, 9%, and 35% lower than in the 91st Avenue WWTP effluent. In contrast, the TRI concentration at 115th Avenue was 60% greater than in the WWTP effluent. Concentrations at Bullard Avenue were significantly lower for all of the wastewater compounds, but the hydrology of the Salt/Gila River system becomes more complex at this site and not all of the flow comes from the WWTP discharge.

## ETHYLENEDIAMINETETRAACETIC, NITRILOTRIACETIC, AND NONYLPHENOLETHOXYCARBOXYLIC ACIDS

Concentrations of EDTA and NTA were monitored in the wetland basins and at several downstream locations from 1998 to 2000 (table 3-7). Figure 3-4a shows the relative removal of EDTA in the Hayfield 2 wetland between July 24 and August 21, 1998. The EDTA concentrations averaged 210 µg/L (ranged from 180 to 250 µg/L) at the inlet and 53 µg/L (ranged from 29 to 87 µg/L) at the outlet, with an average removal of 75 ± 11%. The NTA concentrations were much lower than EDTA and appeared to be stable through the basin (average concentration was 2.6 µg/L at the inlet and 3.3 µg/L at the outlet) with the exception of the peak value on July 28 (fig. 3-4b).

**Table 3-2**. Concentrations of pesticides (USGS NWQL Schedule 2001, table 2-4) detected in water samples from the Hayfield 2 wetland, July 28 to August 21, 1998. [µg/L, microgram per liter; E, value estimated because concentration is below the laboratory reporting level]

| Compound | Inlet 7/28/98 µg/L | Inlet 8/10/98 µg/L | Inlet 8/21/98 µg/L | Outlet 8/10/98 µg/L | Outlet 8/21/98 µg/L |
|---|---|---|---|---|---|
| Atrazine | <0.007 | <0.007 | <0.007 | <0.007 | E0.006 |
| Carbaryl | <0.04 | E0.005 | 0.035 | <0.04 | <0.04 |
| Chloropyrifos | <0.005 | 0.011 | <0.005 | <0.005 | <0.005 |
| Diazinon | 0.089 | 0.100 | 0.048 | 0.049 | 0.044 |
| S-Ethyldipropylthiocarbamate | <0.002 | <0.002 | 0.010 | <0.002 | 0.008 |
| Prometon | 0.025 | 0.012 | <0.01 | 0.013 | 0.010 |
| Simazine | 0.011 | 0.013 | <0.01 | <0.01 | 0.011 |

**Table 3-3**. Concentrations of 3,4-dichloroaniline and chlorpyriphos (USGS Lawrence, Kansas Laboratory, tables 2-5 and 2-6) detected in water samples collected from the Hayfield 2 wetland and the Gila River at Bullard Avenue, August 1998. [µg/L, microgram per liter]

| Compound | Inlet 8/4/98 µg/L | Inlet 8/18/98 µg/L | Outlet 8/4/98 µg/L | Outlet 8/18/98 µg/L | Bullard Ave 8/21/98 µg/L |
|---|---|---|---|---|---|
| Chlorpyriphos | <0.05 | <0.05 | <0.05 | <0.05 | 0.07 |
| 3,4-Dichloroaniline | 0.15 | 0.30 | 0.34 | 0.47 | 0.17 (0.20)[a] |

[a]. Value in parentheses is duplicate analysis.

**Table 3-4**. Volatile organic compounds (USGS NWQL Schedule 2020, table 2-8) detected in the 91st Avenue Wastewater Treatment Plant effluent at the Hayfield wetland inlet splitter box, February 16, 2000. [µg/L, microgram per liter; E, value estimated because concentration is below the LRL; LRL, laboratory reporting limit; % REC, percent recovery]

| Compound | Inlet Splitter Box µg/L | Blank µg/L | Spike % REC | LRL µg/L |
|---|---|---|---|---|
| Acetone | 9.62 | <7.00 | 94 | 5.44 |
| Benzene | E0.02 | <0.04 | 101 | 0.05 |
| Bromochloromethane | 0.31 | <0.04 | 93 | 0.05 |
| Bromodichloromethane | 5.85 | <0.05 | 106 | 0.05 |
| Bromoform | 0.33 | <0.06 | 102 | 0.10 |
| 2-Butanone | 1.66 | <1.60 | 103 | 1.60 |
| *tert*-Butyl methyl ether | E0.09 | <0.17 | 100 | 0.20 |
| Carbon disulfide | 0.25 | <0.07 | 90 | 0.07 |
| Carbon tetrachloride | E0.05 | <0.06 | 100 | 0.09 |
| Chlorobenzene | E0.07 | <0.03 | 104 | 0.05 |
| Chloroethane | E0.06 | <0.12 | 94 | 0.11 |
| Chloroform | 8.31 | <0.05 | 102 | 0.05 |
| Chloromethane | E0.22 | <0.50 | 126 | 0.16 |
| Dibromochloromethane | 2.43 | <0.18 | 104 | 0.18 |
| Dibromomethane | 0.11 | <0.05 | 92 | 0.05 |
| 1,4-Dichlorobenzene | 0.71 | <0.05 | 93 | 0.05 |
| 1,1-Dichloroethane | E0.02 | <0.07 | 100 | 0.07 |
| Diethylether | E0.06 | <0.17 | 92 | 0.16 |
| Hexachloroethane | E0.02 | <0.19 | 101 | 0.36 |
| 1,4-Isopropyltoluene | E0.01 | <0.07 | 94 | 0.10 |
| Methylene chloride | 0.84 | <0.38 | 90 | 0.35 |
| 4-Methyl-2-pentanone | E0.19 | <0.37 | 109 | 0.41 |
| Tetrachloroethene | 0.47 | <0.10 | 107 | 0.12 |
| Toluene | 0.25 | <0.05 | 102 | 0.05 |
| 1,2,4-Trichlorobenzene | E0.04 | <0.19 | 96 | 0.17 |
| Trichloroethene | E0.05 | <0.04 | 106 | 0.05 |
| 1,2,3-Trichloropropane | E0.06 | <0.16 | 88 | 0.19 |
| **Surrogate Standards**[a] | | | | |
| 1,4-Bromofluorobenzene | 94 | 104 | 97 | 103 |
| 1,2-Dichloroethane-$d_4$ | 106 | 106 | 99 | 105 |
| Toluene-$d_8$ | 88 | 102 | 99 | 103 |

[a]. Values are percent recovery

**Table 3-5**. Volatile organic compound concentrations (USGS NWQL Schedule 2022, table 2-8) detected in the Hayfield 1 wetland, February 16, 2000. [DZ, deep water zone; µg/L, microgram per liter; E, value estimated because concentration is below LRL; LRL, laboratory reporting limit; % REC, percent recovery]

| Compound | Inlet µg/L | DZ-1 µg/L | DZ-2 µg/L | DZ-3 µg/L | DZ-4 µg/L | DZ-5 µg/L | Outlet µg/L | Blank µg/L | Spike % REC | LRL µg/L |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | E0.01 | E0.01 | E0.01 | E0.01 | E0.01 | E0.01 | E0.01 | <0.04 | 101 | 0.05 |
| Bromodichloromethane | 2.16 | 1.21 | 0.84 | 0.72 | 0.62 | 0.43 | 0.36 | <0.05 | 106 | 0.05 |
| Bromoform | 0.11 | E0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | 102 | 0.10 |
| *tert*-Butyl methyl ether | E0.13 | E0.12 | E0.14 | E0.13 | E0.12 | E0.08 | E0.08 | <0.17 | 100 | 0.20 |
| Carbon tetrachloride | E0.03 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | <0.06 | 100 | 0.09 |
| Chlorobenzene | E0.03 | E0.02 | E0.01 | E0.01 | <0.03 | <0.03 | <0.03 | <0.03 | 104 | 0.05 |
| Chloroform | 4.45 | 3.25 | 2.79 | 2.55 | 2.25 | 1.73 | 1.50 | <0.05 | 102 | 0.05 |
| Dibromochloromethane | 0.77 | 0.38 | 0.23 | 0.20 | 0.18 | E0.13 | E0.10 | <0.18 | 104 | 0.18 |
| 1,4-Dichlorobenzene | 0.74 | 0.64 | 0.51 | 0.42 | 0.36 | 0.27 | 0.26 | <0.05 | 93 | 0.05 |
| Diethylether | E0.10 | E0.08 | E0.06 | E0.06 | E0.06 | E0.05 | E0.06 | <0.17 | 92 | 0.16 |
| Ethylbenzene | E0.01 | E0.01 | E0.01 | E0.01 | <0.03 | <0.03 | <0.03 | <0.03 | 103 | 0.05 |
| Methylene chloride | 0.87 | 0.67 | 0.53 | 0.46 | 0.42 | E0.36 | E0.32 | <0.38 | 90 | 0.35 |
| Styrene | <0.04 | <0.04 | E0.01 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 | 102 | 0.06 |
| Tetrachloroethene | 0.48 | 0.38 | 0.31 | 0.26 | 0.22 | 0.18 | 0.17 | <0.10 | 107 | 0.12 |
| Toluene | 0.23 | 0.15 | 0.11 | E0.09 | E0.08 | E0.07 | E0.08 | <0.05 | 102 | 0.05 |
| Trichloroethene | E0.07 | E0.05 | E0.04 | E0.04 | E0.03 | E0.03 | E0.03 | <0.04 | 106 | 0.05 |
| 1,3- and 1,4-Xylene | E0.02 | E0.03 | E0.03 | E0.02 | E0.02 | E0.02 | E0.02 | <0.06 | 100 | 0.12 |
| 1,2-Xylene | E0.02 | E0.02 | E0.02 | <0.04 | <0.04 | <0.04 | E0.01 | <0.04 | 101 | 0.07 |
| **Surrogate Standards**[a] | | | | | | | | | | |
| 1,4-Bromofluorobenzene | 103 | 102 | 101 | 103 | 100 | 103 | 103 | 105 | 97 | 103 |
| 1,2-Dichloroethane-$d_4$ | 108 | 105 | 109 | 108 | 108 | 105 | 105 | 106 | 98 | 105 |
| Toluene-$d_8$ | 99 | 100 | 98 | 99 | 98 | 97 | 99 | 100 | 99 | 103 |

[a]. Values in percent recovery

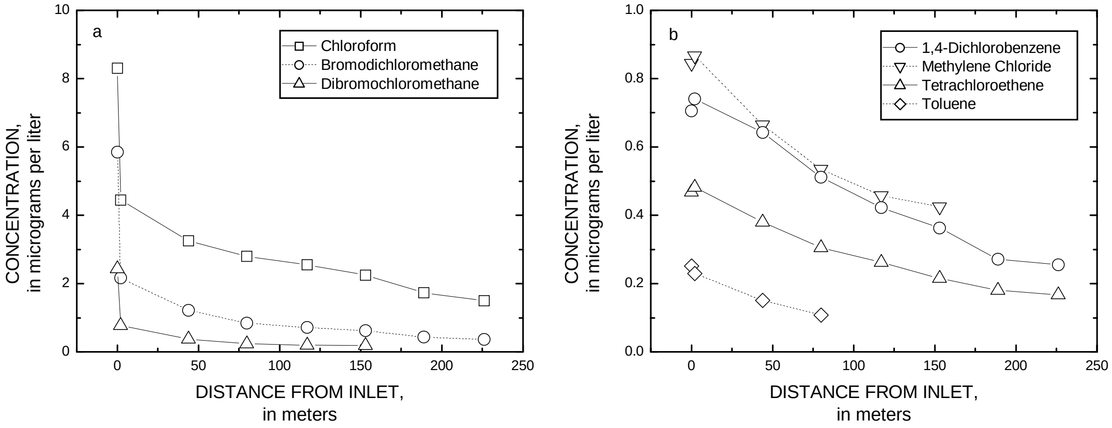

**Figure 3-2**. Distribution of (a) chloroform, bromodichloromethane, and dibromochloromethane and (b) 1,4-dichlorobenzene, methylene chloride, tetrachloroethene, and toluene in the Hayfield 1 wetland, February 16, 2000.

**Table 3-6**. Concentrations of wastewater-derived compounds at the Tres Rios Wetlands and downstream Saly/Gila River sites, 1998 to 2000 (USGS Boulder, Colorado Laboratory, table 2-9). [µg/L, microgram per liter; DUP, duplicate sample; *t*, tert; *n*, normal]

| **Sample Name** | **Date**[a] | **Bisphenol A µg/L** | **4-*t*-Butylphenol µg/L** | **Caffeine µg/L** | **Cholesterol µg/L** | **3-*beta*-Coprostanol Mg/L** | **2,6-Di-*t*-butyl-1,4-benzoquinone µg/L** | **2,6-Di-*t*-butyl-4-methylphenol µg/L** | **1,4-Dichlorobenzene µg/L** | **1,2-Dichlorobenzene µg/L** | **17-*alpha*-Estradiol µg/L** | **17-*beta*-Estradiol µg/L** | **Estrone µg/L** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hayfield Inlet | 7/24/98 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.05 | 0.02 | 0.25 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet (DUP) | 7/24/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.05 | 0.01 | 0.24 | <0.01 | 0.12 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 7/24/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.09 | <0.01 | 0.07 | <0.01 | <0.01 |
| Hayfield Inlet | 7/28/98 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.05 | 0.02 | 0.20 | <0.01 | 0.08 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 7/28/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.06 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 8/4/98 | <0.01 | <0.01 | <0.01 | 0.11 | 0.10 | 0.03 | 0.01 | 0.15 | <0.01 | 0.64 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 8/4/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.07 | <0.01 | 0.08 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 8/10/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.05 | <0.01 | 0.28 | <0.01 | <0.01 |
| Hayfield Inlet | 8/18/98 | <0.01 | <0.01 | <0.01 | 0.13 | 0.06 | 0.06 | 0.02 | 0.12 | <0.01 | 0.34 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 8/18/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.06 | <0.01 | 0.12 | <0.01 | <0.01 |
| Hayfield Inlet | 8/21/98 | <0.01 | <0.01 | <0.01 | 0.12 | 0.06 | 0.05 | 0.02 | 0.14 | <0.01 | 0.13 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 8/21/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.05 | <0.01 | 0.12 | <0.01 | <0.01 |
| Bullard Avenue | 7/24/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | 0.06 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bullard Avenue | 8/21/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 2/15/00 | 0.12 | 0.03 | 0.49 | 0.04 | <0.01 | 0.25 | 0.02 | 0.18 | <0.01 | <0.01 | 0.01 | <0.01 |
| Hayfield 1 Outlet | 2/15/00 | 0.02 | <0.01 | 0.08 | 0.11 | <0.01 | 0.10 | <0.01 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 2/15/00 | 0.03 | 0.02 | 0.28 | 0.49 | <0.01 | 0.16 | <0.01 | 0.03 | 0.01 | 0.64 | <0.01 | <0.01 |
| Cobble Inlet | 2/14/00 | 0.12 | 0.02 | 0.65 | 0.57 | 0.36 | 0.47 | 0.04 | 0.17 | <0.01 | 0.03 | <0.01 | <0.01 |
| Cobble 1 Outlet | 2/14/00 | 0.11 | 0.02 | 0.14 | 1.1 | <0.01 | 0.09 | 0.01 | 0.08 | <0.01 | 0.35 | <0.01 | <0.01 |
| Cobble 2 Outlet | 2/14/00 | 0.10 | 0.05 | 0.03 | 0.64 | <0.01 | 0.12 | 0.02 | 0.07 | <0.01 | 0.50 | <0.01 | <0.01 |
| 91 Avenue Well | 2/16/00 | <0.01 | <0.01 | <0.01 | 1.2 | 1.10 | 0.27 | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | <0.01 |
| 115 Avenue | 2/13/00 | 0.08 | 0.03 | 0.52 | 0.30 | 0.09 | 0.22 | 0.02 | 0.08 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bullard Avenue | 2/13/00 | <0.01 | 0.02 | 0.03 | 0.63 | 0.56 | 0.18 | <0.01 | 0.03 | <0.01 | 0.01 | <0.01 | 0.03 |

[a]. Samples from 1998 were isolated by solid phase extraction.

**Table 3-6.** Continued.

| Sample Name | Date[a] | 4-Methylphenol µg/L | 4-Nonylphenol µg/L | 4-Nonylphenol-monoethoxylate µg/L | 4-Nonylphenol-diethoxylate µg/L | 4-Nonylphenol-triethoxylate µg/L | 4-Nonylphenol-tetraethoxylate µg/L | 4-*n*-Octylphenol µg/L | 4-*t*-Octylphenol µg/L | 4-*t*-Octylphenol-monoethoxylate µg/L | 4-*t*-Octylphenol-diethoxylate µg/L | 4-Propylphenol µg/L | Triclosan µg/L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hayfield Inlet | 7/24/98 | <0.01 | 0.37 | 0.47 | 0.36 | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | <0.01 | <0.01 | 0.08 |
| Hayfield Inlet (DUP) | 7/24/98 | <0.01 | 0.35 | 0.28 | 0.25 | <0.01 | <0.01 | <0.01 | 0.04 | <0.01 | <0.01 | <0.01 | 0.10 |
| Hayfield 2 Outlet | 7/24/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 7/28/98 | <0.01 | 0.40 | 0.42 | 0.32 | <0.01 | <0.01 | <0.01 | 0.05 | <0.01 | <0.01 | <0.01 | 0.10 |
| Hayfield 2 Outlet | 7/28/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 8/4/98 | <0.01 | 0.34 | 0.27 | 0.15 | <0.01 | <0.01 | <0.01 | 0.05 | 0.01 | <0.01 | <0.01 | 0.09 |
| Hayfield 2 Outlet | 8/4/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield 2 Outlet | 8/10/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 8/18/98 | <0.01 | 0.17 | 0.23 | 0.16 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | 0.04 |
| Hayfield 2 Outlet | 8/18/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.05 |
| Hayfield Inlet | 8/21/98 | <0.01 | 0.14 | 0.35 | 0.19 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | 0.04 |
| Hayfield 2 Outlet | 8/21/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | 0.07 |
| Bullard Avenue | 7/24/98 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Bullard Avenue | 8/21/98 | <0.01 | 0.07 | <0.01 | 0.04 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | <0.01 |
| Hayfield Inlet | 2/15/00 | 0.03 | 0.66 | 2.26 | 0.68 | 0.39 | <0.01 | <0.01 | 0.05 | 0.05 | 0.11 | <0.01 | 0.08 |
| Hayfield 1 Outlet | 2/15/00 | <0.01 | 0.22 | 0.07 | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 | 0.04 |
| Hayfield 2 Outlet | 2/15/00 | <0.01 | 0.60 | 0.10 | <0.01 | <0.01 | <0.01 | 0.01 | 0.03 | <0.01 | <0.01 | 0.03 | 0.13 |
| Cobble Inlet | 2/14/00 | 0.01 | 0.64 | 2.89 | <0.01 | <0.01 | <0.01 | 0.01 | 0.03 | 0.03 | 0.10 | 0.03 | 0.13 |
| Cobble 1 Outlet | 2/14/00 | <0.01 | 0.36 | 0.03 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 | 0.04 | 0.11 |
| Cobble 2 Outlet | 2/14/00 | <0.01 | 0.38 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.02 | <0.01 | <0.01 | 0.04 | 0.07 |
| 91 Avenue Well | 2/16/00 | <0.01 | 0.04 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| 115 Avenue | 2/13/00 | <0.01 | 0.59 | 0.49 | 0.35 | 0.48 | 0.13 | 0.01 | 0.04 | 0.01 | 0.03 | <0.01 | 0.17 |
| Bullard Avenue | 2/13/00 | <0.01 | 0.17 | 0.03 | 0.09 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | 0.03 | 0.08 |

a. Samples from 1998 were isolated by solid phase extraction.

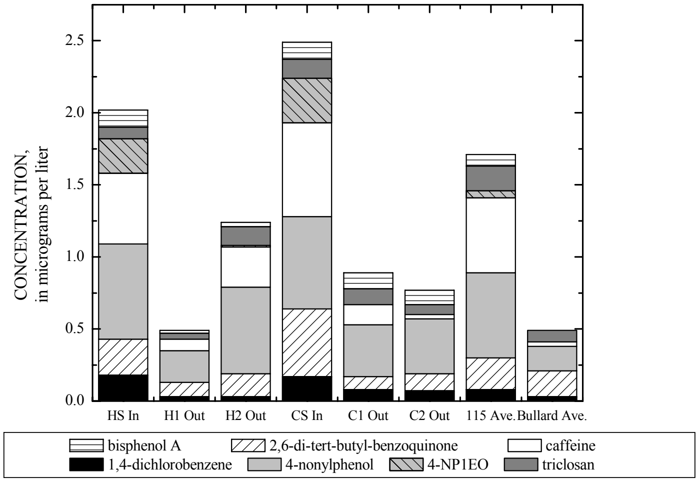

**Figure 3-3**. Concentrations of select wastewater-derived compounds in the inlets and outlets of the Hayfield and Cobble wetlands, and the 115th Avenue and Bullard Avenue downstream Gila River sites, February 13 and 14, 2000.[H, Hayfield; H1, Hayfield 1 wetland; H2, Hayfield 2 wetland; C, Cobble; C1, Cobble 1 wetland; C2, Cobble 2 wetland; Ave, Avenue; In, Inlet; Out, outlet]

**Table 3-7**. Concentrations of ethylenediaminetetraacetic acid (EDTA), nitrilotriacetic acid (NTA), nonylphenolmonoethoxycarboxylate (NP1EC), nonylphenoldiethoxycarboxylate (NP2EC), nonylphenoltriethoxycarboxylate (NP3EC), and nonylphenoltetraethoxycarboxylate (NP4EC) at the Tres Rios wetlands and downstream Salt/Gila River sites, 1998 to 2000 (USGS Boulder, Colorado Laboratory, table 2-10). [µg/L, microgram per liter; ND, not determined; % REC, percent recovery; DUP, duplicate]

| Date | Site Name | EDTA µg/L | NTA µg/L | NP1EC µg/L | NP2EC µg/L | NP3EC µg/L | NP4EC µg/L | 4-*n*-NP2EC[a] (% REC) |
|---|---|---|---|---|---|---|---|---|
| 7/24/98 | Hayfield Inlet | 240 | 2.7 | 110 | 75 | 1.7 | 0.2 | ND |
| 7/24/98 | Hayfield 2 Outlet | 87 | 3.2 | 57 | 51 | 1.1 | 0.1 | ND |
| 7/24/98 | Bullard Avenue | 42 | 6.6 | 81 | 56 | 0.5 | <0.1 | ND |
| 7/28/98 | Hayfield Inlet | 250 | 2.5 | 100 | 82 | 1.5 | 0.1 | ND |
| 7/28/98 | Hayfield 2 Outlet | 53 | 6.8 | 63 | 60 | 8.6 | 7.9 | ND |
| 8/4/98 | Hayfield Inlet | 200 | 3.5 | 100 | 97 | 1.7 | 0.1 | ND |
| 8/4/98 | Hayfield 2 Outlet | 37 | 3.1 | 44 | 58 | 1.2 | <0.1 | ND |
| 8/10/98 | Hayfield Inlet | 180 | 2.4 | 110 | 95 | 1.5 | 1.0 | ND |
| 8/10/98 | Hayfield 2 Outlet | 73 | 2.5 | 58 | 70 | 1.3 | 0.2 | ND |
| 8/18/98 | Hayfield Inlet | 210 | 2.0 | 76 | 66 | 1.4 | 0.3 | ND |
| 8/18/98 | Hayfield 2 Outlet | 29 | 1.9 | 39 | 47 | 1.0 | 0.2 | ND |
| 8/21/98 | Hayfield Inlet | 180 | 2.6 | 56 | 51 | 1.1 | <0.1 | ND |
| 8/21/98 | Hayfield 2 Outlet | 39 | 2.5 | 38 | 37 | 0.8 | <0.1 | ND |
| 8/21/98 | Bullard Avenue | 36 | 1.8 | 26 | 28 | 0.6 | <0.1 | ND |
| 6/22/99 | Hayfield Inlet | 190 | 3.5 | 55 | 97 | 1.1 | 0.1 | 64 |
| 6/22/99 | Hayfield Inlet (DUP) | 190 | 3.9 | 54 | 96 | 0.6 | 0.1 | 65 |
| 6/22/99 | Hayfield 1 Outlet | 51 | 1.9 | 51 | 73 | 0.7 | 0.1 | 73 |
| 6/23/99 | Bullard Avenue | 23 | 1.5 | 37 | 66 | 1.1 | 0.1 | 54 |
| 2/13/00 | 115th Avenue | 71 | 1.2 | 68 | 65 | 0.9 | 0.1 | 44 |
| 2/13/00 | Bullard Avenue | 45 | 1.3 | 53 | 63 | 0.8 | 0.1 | 35 |
| 2/14/00 | Cobble Inlet | 240 | 1.1 | 150 | 160 | 1.7 | 0.3 | 87 |
| 2/14/00 | Cobble 1 Outlet | 76 | 1.4 | 100 | 130 | 1.2 | 0.2 | 85 |
| 2/14/00 | Cobble 2 Outlet | 97 | 1.2 | 95 | 140 | 1.2 | 0.2 | 88 |
| 2/15/00 | Hayfield Inlet | 310 | 1.6 | 140 | 150 | 0.9 | 0.1 | 86 |
| 2/15/00 | Hayfield 1 Outlet | 41 | 1.2 | 100 | 120 | 1.0 | 0.2 | 84 |
| 2/15/00 | Hayfield 2 Outlet | 46 | 1.1 | 21 | 79 | 1.4 | 0.2 | 89 |
| 2/16/00 | 91st Avenue Well | 9.7 | 0.4 | 1.2 | 3.5 | 0.1 | <0.1 | 64 |

[a] Surrogate standard (4-*normal*-nonylphenoldiethoxycarboxylate).

Figure 3-5a depicts the decreasing EDTA levels downstream of the 91st Avenue WWTP discharge. The 91st Avenue effluent EDTA concentrations ranged from 180 to 310 µg/L and concentrations in the Gila River at Bullard Avenue ranged from 23 to 45 µg/L, an average decrease of 84% after 12 km of travel. Figure 3-5b shows the NTA levels; the 91st Avenue effluent averaged 2.6 µg/L and the Gila River at Bullard Avenue averaged 2.8 µg/L.

Between 1998 and 2000, concentrations of NP1EC ranged from 54 to 150 µg/L at the wetland inlets and 21 to 100 µg/L at the outlets (table 3-7). Concentrations of NP2EC ranged from 51 to 160 µg/L at the inlets and 37 to 140 µg/L at the outlets. On average, NP1EC and NP2EC concentrations decreased by 47% and 36% respectively during wetland treatment. Concentrations of NP3EC and NP4EC remained relatively low and stable throughout the wetlands with the exception of two H2 samples.

The H2 wetland NP1EC-NP4EC concentrations were monitored weekly between July 24 and August 21, 1998 (table 3-7). During this time, concentrations of NP1EC in the Hayfield influent averaged 93 µg/L (ranged from 56 to 112 µg/L), and NP2EC concentrations averaged 78 µg/L (ranged from 52 to 97 µg/L), and decreased 46 ± 9% and 30 ± 5% respectively at the wetland outlet (fig. 3-6). Although the NP3EC and NP4EC concentrations experienced a spike in the H2 outlet on July 28, overall, the levels were a fraction of the NP1EC and NP2EC concentrations and showed a slight reduction from inlet to outlet.

Downstream locations also were monitored for NP1EC to NP4EC (fig. 3-7). The 91st Avenue WWTP effluent (Hayfield influent) had average concentrations of 90 and 93 µg/L of NP1EC and NP2EC respectively, and the Gila River at Bullard Avenue averaged 49 and 53 µg/L, resulting in removals of 44% and 40% for NP1EC and NP2EC. Concentrations of NP3EC and NP4EC were very low at the downstream sites and are not shown in the figure.

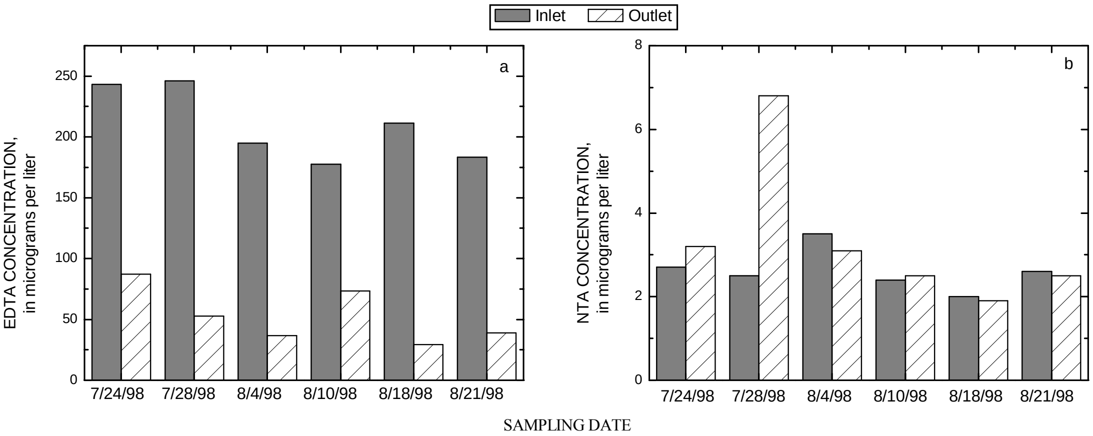

**Figure 3-4**. Concentrations of (a) ethylenediaminetetraacetic acid, EDTA, and (b) nitrilotriacetic acid, NTA, in the Hayfield 2 wetland, July 24 to August 21, 1998.

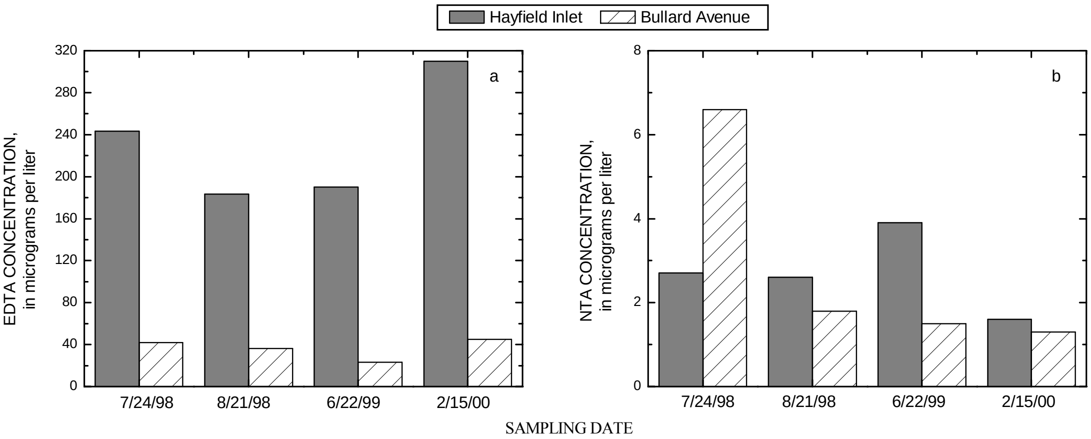

**Figure 3-5**. Concentrations of (a) ethylenediaminetetraacetic acid (EDTA), and (b) nitrilotriacetic acid (NTA) in the 91st Avenue Wastewater Treatment Plant effluent (Hayfield inlet) and the Gila River at Bullard Avenue, 1998 to 2000.

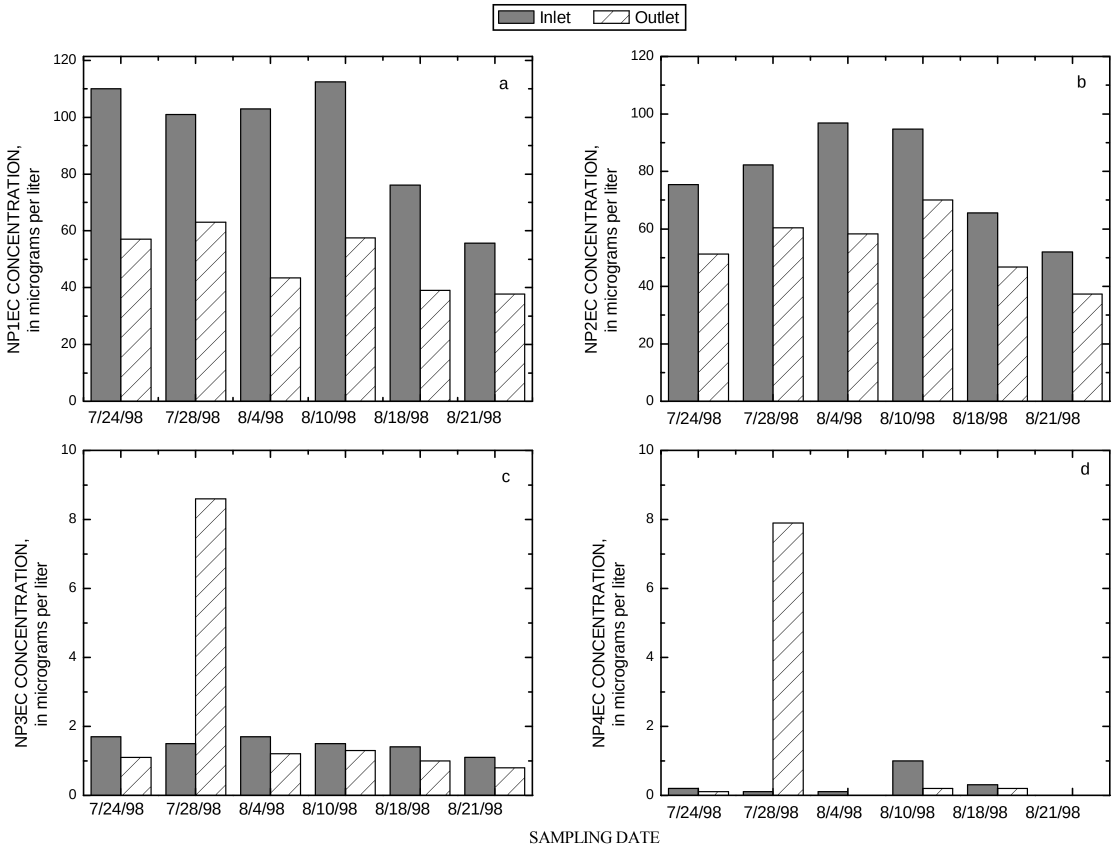

**Figure 3-6**. Concentrations of (a) nonylphenolmonoethoxycarboxylate, NP1EC, (b) nonylphenoldiethoxycarboxylate, NP2EC, (c) nonylphenoltriethoxycarboxylate, NP3EC, and (d) nonylphenoltetraethoxycarboxylate, NP4EC, at the Hayfield 2 wetland inlet and outlet, July 24 to August 21, 1998.

## FISH TISSUE

The fish specimens collected in this study exhibited no visual signs of adverse health effects. Whole body extracts establish tissue concentration levels and thus potential bioaccumulation risks to animals that feed on native fish. Study of filet tissue evaluates the presence of chemicals that are likely to pose a threat to humans from dietary intake. Examination of fish tissue evaluates persistent chemicals not metabolized by the organism.

*Gambusia* and *Tilapia* samples were collected from the H2 wetland during July 1998 and analyzed for organochlorine compounds (table 3-8, fig. 3-8). The lipid content of the whole body *Gambusia* tissue was 3.3%, whereas the lipid content of the *Tilapia* whole-body and filet tissue was 2.8% and 0.9% respectively. The *Tilapia* whole-body tissue contained 9 µg/kg *p,p'*-DDD, 26 µg/kg *p,p'*-DDE, and 5 µg/kg dieldrin. None of the target compounds were detected in the *Tilapia* filet tissue. The *Gambusia* whole-body composite sample contained 35 µg/kg of *p,p'*-DDE. Overall, the fish tissue analysis showed accumulation of organochlorine pesticides during the 1998 sampling.

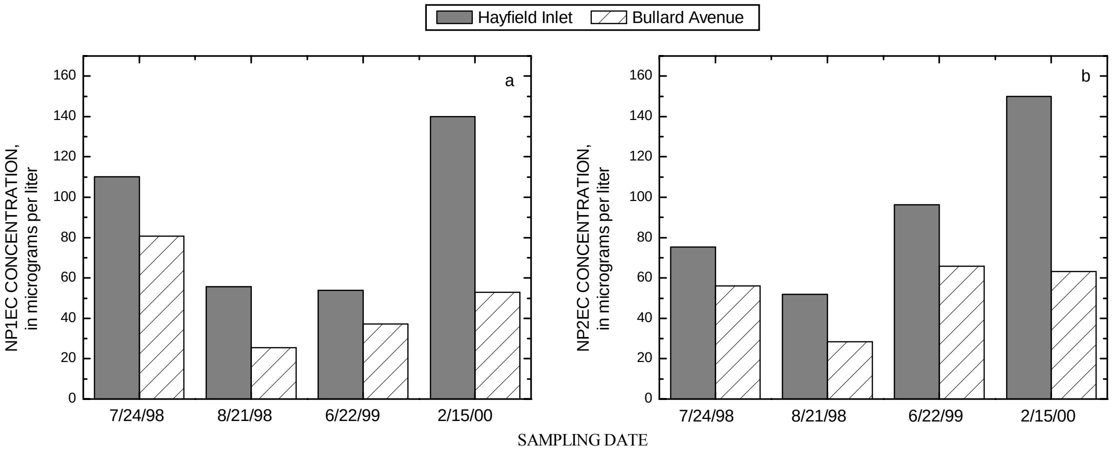

**Figure 3-7**. Concentrations of (a) nonylphenolmonoethoxycarboxylate (NP1EC), and (b) nonylphenoldiethoxycarboxylate (NP2EC) in the 91st Avenue Wastewater Treatment Plant effluent (Hayfield inlet) and the Gila River at Bullard Avenue, 1998 to 2000.

*Tilapia* and *Gambusia* were collected from the Hayfield and Cobble wetlands during February 2000. A composite of whole-body *Tilapia* contained 10 µg/kg of *trans*-nonachlor and 13 µg/kg of *p,p'*-DDE (table 3-9) whereas composite filet tissue showed no accumulation of target compounds above method detection limits. The liver tissue contained 9 µg/kg of *trans*-nonachlor and 13 µg/kg of *p,p'*-DDE (similar to the whole-body values), and the other tissue contained 4.5 µg/kg of *trans*-nonachlor and 6.5 µg/kg of *p,p'*-DDE (fig. 3-9). The lipid content of the *Tilapia* whole-body tissue was 1.5%, the filet was 0.9%, the liver was 3.3%, and the other tissue was 1.3%. Analysis of the *Gambusia* whole-body composite sample detected 3 µg/kg of *cis*-chlordane, 4 µg/kg of *trans*-chlordane, 44 µg/kg of *p,p'*-DDE, 8.3 µg/kg of dieldrin, 6.4 µg/kg of lindane, and 61 µg/kg of *trans*-nonachlor (fig. 3-10). The greatest organochlorine concentration in the *Gambusia* whole-body tissue was 2400 µg/kg for total PCBs (table 3-9). The lipid content of the *Gambusia* whole-body tissue was 3.4%.

Table 3-9 also reports concentrations of organochlorine pesticides detected in a June 1996 whole-body *Tilapia* specimen collected at the 91st Avenue effluent channel (USGS National Water Quality Assessment, NAWQA, Program). The sample contained 24 µg/kg *p,p'*-DDT, 17 µg/kg dieldrin, 29 µg/kg *cis*-nonachlor, and 14 µg/kg *trans*-nonachlor. The most significant concentrations were 1800 µg/kg for toxaphene and 2200 µg/kg for *p,p'*-DDE. These higher concentrations suggest greater exposure to HOC in the Salt River than in the treatment wetlands.

The compartmentalized approach indicates bioconcentration potential for animals that feed on whole *Tilapia* residing in the wetlands. The absence of contaminants in the filet tissue indicates a reduced risk to humans that eat only the filet of the *Tilapia*. The *Tilapia* and *Gambusia* data both show the presence of *p,p'*-DDE and *trans*-nonachlor. Concentrations in the *Gambusia* were higher than in the *Tilapia*. *Gambusia* also accumulated several compounds not detected in the *Tilapia* specimens but that were present in the SPMD extracts.

**Table 3-8**. Concentrations (wet weight) of organochlorine pesticides (USGS NWQL Schedule 2101, table 2-16) in *Tilapia* whole-body and filet tissue (collected July 23, 1998), *Gambusia* whole-body tissue (collected July 23, 1998), and sediment samples (collected August 21, 1998) from the Hayfield wetlands. [µg/kg, microgram per kilogram; ND, not determined; E, estimated - compound was detected at concentrations below the laboratory reporting level]

| **Compound** | ***Tilapia* Whole Body µg/kg** | ***Tilapia* Filet µg/kg** | **Gambusia Whole Body µg/kg** | **Hayfield 2 Inlet Sediment µg/kg** | **Hayfield 2 Outlet Sediment µg/kg** |
|---|---|---|---|---|---|
| Lipid | 2.8% | 0.9% | 3.3% | ND | ND |
| *cis*-Chlordane | <5 | <5 | <5 | <1 | E<1 |
| *trans*-Chlordane | <5 | <5 | <5 | 1 | E<1 |
| Dacthal | <5 | <5 | <5 | <1 | E<1 |
| *p,p'*-DDD | 9 | <5 | <5 | E<1 | E<1 |
| *p,p'*-DDE | 26 | <5 | 35 | E<1 | E<1 |
| Dieldrin | 5.1 | <5 | <5 | <1 | E<1 |
| Endosulfan I | <5 | <5 | <5 | <1 | E<1 |
| Hexachlorobenzene | <5 | <5 | <5 | <1 | E<1 |
| *cis*-Nonachlor | <5 | <5 | <5 | <1 | E<1 |
| *trans*-Nonachlor | <5 | <5 | <5 | <1 | E<1 |
| **Surrogate Standards**[a] | | | | | |
| 3,5-Dichlorobiphenyl | 72 | 98 | 72 | ND | ND |
| *alpha*-Hexachlorohexane $d_6$ | 84 | 85 | 69 | 102 | 54 |
| Nonachlorobiphenyl | 84 | 85 | 67 | ND | ND |

[a]. Surrogate standard recovery in percent.

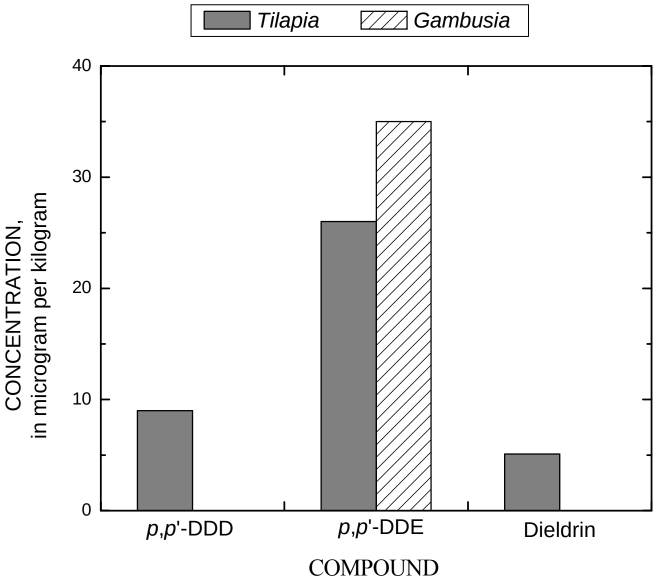

**Figure 3-8**. Concentrations of organochlorine pesticides in *Tilapia* and *Gambusia* whole-body tissue collected in the Hayfield 2 wetland, July 23, 1998.

**Table 3-9**. Concentrations of organochlorine pesticides (USGS NWQL Schedule 2101, table 2-16) in *Tilapia* whole-body, filet, liver, and other tissue and *Gambusia* whole-body tissue collected February 14, 2000 at the Hayfield and Cobble wetlands, and June 1996 at the 91st Avenue effluent channel. [µg/kg, microgram per kilogram; E, estimated concentration; ND, not determined]

| Compound | *Tilapia* Whole Body µg/kg | *Tilapia* Filet µg/kg | *Tilapia* Liver µg/kg | *Tilapia* Other µg/kg | *Gambusia* Whole Body µg/kg | *Tilapia*[a] Whole Body µg/kg |
|---|---|---|---|---|---|---|
| Lipid | 1.5% | 0.9% | 3.3% | 1.3% | 3.4% | 4.8% |
| *cis*-Chlordane | <5 | <5 | <5 | <5 | E3 | <5 |
| *trans*-Chlordane | <5 | <5 | <5 | <5 | E4 | <5 |
| *p,p'*-DDD | <5 | <5 | <5 | <5 | <5 | 9 |
| *o,p'*-DDE | <5 | <5 | <5 | <5 | <5 | 9 |
| *p,p'*-DDE | 13 | <5 | 13 | 6.5 | 44 | 2200 |
| *o,p'*-DDT | <5 | <5 | <5 | <5 | <5 | 7 |
| *p,p'*-DDT | <5 | <5 | <5 | <5 | <5 | 24 |
| Dieldrin | <5 | <5 | <5 | <5 | 8.3 | 17 |
| Lindane | <5 | <5 | <5 | <5 | 6.4 | <5 |
| *o,p'*-Methoxychlor | <5 | <5 | <5 | <5 | <5 | 12 |
| *p,p'*-Methoxychlor | <5 | <5 | <5 | <5 | <5 | 7 |
| *cis*-Nonachlor | <5 | <5 | <5 | <5 | <5 | 29 |
| *trans*-Nonachlor | 10 | <5 | 9 | E4.5 | 61 | 14 |
| PCB | <50 | <50 | <50 | <50 | 2400 | <50 |
| Toxaphene | <200 | <200 | <200 | <200 | <200 | 1800 |
| **Surrogate Standards**[b] | | | | | | |
| *alpha*-Hexachlorohexane $d_6$ | 102 | 106 | 90 | 95 | 83 | 87 |
| Nonachlorobiphenyl | 91 | 84 | 81 | 81 | 78 | ND |

[a]. Sample collected 6/5/96 at the 91st Avenue effluent channel.

[b]. Surrogate standard recovery in percent.

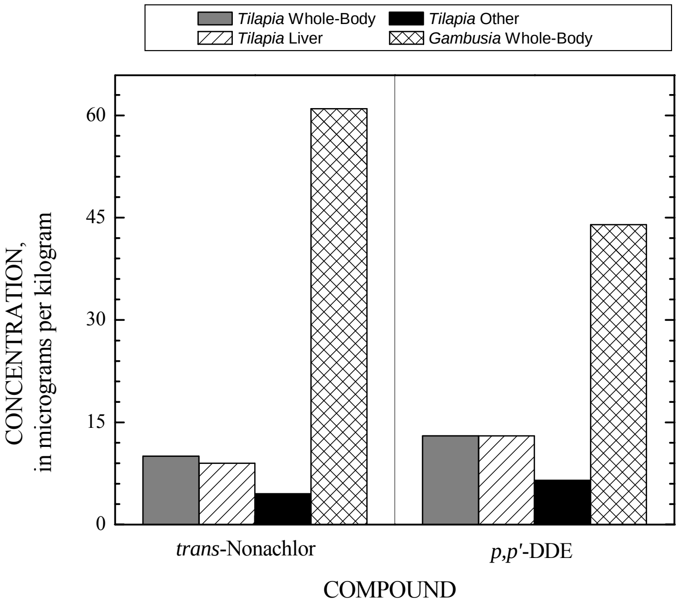

**Figure 3-9**. Concentrations of *p,p'*-DDE and *trans*-nonachlor in *Tilapia* whole-body, liver, and other tissue and *Gambusia* whole-body tissue collected in the Hayfield and Cobble wetlands, February 14, 2000.

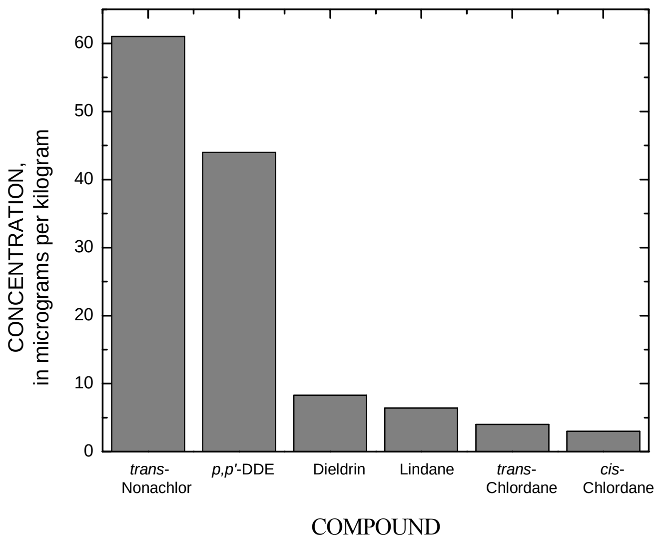

**Figure 3-10**. Concentrations of organochlorine pesticides in *Gambusia* whole-body tissue collected in the Cobble wetland, February 14, 2000.

## SEMIPERMEABLE MEMBRANE DEVICES

### 1998 DEPLOYMENT

Results from the 28 day summer (July 24 to August 21, 1998) SPMD deployment indicate that concentrations of HOC declined between the inlet and outlet of the H2 wetland, and also decreased downstream of the 91st Avenue WWTP (table 3-10). Concentrations of HOC detected in the SPMD extracts were converted to µg/kg using the standard weight of 5 SPMD (22.495 grams). Compounds detected in the trip blank were transferred to the SPMD through airborne transport or handling of the devices during deployment, retrieval, and laboratory processing. The trip blank contained traces (<5 µg/kg) of hexachlorobenzene, *trans*-nonachlor, pentachloroanisole, and more significant concentrations of *cis*-chlordane, and *trans*-chlordane.

Target HOC in the SPMD extracts typically decreased from inlet to outlet within the H2 wetland (fig. 3-11). The SPMD field data indicate a 70 to 90% reduction in *cis*-chlordane, *trans*-chlorodane, dieldrin, *p,p'*-DDE, heptachlor epoxide, lindane, and *trans*-nonachlor, and a 90 to >99% reduction in dacthal, hexachlorobenzene, *cis*-nonachlor, oxychlordane, and pentachloroanisole concentrations between the wetland inlet and outlet locations. Endosulfan isomers exhibited more conservative behavior within the system with endosulfan I showing little change in concentration whereas endosulfan II decreased 96% within the wetland. In addition to HOC, several wastewater compounds also were detected in the SPMD, with NP and TRI having the highest concentrations. There was no significant reduction in wastewater compound concentrations between the inlet and outlet, although concentrations were only estimated.

The SPMD recovered from the Bullard Avenue site were covered with a thick algae biomass that may have hindered contaminant uptake. Generally, concentrations at the Bullard

Avenue site decreased 80 to >99% relative to the H2 wetland outlet for *p,p'*-DDE, endosulfan I, endosulfan II, heptachlor epoxide, and lindane. *Cis*-chlordane, *trans*-chlordane, hexachlorobenzene, *trans*-nonachlor, and pentachloroanisole also showed significant decreases in SPMD concentrations, and were present at levels near those detected in the trip blank. The SPMD deployed at the Bullard Avenue site had nominal levels of *o,p'*-DDE, endrin, and *cis*-nonachlor which were not detected in the H2 wetland effluent.

**Table 3-10**. Concentrations of organochlorine pesticides (USGS NWQL Schedule 2101, table 2-16) and wastewater-derived compounds (table 2-9) in semipermeable membrane devices deployed in the Hayfield 2 wetland inlet and outlet and the Gila River at Bullard Avenue, July 24 to August 21, 1998. [µg/kg, micrograms per kilogram; E, value estimated because concentration is below laboratory reporting level, above highest point on the calibration curve, or for the wastewater compounds have not been validated through the GPC cleanup procedure; ND, not determined]

| Compound | Trip Blank µg/kg | Inlet µg/kg | Outlet µg/kg | Bullard Avenue µg/kg |
|---|---|---|---|---|
| **Organochlorine Compounds** | | | | |
| *cis*-Chlordane | 3.2 | E32 | 8.8 | 1.2 |
| *trans*-Chlordane | 3.8 | E38 | 10 | 1.1 |
| Dacthal | <1 | E0.24 | <5 | <5 |
| *o,p'*-DDE | <5 | <5 | <5 | 1.4 |
| *p,p'*-DDE | <5 | 13 | 3.6 | E0.30 |
| Dieldrin | <5 | E92 | E26 | 5.2 |
| Endosulfan I | <5 | E24 | E24 | 2.4 |
| Endosulfan II | <5 | 168 | E7.4 | E0.90 |
| Endrin | <5 | <5 | <5 | 1.2 |
| Heptachlor epoxide | <5 | 13 | 3.2 | E0.26 |
| Hexachlorobenzene | E0.60 | E18 | 1.8 | E0.34 |
| Lindane | <5 | E140 | 38 | 2.2 |
| *cis*-Nonachlor | <5 | 2.8 | <5 | E0.24 |
| *trans*-Nonachlor | E0.98 | 13 | 3.4 | E0.76 |
| Oxychlordane | <5 | 4.6 | <5 | <5 |
| Pentachloroanisole | E0.50 | E36 | 2.4 | E0.42 |
| **Wastewater Compounds** | | | | |
| Bisphenol A | <0.1 | E0.1 | <0.1 | ND |
| 2,6-Di-*tert*-butylbenzoquinone | <0.1 | <0.1 | E0.1 | ND |
| 2,6-Di-*tert*-butylphenol | <0.1 | E0.1 | <0.1 | ND |
| 1,4-Dichlorobenzene | <0.1 | E0.2 | E0.3 | ND |
| Nonylphenol | E0.1 | E15.2 | E19.8 | ND |
| Nonylphenolmonoethoxylate | <0.1 | E0.1 | <0.1 | ND |
| Nonylphenoldiethoxylate | <0.1 | E0.4 | E0.1 | ND |
| *normal*-Octylphenol | <0.1 | E0.5 | E0.6 | ND |
| *tert*-Octylphenol | E2.3 | E0.3 | E0.9 | ND |
| Octylphenoldiethoxylate | <0.1 | E0.8 | E3.2 | ND |
| Triclosan | <0.1 | E4.6 | E4.2 | ND |
| **Surrogate Standards**[a] | | | | |
| *alpha*-Hexachlorohexane $d_6$ | ND | ND | ND | ND |
| Nonachlorobiphenyl | ND | ND | ND | ND |

[a]. Surrogate standard recovery in percent.

## 1999 DEPLOYMENT

A SPMD time-course study was conducted in 1999 to evaluate uptake characteristics of HOC in the wetland basins. Duplicate canisters containing 5 individual SPMD were deployed in the H1 wetland inlet and outlet, and single SPMD were removed from both locations after 1, 2, 4, 6, and 8 weeks to determine concentrations of HOC amassing in the SPMD as a function of time (table 3-11). *Cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor had significant removal (90 ± 8%, 97 ± 3%, and 81 ± 5% respectively) between the H1 wetland inlet and outlet (fig. 3-12). At the inlet, *cis*-chlordane and *trans*-chlordane reached steady state by the end of week 4. The outlet *trans*-nonachlor levels appeared to reach steady state by the end of week 6.

Dieldrin had linear uptake in the first 2 weeks and reached equilibrium by the end of week 4 at the Hayfield 1 inlet (fig. 3-13a). The outlet SPMD had linear uptake for 4 weeks and reached steady state by week 6. Clearance of dieldrin was observed during weeks 6 and 8 at the inlet and during week 8 at the outlet. The average removal of dieldrin in the wetland was 64 ± 12%. Pentachloroanisole achieved equilibrium with the inlet SPMD in 4 weeks and then experienced a rapid clearance (fig. 3-13b). Outlet concentrations were 17 to 42% larger than inlet levels during the first 2 weeks. At week 4, the inlet SPMD pentachloroanisole concentration was 71% larger than the outlet concentration. Between weeks 4 and 8, the inlet pentachloroanisole levels decreased (46 ± 10%) from initial steady-state conditions and the outlet levels completely disappeared. Lindane followed a similar pattern of uptake as dieldrin and reached equilibrium with the inlet SPMD rapidly (fig. 3-13c), and the outlet SPMD exhibited linear uptake for the first 2 weeks and then leveled off. Lindane underwent an average of 37 ± 20% removal within the wetland. The inlet and outlet *p,p'*-DDE concentrations mimicked each other throughout the 8 week period (fig. 3-13d). The outlet levels were 10 to 48% higher than inlet concentrations for the first 4 weeks. The apparent internal loading may have resulted from historical DDT use in the former agricultural field at this site. The inlet and outlet SPMD had a 35 to 41% clearance of *p,p'*-DDE in week 6, and by week 8 the concentrations had increased 50 ± 8%. These results show the dynamic nature of the exposure of aquatic organisms to HOC.

## SEDIMENT

Sediment samples provide a record of compounds that have sorbed and settled out of solution over time. Aquatic organisms ingest colloidal and particulate bound pollutants that can bioaccumulate. Wetland soils indicate types of contaminants that can be resuspended by disturbance or desorption mechanisms. The amount of chemical sorbed to sediments is a function of contact time, sediment properties, and compound properties. Table 3-8 presents data for HOC associated with wetland soils collected from the H2 wetland inlet and outlet on August 21, 1998. In addition to the compounds listed in table 3-8, the inlet sediments contained trace levels of *cis*-chlordane, *trans*-chlordane, dacthal, dieldrin, endosulfan I, hexachlorobenzene, *cis*-nonachlor, and *trans*-nonachlor. The outlet soil sample had no detectable HOC.

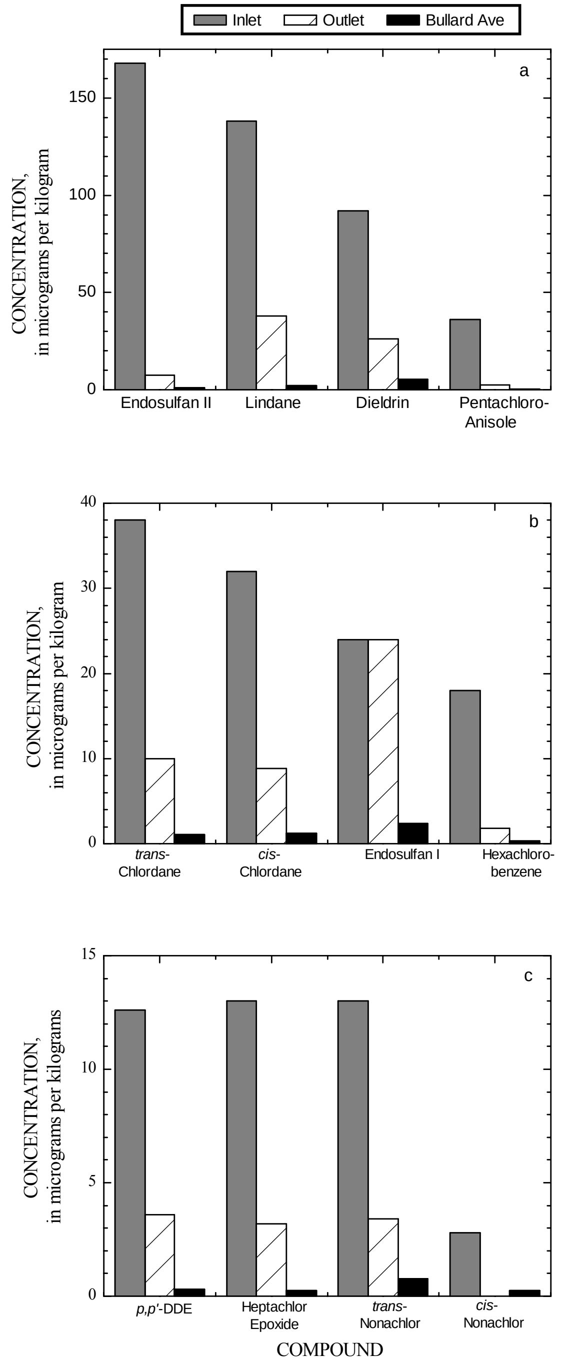

**Figure 3-11**. Concentrations of (a) endosulfan II, lindane, dieldrin, and pentachloroanisole, (b) *trans*-chlordane, *cis*-chlordane, endosulfan I, and hexachlorobenzene, and (c) *p,p'*-DDE, heptachlor epoxide, *trans*-nonachlor, and *cis*-nonachlor in semipermeable membrane devices deployed at the Hayfield 2 wetland inlet and outlet and the Gila River at Bullard Avenue, July 24 to August 21, 1998.

**Table 3-11**. Concentrations of organochlorine pesticides (USGS NWQL Schedule 2101, table 2-16) in semipermeable membrane devices collected after 1, 2, 4, 6, and 8 week deployments at the Hayfield 1 wetland inlet and outlet, June 24 to August 19, 1999. [% REC, percent recovery; µg/kg, microgram per kilogram; E, estimated value]

| Compound | Reagent Spike % REC | Reagent Blank µg/kg | Trip Blank µg/kg | Inlet 7/1/99 µg/kg | Outlet 7/1/99 µg/kg | Inlet 7/8/99 µg/kg | Outlet 7/8/99 µg/kg |
|---|---|---|---|---|---|---|---|
| *cis*-Chlordane | 109 | <5.0 | E1.4 | E2.8 | E1.7 | E3.0 | E1.0 |
| *trans*-Chlordane | 112 | <5.0 | E2.1 | E3.9 | E2.2 | E3.3 | E1.4 |
| *p,p'*-DDE | 97 | <5.0 | <5.0 | E1.4 | E2.7 | E2.0 | E3.4 |
| Dieldrin | 120 | <5.0 | <5.0 | E3.6 | E1.0 | 5.2 | E1.6 |
| Endrin | 133 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 | <5.0 |
| Hexachlorobenzene | 92 | <5.0 | <5.0 | <5.0 | E1.0 | <5.0 | E1.5 |
| Lindane | 107 | <5.0 | <5.0 | 7.1 | E2.8 | 7.4 | 5.6 |
| *trans*-Nonachlor | 109 | <5.0 | E1 | E26 | E6.0 | E42 | E12 |
| Pentachloroanisole | 105 | <5.0 | <5.0 | E4.5 | 7.8 | 10 | 12 |
| **Surrogate Standards**[a] | | | | | | | |
| *alpha*-Hexachlorohexane $d_6$ | 70 | 60 | 72 | 92 | 61 | 109 | 68 |
| Nonachlorobiphenyl | 65 | 65 | 63 | 67 | 66 | 66 | 66 |

| Compound | Inlet 7/22/99 µg/kg | Outlet 7/22/99 µg/kg | Inlet 8/5/99 µg/kg | Outlet 8/5/99 µg/kg | Inlet 8/19/99 µg/kg | Outlet 8/19/99 µg/kg |
|---|---|---|---|---|---|---|
| *cis*-Chlordane | 6.0 | E1.7 | E4.8 | E1.8 | 5.2 | E1.7 |
| *trans*-Chlordane | 6.9 | E1.7 | 6.4 | E2.4 | 6.5 | E1.7 |
| *p,p'*-DDE | 6.0 | 6.7 | E4.3 | E2.2 | 7.7 | 5.0 |
| Dieldrin | 13 | E3.1 | 11 | 5.3 | 10 | E4.8 |
| Endrin | <12 | <5.0 | <11 | <5.0 | <14 | <5.0 |
| Hexachlorobenzene | <5.0 | E 2.5 | <5.0 | <5.0 | E2.7 | <5.0 |
| Lindane | 13 | 5.8 | 10 | 7.2 | 9.8 | 8.2 |
| *trans*-Nonachlor | E120 | E16 | E122 | E26 | E130 | E23 |
| Pentachloroanisole | E28 | E8.1 | E13 | E1.7 | E17 | <5.0 |
| **Surrogate Standards**[a] | | | | | | |
| *alpha*-Hexachlorohexane $d_6$ | 103 | 70 | 125 | 65 | 133 | 70 |
| Nonachlorobiphenyl | 66 | 68 | 65 | 59 | 67 | 63 |

[a]. Surrogate standard recovery in percent.

## BIOACCUMULATION

The SPMD exposure experiments correlate with the bioavailable *p,p'*-DDE present in the aqueous phase and fish tissue (fig. 3-14a). The SPMD analysis indicates a 71% decrease in *p,p'*-DDE from inlet to outlet in 1998 and a slight increase in 1999. The fish biomass analysis shows accumulation of *p,p'*-DDE in whole-body *Tilapia* and *Gambusia* collected in 1998 and 2000. The levels of *p,p'*-DDE in *Gambusia* were 44% higher than in *Tilapia*. The *Tilapia* filet samples were free of *p,p'*-DDE in both samplings. The levels of *p,p'*-DDE in the SPMD averaged 63% lower than those detected in *Tilapia* and 79% less than detected in *Gambusia*.

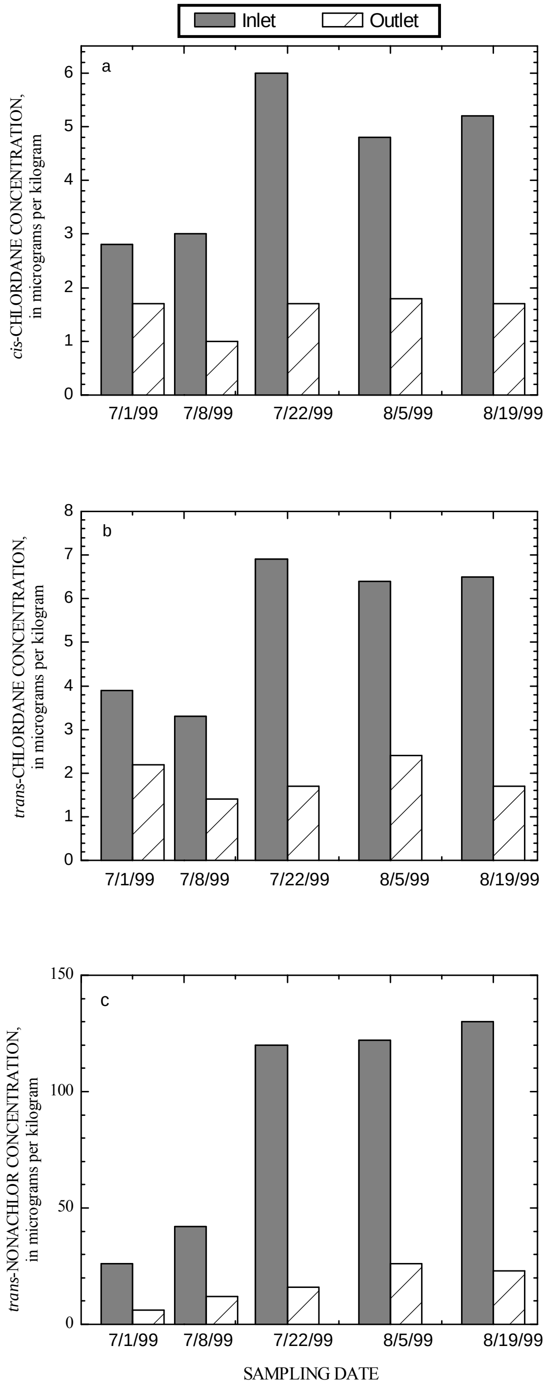

**Figure 3-12**. Concentrations of (a) *cis*-chlordane, (b) *trans*-chlordane, and (c) *trans*-nonachlor in semipermeable membrane devices deployed in the Hayfield 1 wetland inlet and outlet, June 24 to August 19, 1999.

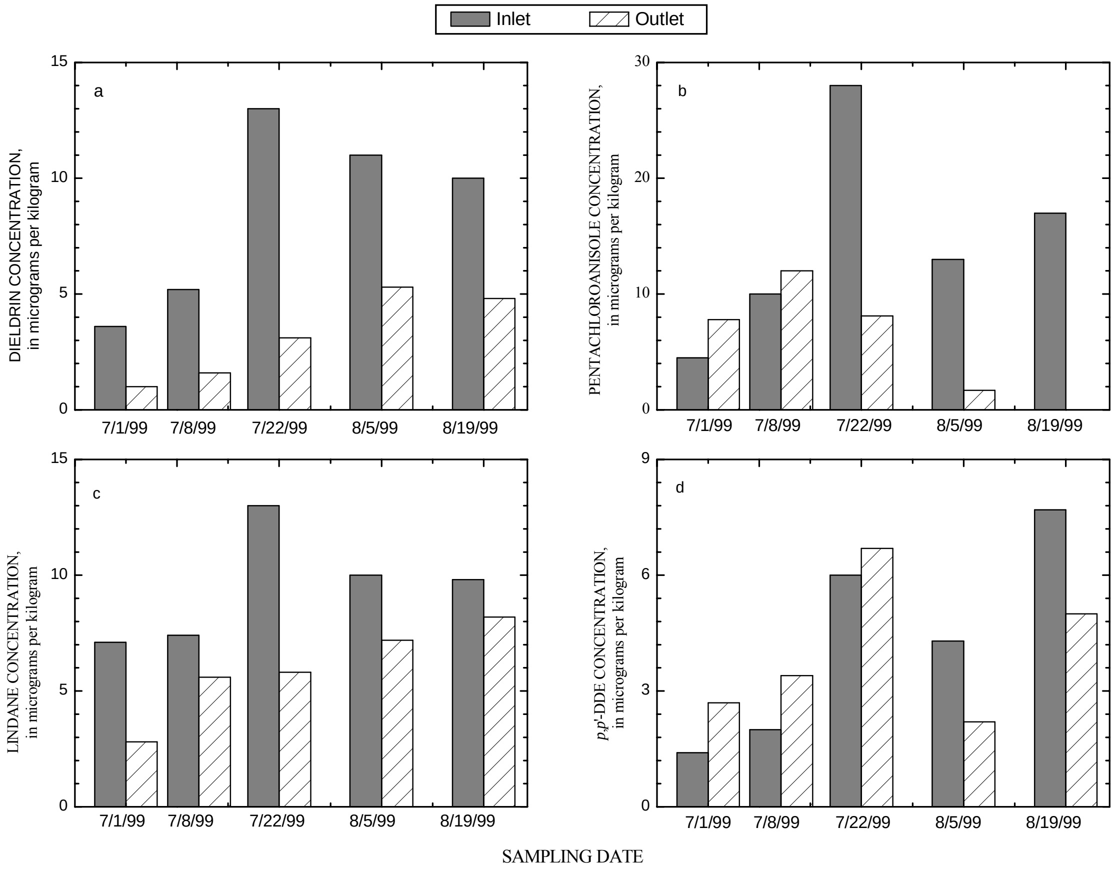

**Figure 3-13**. Concentrations of (a) *p,p'*-DDE, (b) dieldrin, (c) lindane, and (d) pentachloroanisole in semipermeable membrane devices deployed in the Hayfield 1 wetland inlet and outlet, June 24 to August 19, 1999.

The SPMD analysis also showed accumulation of *trans*-nonachlor, which averaged 75% removal between inlet and outlet sites in 1998. Concentrations in 1999 were much higher but showed a similar removal (fig. 3-14b). The 2000 *Tilapia* samples indicated nominal accumulations of *trans*-nonachlor in whole-body and liver extracts, with the other tissue extract having half as much *trans*-nonachlor. The 2000 *Gambusia* whole-body tissue had concentrations of *trans*-nonachlor six-times higher than the whole-body *Tilapia*. The 1998 sampling did not detect *trans*-nonachlor in fish tissue.

Dieldrin was detected in one *Tilapia* and one *Gambusia* sample as well as in both SPMD deployments (fig. 3-15a). There was a 76% decrease in dieldrin concentrations across the wetlands in SPMD deployed for 4 weeks during 1999. The inlet SPMD concentration was 36% higher than the *Gambusia* concentration. The dieldrin concentration in *Tilapia* was 25% lower than in *Gambusia*.

Lindane was accumulated during both SPMD experiments and was detected in one *Gambusia* sample (fig. 3-15b). The 1998 SPMD deployment showed a 73% decrease in lindane concentrations across the H2 wetland, and concentrations decreased by 53% in the H1 wetland during 1999. The concentration of lindane in *Gambusia* was equivalent to the H1 wetland outlet SPMD levels. Lindane was not detected in the *Tilapia* samples.

The *cis*-chlordane and *trans*-chlordane isomers significantly accumulated in the SPMD during the 1998 deployment, with an average 82% decrease between inlet and outlet (fig. 3-15c). The 1999 SPMD experiment had much lower levels of both isomers in the inlet samplers, with a >90% removal across the Hayfield 1 wetland. The 2000 *Gambusia* sample had 4 µg/kg *trans*-chlordane and 3 µg/kg *cis*-chlordane, roughly equal to the 1999 inlet SPMD concentrations. The *Tilapia* tissue did not have detectable chlordane concentrations.

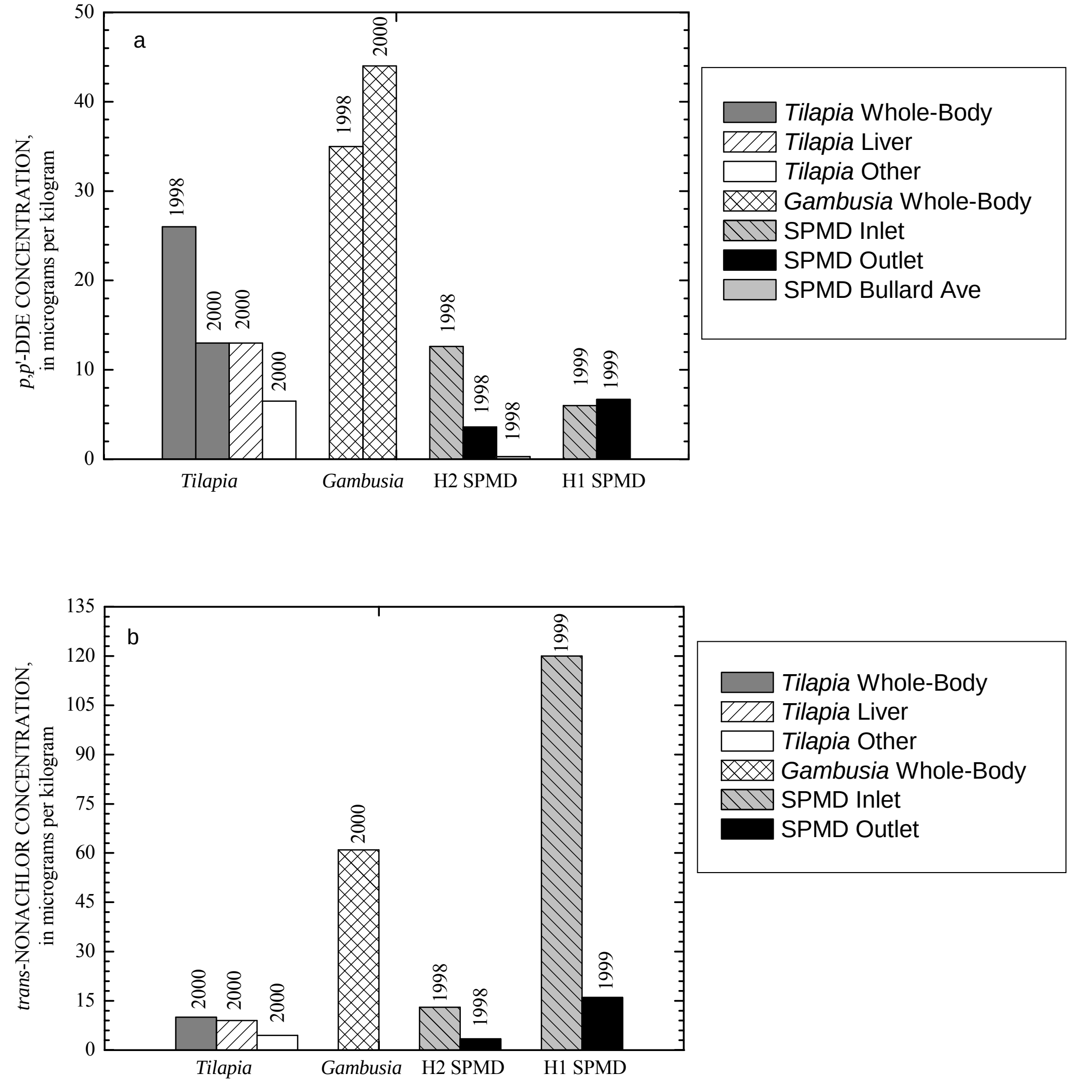

**Figure 3-14**. Concentrations of (a) *p,p'*-DDE, and (b) *trans*-nonachlor in *Tilapia* whole-body, liver, and other tissue and *Gambusia* whole-body tissue (collected from the Hayfield and Cobble wetlands, July 23, 1998 and February 14, 2000), and inlet and outlet semipermeable membrane devices (SPMD) deployed in the Hayfield wetlands (Hayfield 2 wetlans, H2, deployed July 24 to August 21, 1998; Hayfield 1 wetland, H1, deployed June 24 to July 22, 1999).

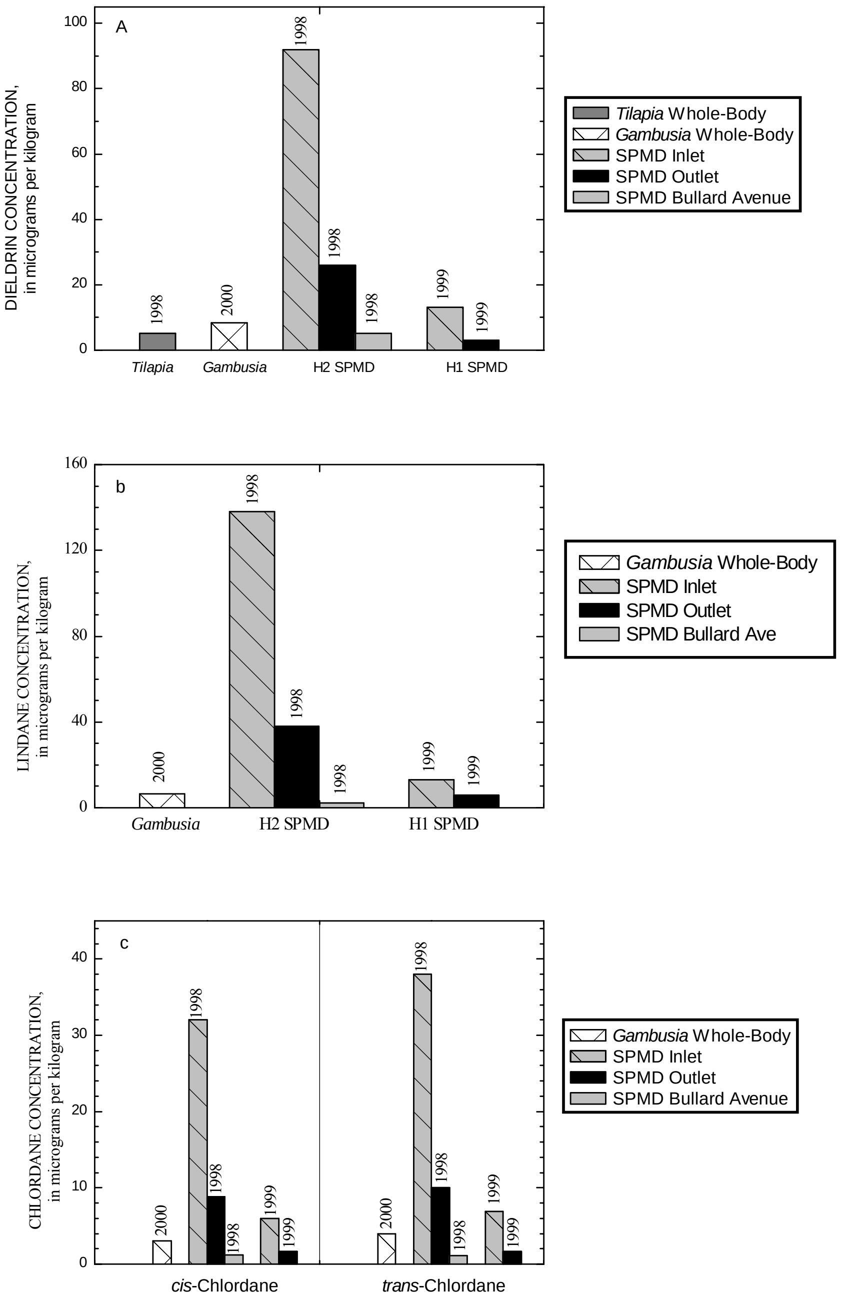

**Figure 3-15**. Concentrations of (a) *cis*-chlordane and *trans*-chlordane, (b) dieldrin, and (c) lindane in *Tilapia* whole-body tissue and *Gambusia* whole-body tissue (collected from the Hayfield and Cobble wetlands, July 23, 1998 and February 14, 2000), and inlet and outlet semipermeable membrane devices deployed in the Hayfield wetlands (Hayfield 2 wetland, H2, deployed July 24 to August 21, 1998; Hayfield 1 wetland, H1, deployed June 24 to July 22, 1999).

# CHAPTER 4 - INORGANIC CONSTITUENTS IN WATER, BIOTA, AND SEDIMENT

In addition to the field measurements and organic compounds reported in Chapter 3, inorganic compounds including major cations and anions, trace elements, and nutrients were measured. Results for these analyses are reported in this Chapter.

## QUALITY ASSURANCE

### ACCURACY

The level of accuracy for the determinations of major cations and trace element concentrations performed in this study was evaluated by three specific techniques: (1) measurement of natural matrix standard reference materials, (2) determination of spike recovery information for selected elements, and (3) measurement of laboratory blanks. This approach provides information regarding the proximity of reported analytical results to the best-known values of various elements in the measured samples. This information was used during data interpretation to evaluate bias or systematic error in the concentrations of major cations and trace elements in samples collected during the study.

### STANDARD REFERENCE MATERIALS

Two types of SRM were used: (1) natural matrix certified SRM produced by NIST, and (2) natural matrix non-certified Standard Reference Water Samples (SRWS) produced by the USGS. Multiple SRM were analyzed with all batches of water samples at a frequency of about 30% of the total number of samples. The NIST standards for dissolved samples used in this study included: SRM 1643a Trace Elements in Water, SRM 1643b Trace Elements in Water, SRM 1643d Trace Elements in Water. The USGS SRWS used in this study included: T-99, T-101, T-103, T-105, T-107, T-111, T-113, T-117, T-119, T-125, T-129, T-131, T-133, T-135, T-137, T-143 and T-145 for trace elements, and Hg-7, Hg-10, Hg-12, Hg-15 and Hg-24 for Hg determinations. Certified and “most probable values” for selected elements in each of these standards are tabulated elsewhere (Peart, 1998). Results of repeated analysis of selected elements are shown in figure 4-1. Standards used in this study for nutrient determinations include USGS SRWS N-69 and N-70. Standards used for anion measurements include USGS SRWS M-102, M-104 and M-134.

### SPIKE RECOVERIES

Selected samples were spiked, immediately after processing, for the following elements: As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, U, and Zn. Nominal concentrations for spiked elements are listed in table 4-1 along with the number of spiked samples and the frequency distribution of recovery (percent of observations within a range of percent recoveries). Specific quantities of the spike added varied, depending on the final volume of sample processed. Recovery was calculated by dividing the measured concentration of the spike by the expected value, then multiplying by 100 to convert to percent.

## BLANKS

Blanks for each step of sampling and processing, laboratory reagent blanks, and deionized water blanks were analyzed (10% frequency) with all samples. Only reagent blanks were used to correct analyte determinations. Process blanks were used to monitor potential contamination during sample collection and handling.

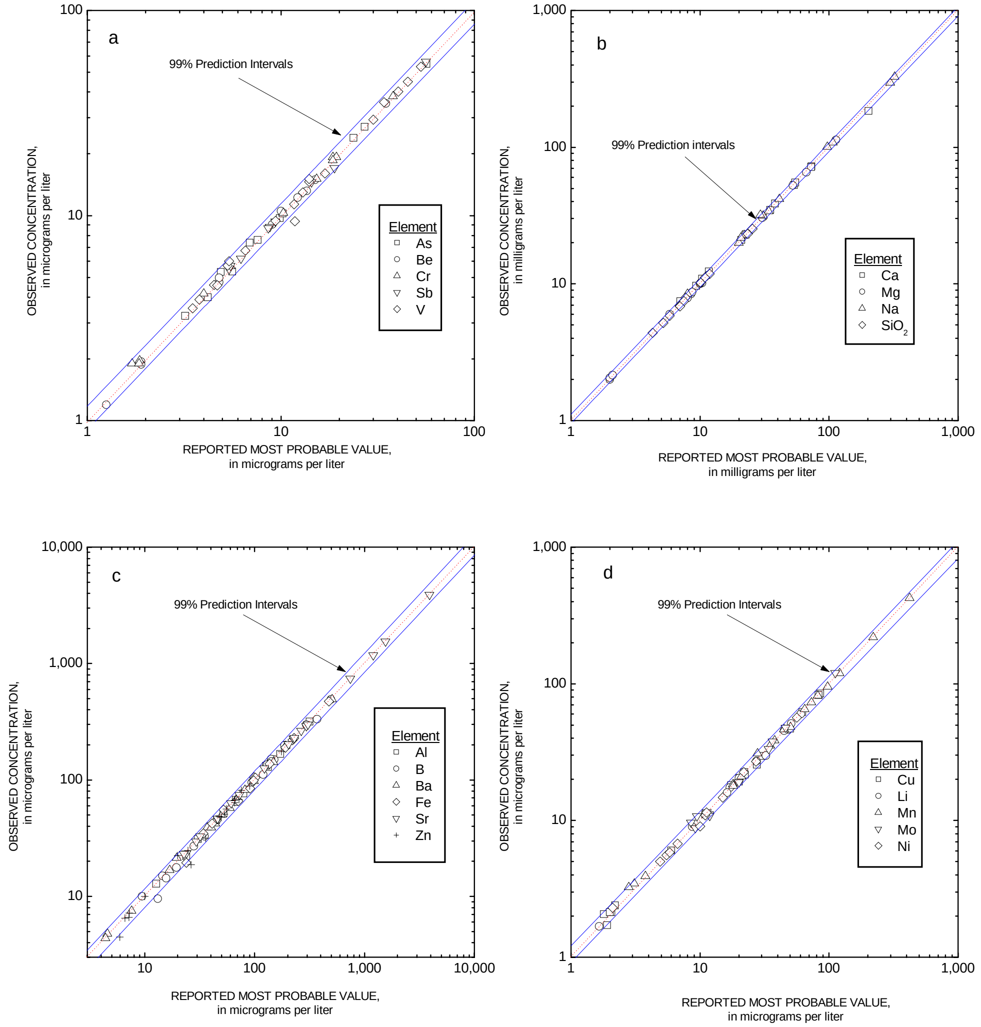

**Figure 4-1**. Correlation plots of observed concentrations of (a) antimony, arsenic, beryllium, chromium and vanadium, (b) calcium, magnesium, sodium and silica, (c) aluminum, boron, barium, iron, strontium and zinc, and (d) copper, lithium, manganese, molybdenum and nickel as a function of the Standard Reference Water Sample Program most probable value. Solid lines represent the probable error at the 99% confidence interval.

## PRECISION

All samples for dissolved constituents were determined in triplicate. Table 4-2 summarizes the relative standard deviation (RSD) of select elements. As concentrations approach the detection limit for specific elements, the precision of determination decreases. Figure 4-2 shows how the RSD increases as concentrations decrease for a typical element (Cd). The RSD is calculated by dividing the standard deviation by the mean, and multiplying by 100. The vertical lines represent the detection limit and ten times the detection limit. It is clear that RSD increases exponentially with decreasing concentration.

**Table 4-1**. Percentage of determinations for selected elements that fall within the specified range of recovery for the certified or most probable value of the spike addition in water samples. [$\text{REC}_{\text{Spike}}$, percent recovery with respect to spiked samples; N, number of observations; Conc., spiked concentration; %, percent; µg/L, micrograms per liter]

| **$\text{REC}_{\text{Spike}}$** | **Percentage of spiked samples within the specified $\text{REC}_{\text{Spike}}$ range** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Range (%)** | **As** | **Cd** | **Co** | **Cr** | **Cu** | **Hg** | **Ni** | **Pb** | **Se** | **U** | **Zn** |
| 0 – 200 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 50 – 150 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 100 | 98 |
| 75 – 125 | 98 | 100 | 100 | 98 | 98 | 100 | 100 | 98 | 100 | 98 | 98 |
| 85 – 115 | 92 | 94 | 100 | 98 | 98 | 89 | 100 | 96 | 98 | 80 | 91 |
| 90 – 110 | 78 | 88 | 98 | 88 | 85 | 69 | 96 | 82 | 94 | 62 | 83 |
| 95 – 105 | 58 | 69 | 69 | 52 | 60 | 44 | 70 | 56 | 70 | 42 | 55 |
| N | 50 | 48 | 49 | 50 | 47 | 36 | 50 | 50 | 50 | 50 | 47 |
| Conc. (µg/L) | 10 | 1 | 5 | 50 | 10 | 0.004 | 10 | 50 | 20 | 10 | 10 |

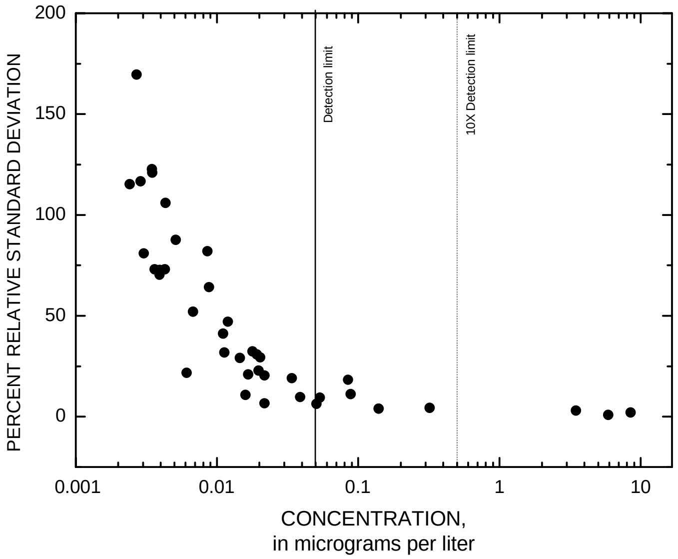

**Figure 4-2**. Plot of precision for the determination of cadmium as a function of concentration.

**Table 4-2**. Percentage of replicate samples whose relative standard deviations fall below the specified values. [MDL, method detection limit; µg/L, microgram per liter; %<, percent less than; RSD, percent relative standard deviation; N, number of samples]

| **Element** | **MDL µg/L** | **N** | **%< MDL** | **%< 100% RSD** | **%< 50% RSD** | **%< 25% RSD** | **%< 15% RSD** | **%< 10% RSD** | **%< 5% RSD** |
|---|---|---|---|---|---|---|---|---|---|
| Al | 0.05 | 46 | 0 | 100 | 100 | 100 | 98 | 89 | 76 |
| As | 0.04 | 46 | 0 | 100 | 100 | 98 | 93 | 89 | 72 |
| B | 4 | 46 | 4 | 100 | 100 | 98 | 98 | 91 | 76 |
| Ba | 0.01 | 46 | 0 | 100 | 100 | 100 | 100 | 98 | 89 |
| Be | 0.02 | 46 | 93 | 100 | 100 | 100 | 96 | 93 | 93 |
| Bi | 0.01 | 46 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Ca | 20 | 46 | 0 | 100 | 100 | 100 | 100 | 98 | 93 |
| Cd | 0.006 | 46 | 41 | 100 | 98 | 93 | 89 | 80 | 70 |
| Ce | 0.001 | 46 | 2 | 100 | 98 | 85 | 67 | 54 | 37 |
| Co | 0.01 | 46 | 52 | 100 | 100 | 96 | 91 | 89 | 83 |
| Cr | 0.2 | 46 | 26 | 100 | 100 | 93 | 80 | 65 | 43 |
| Cs | 0.06 | 46 | 67 | 96 | 93 | 91 | 85 | 76 | 67 |
| Cu | 0.02 | 46 | 0 | 100 | 98 | 98 | 98 | 96 | 74 |
| Dy | 0.002 | 46 | 59 | 100 | 100 | 91 | 89 | 85 | 72 |
| Er | 0.002 | 46 | 59 | 100 | 98 | 96 | 87 | 85 | 70 |
| Eu | 0.001 | 46 | 72 | 98 | 96 | 89 | 85 | 80 | 76 |
| Fe | 0.7 | 46 | 11 | 100 | 74 | 57 | 41 | 35 | 33 |
| Gd | 0.003 | 46 | 43 | 100 | 100 | 91 | 74 | 65 | 61 |
| Hg | 0.0004 | 47 | 19 | 100 | 100 | 74 | 60 | 55 | 36 |
| Ho | 0.0005 | 46 | 52 | 102 | 100 | 91 | 85 | 78 | 70 |
| K | 10 | 46 | 0 | 100 | 100 | 98 | 98 | 96 | 93 |
| La | 0.0005 | 46 | 0 | 100 | 98 | 93 | 70 | 61 | 35 |
| Li | 0.1 | 46 | 4 | 100 | 100 | 100 | 100 | 100 | 80 |
| Lu | 0.0005 | 46 | 74 | 100 | 96 | 91 | 85 | 83 | 80 |
| Mg | 15 | 46 | 0 | 100 | 100 | 100 | 100 | 98 | 91 |
| Mn | 0.02 | 46 | 0 | 100 | 100 | 98 | 98 | 96 | 89 |
| Mo | 0.03 | 46 | 7 | 100 | 100 | 98 | 85 | 72 | 50 |
| Na | 70 | 46 | 0 | 100 | 100 | 100 | 96 | 93 | 74 |
| Nd | 0.003 | 46 | 26 | 100 | 96 | 87 | 74 | 61 | 48 |
| Ni | 0.02 | 46 | 0 | 100 | 100 | 98 | 93 | 87 | 70 |
| Pb | 0.006 | 46 | 57 | 98 | 89 | 74 | 70 | 67 | 65 |
| Pr | 0.0005 | 46 | 17 | 100 | 100 | 87 | 74 | 65 | 52 |
| Rb | 0.002 | 46 | 0 | 100 | 100 | 100 | 98 | 98 | 80 |
| Re | 0.0013 | 46 | 83 | 100 | 100 | 93 | 91 | 91 | 87 |
| Sb | 0.02 | 46 | 9 | 100 | 100 | 91 | 80 | 72 | 46 |
| Se | 0.2 | 46 | 80 | 100 | 100 | 98 | 98 | 96 | 89 |
| $SiO_2$ | 50 | 46 | 0 | 100 | 100 | 100 | 100 | 98 | 93 |
| Sm | 0.003 | 46 | 74 | 100 | 100 | 96 | 93 | 89 | 85 |
| Sr | 0.02 | 46 | 0 | 100 | 100 | 100 | 98 | 98 | 96 |
| Tb | 0.0007 | 46 | 63 | 100 | 98 | 89 | 78 | 74 | 72 |
| Tl | 0.005 | 46 | 85 | 100 | 100 | 100 | 98 | 98 | 96 |
| Tm | 0.0005 | 46 | 74 | 100 | 98 | 91 | 89 | 85 | 80 |
| U | 0.002 | 46 | 7 | 100 | 100 | 98 | 96 | 87 | 70 |
| V | 0.05 | 46 | 4 | 100 | 100 | 100 | 100 | 98 | 93 |
| Y | 0.0004 | 46 | 0 | 100 | 100 | 93 | 85 | 74 | 46 |
| Yb | 0.0014 | 46 | 48 | 100 | 96 | 87 | 74 | 67 | 63 |
| Zn | 0.08 | 46 | 0 | 98 | 98 | 91 | 67 | 59 | 33 |
| Zr | 0.01 | 46 | 67 | 100 | 100 | 91 | 83 | 80 | 78 |

# WATER

## MAJOR CATIONS AND ANIONS

Major cations were measured in water samples collected from the inlet and outlet of the Hayfield 2 wetland on 5 separate days during July and August 1998 (table 4-3). These data demonstrate that although there was a slight increase in outlet concentrations, within experimental error, there was little difference in the bulk water chemistry between the inlet and outlet on a particular day or over the one-month period for which samples were collected (fig. 4-3). These results are consistent with specific conductance and TOC measurements.

Major anion and cation results for water samples collected in 1999 and 2000 from the Hayfield inlet and Hayfield 1 and 2 outlets, the Cobble inlet and Cobble 1 and 2 outlet, the Gila River at Bullard Avenue, the Gila River at 115th Avenue, and the 91st Avenue dewatering well sites are presented in table 4-4. As was observed for the 1998 data, there was little difference in the bulk water chemistry between the inlets and outlets of the Hayfield and Cobble wetlands. Results for replicate samples, collected for quality control purposes, also are included in table 4-4 and show excellent agreement. For the Cobble wetlands inlet and outlet samples collected in June 1999 and February 2000, no differences are observed for any of the major ions. Comparable samples collected from the Hayfield site in February 2000 indicated a minor elevation in concentration of major constituents in the outlets relative to the inlet.

**Table 4-3**. Summary of major cation results for water samples collected from the Hayfield wetland inlet and Hayfield 2 wetland outlet, July to August 1998.

| Element | Concentration Unit | Hayfield Inlet 7/24/98 | Hayfield 2 Outlet 7/24/98 | Hayfield Inlet 7/28/98 | Hayfield 2 Outlet 7/28/98 | Hayfield Inlet 8/4/98 |
|---|---|---|---|---|---|---|
| Ca | mg/L | 59 ± 1 | 61 ± 2 | 62 ± 2 | 62 ± 0 | 61 ± 2 |
| Mg | mg/L | 23 ± 0 | 25 ± 1 | 25 ± 1 | 25 ± 0 | 25 ± 0 |
| Na | mg/L | 215 ± 0 | 227 ± 2 | 232 ± 9 | 232 ± 2 | 229 ± 0 |
| K | mg/L | 18 ± 1 | 20 ± 1 | 19 ± 1 | 21 ± 1 | 20 ± 0 |
| $SiO_2$ | mg/L | 19 ± 0 | 19 ± 0 | 20 ± 0 | 20 ± 0 | 20 ± 0 |

| Element | Concentration Unit | Hayfield 2 Outlet 8/4/98 | Hayfield Inlet 8/10/98 | Hayfield 2 Outlet 8/10/98 | Hayfield Inlet 8/18/98 | Hayfield 2 Outlet 8/18/98 |
|---|---|---|---|---|---|---|
| Ca | mg/L | 62 ± 2 | 58 ± 3 | 63 ± 0 | 61 ± 3 | 62 ± 2 |
| Mg | mg/L | 26 ± 0 | 24 ± 0 | 25 ± 0 | 25 ± 0 | 25 ± 0 |
| Na | mg/L | 233 ± 1 | 227 ± 2 | 239 ± 1 | 234 ± 0 | 232 ± 0 |
| K | mg/L | 22 ± 0 | 19 ± 0 | 21 ± 0 | 20 ± 0 | 21 ± 0 |
| $SiO_2$ | mg/L | 20 ± 1 | 18 ± 0 | 20 ± 2 | 20 ± 0 | 19 ± 1 |

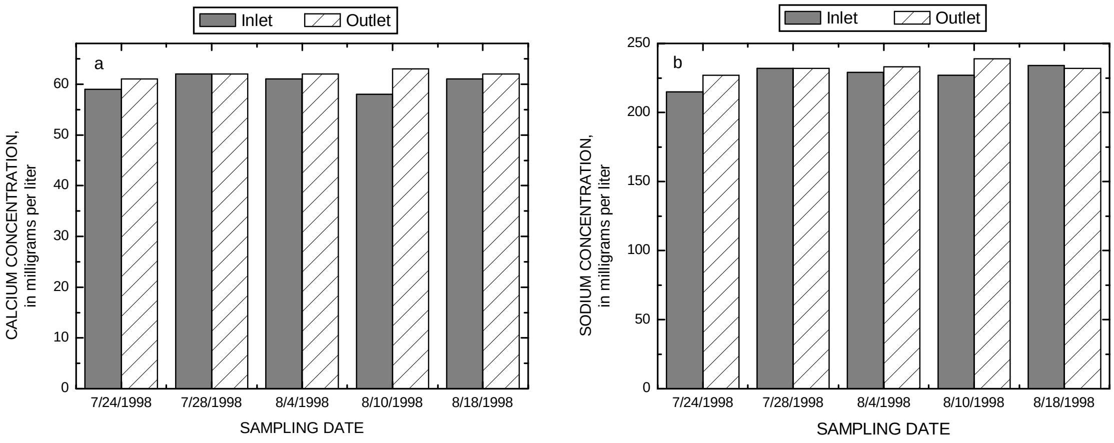

**Figure 4-3**. Plots of dissolved (a) calcium and (b) sodium concentrations in water samples collected from the Hayfield 2 wetland inlet and outlet on various days from July 24 to August 18, 1998.

## TRACE ELEMENTS

Trace elements listed in table 2-11 were determined in water samples collected from the inlet and outlet of the H2 wetland during July and August 1998 (table 4-5). The results are fairly consistent from day to day for both inlet and outlet samples. Several trace elements had average concentrations in the inlet that were higher (>20%) that in the outlet (Al, Bi, Cd, Cr, Cs, Cu, Gd, Ni, Pb, Sb, Se, Tl, U, V, Zn), some had similar concentrations (<20% difference) in the inlet and outlet (As, B, Co, Fe, Li, Mo, Rb, Re, Sr, Te, and Zr), and others had greater (>20%) concentrations in the outlet than the inlet (Ba, Be, Ce, Dy, Er, Eu, Ho, La, Lu, Mn, Nd, Pr, Sm, Tb, Th, Tm, Y, Yb). Example plots of As, Cu, Pb and Zn are shown in figure 4-4. These results show that As concentrations increase slightly in the wetlands (average outlet concentration was 9.2% higher than the inlet), whereas the Cu, Pb, and Zn concentrations were significantly reduced (92%, 56% and 60% respectively).

Trace element analyses for water samples collected in 1999 and 2000 from the Hayfield wetland inlet and H1 and H2 outlets, the Cobble wetland inlet and C1 and C2 outlets, the Gila River at Bullard Avenue, the Gila River at 115th Avenue, and the 91st Avenue dewatering well sites are presented in table 4-6. Comparison of results for selected trace elements (Al, As, Cd, Cu, Pb, and Zn) at each of the sites sampled during February 2000 are shown in figure 4-5.

**Table 4-4**. Summary of duplicate major anion and cation results for water samples collected from the Cobble wetland inlet, Cobble 2 wetland outlet, and the Gila River at Bullard Avenue during June 1999, and from the Cobble wetland inlet, Cobble 1 and Cobble 2 wetlands outlets, Hayfield wetland inlet, Hayfield 1 and Hayfield 2 wetlands outlets, the Gila River at 115th and Bullard Avenues, and the 91st Avenue dewatering well during February 2000.

| Element | Concentration Unit | Cobble Inlet 6/23/99 | Cobble Inlet 6/23/99 | Cobble 2 Outlet 6/23/99 | Cobble 2 Outlet 6/23/99 | Bullard Avenue 6/23/99 | Bullard Avenue 6/23/99 |
|---|---|---|---|---|---|---|---|
| Ca | mg/L | 67 ± 23 | 66 ± 3 | 63 ± 5 | 69 ± 5 | 110 ± 10 | 110 ± 10 |
| Mg | mg/L | 28 ± 9 | 28 ± 0 | 26 ± 2 | 29 ± 2 | 47 ± 6 | 48 ± 7 |
| Na | mg/L | 290 ± 10 | 270 ± 0 | 280 ± 0 | 290 ± 10 | 390 ± 20 | 400 ± 0 |
| K | mg/L | 24 ± 1 | 22 ± 1 | 21 ± 0 | 20 ± 3 | 20 ± 1 | 21 ± 0 |
| $SiO_2$ | mg/L | 18 ± 5 | 19 ± 1 | 16 ± 1 | 17 ± 1 | 20 ± 2 | 20 ± 2 |
| Cl | mg/L | 420 ± 50 | 550 ± 40 | 530 ± 10 | 410 ± 0 | 730 ± 20 | 690 ± 50 |
| $SO_4$ | mg/L | 194 ± 60 | 192 ± 7 | 185 ± 12 | 193 ± 4 | 275 ± 31 | 276 ± 34 |

| Element | Concentration Unit | Cobble Inlet 2/14/00 | Cobble Inlet 2/14/00 | Cobble 1 Outlet 2/14/00 | Cobble 1 Outlet 2/14/00 | Cobble 2 Outlet 2/14/00 | Cobble 2 Outlet 2/14/00 |
|---|---|---|---|---|---|---|---|
| Ca | mg/L | 60 ± 3 | 61 ± 1 | 65 ± 2 | 64 ± 2 | 64 ± 2 | 66 ± 2 |
| Mg | mg/L | 30 ± 1 | 30 ± 1 | 31 ± 1 | 31 ± 1 | 30 ± 1 | 31 ± 0 |
| Na | mg/L | 169 ± 1 | 165 ± 2 | 173 ± 3 | 172 ± 2 | 167 ± 4 | 169 ± 1 |
| K | mg/L | 17 ± 0 | 17 ± 0 | 18 ± 0 | 18 ± 0 | 17 ± 0 | 18 ± 1 |
| $SiO_2$ | mg/L | 19 ± 1 | 19 ± 0 | 18 ± 0 | 17 ± 0 | 18 ± 0 | 18 ± 1 |
| Cl | mg/L | 300 ± 20 | 280 ± 30 | 300 ± 10 | 330 ± 10 | 270 ± 30 | 310 ± 10 |
| $SO_4$ | mg/L | 190 ± 5 | 191 ± 4 | 210 ± 6 | 202 ± 5 | 199 ± 6 | 204 ± 5 |

| Element | Concentration Unit | Hayfield Inlet 2/15/00 | Hayfield Inlet 2/15/00 | Hayfield 1 Outlet 2/15/00 | Hayfield 1 Outlet 2/15/00 | Hayfield 2 Outlet 2/15/00 | Hayfield 2 Outlet 2/15/00 |
|---|---|---|---|---|---|---|---|
| Ca | mg/L | 65 ± 12 | 61 ± 21 | 64 ± 5 | 69 ± 1 | 70 ± 4 | 69 ± 4 |
| Mg | mg/L | 31 ± 6 | 29 ± 9 | 30 ± 2 | 32 ± 1 | 33 ± 3 | 33 ± 2 |
| Na | mg/L | 190 ± 10 | 190 ± 10 | 190 ± 20 | 210 ± 10 | 180 ± 10 | 190 ± 10 |
| K | mg/L | 19 ± 1 | 19 ± 1 | 19 ± 2 | 22 ± 1 | 19 ± 1 | 19 ± 1 |
| $SiO_2$ | mg/L | 20 ± 3 | 19 ± 5 | 16 ± 0 | 17 ± 1 | 15 ± 1 | 15 ± 1 |
| Cl | mg/L | 180 ± 30 | 170 ± 0 | 170 ± 10 | 170 ± 10 | 180 ± 30 | 180 ± 30 |
| $SO_4$ | mg/L | 189 ± 32 | 176 ± 56 | 185 ± 11 | 199 ± 56 | 204 ± 12 | 202 ± 10 |

| Element | Concentration Unit | Bullard Avenue 2/13/00 | Bullard Avenue 2/13/00 | 115th Avenue 2/13/00 | 115th Avenue 2/13/00 | 91st Avenue Well 2/16/00 |
|---|---|---|---|---|---|---|
| Ca | mg/L | 94 ± 2 | 93 ± 4 | 115 ± 2 | 118 ± 2 | 57 ± 0 |
| Mg | mg/L | 46 ± 1 | 46 ± 2 | 52 ± 2 | 54 ± 1 | 27 ± 1 |
| Na | mg/L | 270 ± 7 | 276 ± 4 | 364 ± 2 | 380 ± 6 | 290 ± 80 |
| K | mg/L | 14 ± 0 | 14 ± 0 | 15 ± 0 | 15 ± 0 | 5.9 ± 2 |
| $SiO_2$ | mg/L | 21 ± 0 | 21 ± 1 | 20 ± 0 | 21 ± 0 | 32 ± 0 |
| Cl | mg/L | 660 ± 20 | 550 ± 0 | 910 ± 30 | 910 ± 40 | 250 ± 20 |
| $SO_4$ | mg/L | 245 ± 2 | 249 ± 2 | 300 ± 4 | 310 ± 1 | 182 ± 2 |

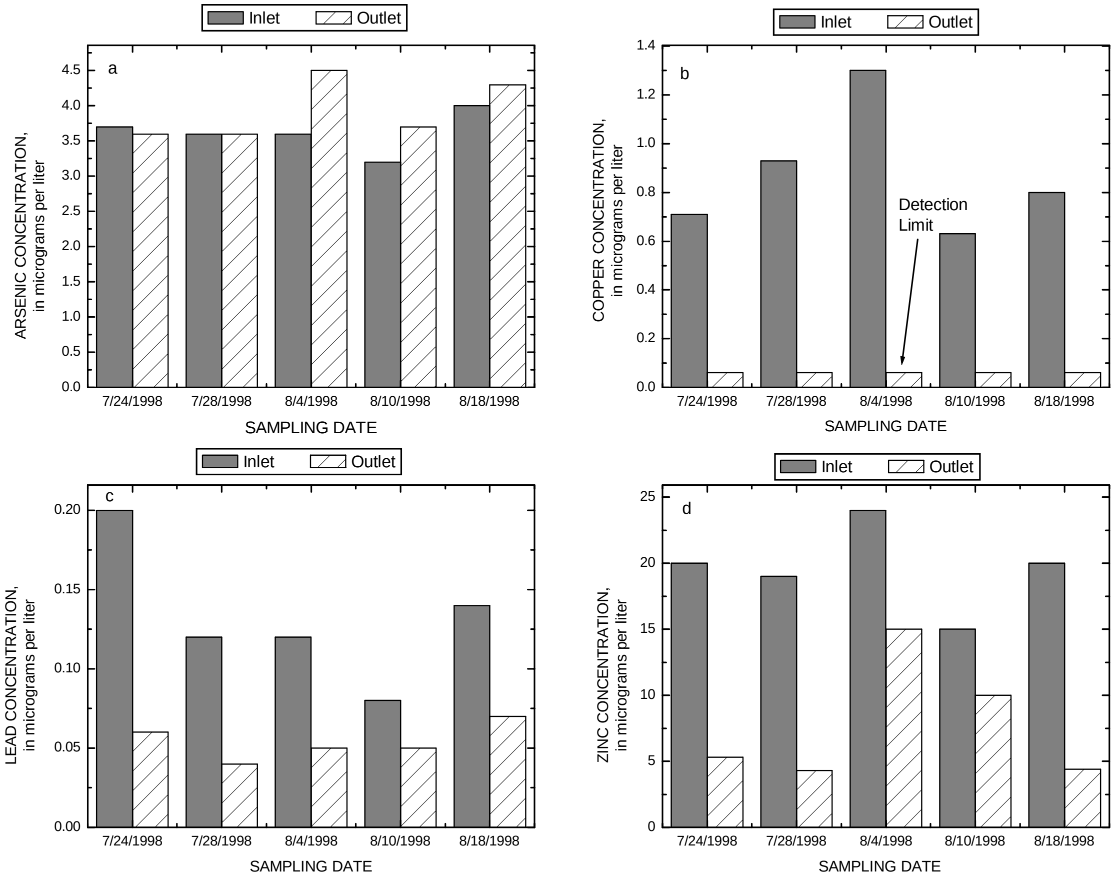

**Figure 4-4**. Plots of dissolved (a) arsenic, (b) copper, (c) lead, and (d) zinc concentrations in water samples collected from the Hayfield 2 wetland inlet and outlet on various days from July 24 to August 18, 1998.

**Table 4-5**. Concentrations of dissolved trace elements for water samples collected from the Hayfield wetland inlet and the Hayfield 2 wetland outlet during July to August 1998. [µg/L, micrograms per liter]

| **Element** | **Concentration Unit** | **Hayfield Inlet 7/24/98** | **Hayfield 2 Outlet 7/24/98** | **Hayfield Inlet 7/28/98** | **Hayfield 2 Outlet 7/28/98** | **Hayfield Inlet 8/4/98** |
|---|---|---|---|---|---|---|
| Al | µg/L | 9.9 ± 1 | 1.8 ± 0.2 | 11 ± 1 | 1.9 ± 0.3 | 7.9 ± 0.4 |
| As | µg/L | 3.7 ± 0 | 3.6 ± 0 | 3.6 ± 0.3 | 3.6 ± 0 | 3.6 ± 0 |
| B | µg/L | 364 ± 13 | 354 ± 1 | 413 ± 2 | 391 ± 7 | 385 ± 1 |
| Ba | µg/L | 23 ± 0 | 29 ± 1 | 22 ± 0 | 31 ± 0 | 19 ± 0 |
| Be | µg/L | < 0.008 ± 0.005 | 0.01 ± 0.004 | < 0.008 ± 0.009 | < 0.008 ± 0.003 | < 0.008 ± 0.003 |
| Bi | µg/L | 0.009 ± 0.003 | 0.002 ± 0 | 0.005 ± 0 | 0.003 ± 0.001 | 0.006 ± 0.002 |
| Cd | µg/L | 0.23 ± 0 | 0.027 ± 0.003 | < 0.002 ± 0.007 | < 0.002 ± 0.006 | < 0.002 ± 0.006 |
| Ce | µg/L | 0.018 ± 0 | 0.033 ± 0 | 0.02 ± 0 | 0.037 ± 0 | 0.014 ± 0 |
| Co | µg/L | 0.36 ± 0.03 | 0.48 ± 0.05 | 0.31 ± 0.01 | 0.28 ± 0 | 0.28 ± 0 |
| Cr | µg/L | 0.7 ± 0.1 | 0.5 ± 0.1 | 0.8 ± 0.3 | 0.5 ± 0.2 | 0.7 ± 0.2 |
| Cs | µg/L | 0.108 ± 0 | 0.065 ± 0 | 0.097 ± 0.002 | 0.068 ± 0.003 | 0.091 ± 0.003 |
| Cu | µg/L | 0.71 ± 0.04 | 0.07 ± 0.01 | 0.93 ± 0.05 | < 0.06 ± 0.06 | 1.3 ± 0.2 |
| Dy | µg/L | 0.0028 ± 0.0004 | 0.0052 ± 0.001 | 0.0026 ± 0 | 0.006 ± 0.0001 | 0.0018 ± 0.0003 |
| Er | µg/L | 0.002 ± 0.0005 | 0.0045 ± 0.0002 | 0.0021 ± 0.0007 | 0.0045 ± 0.0006 | 0.0019 ± 0.0005 |
| Eu | µg/L | 0.0017 ± 0.0006 | 0.0025 ± 0.0006 | 0.0016 ± 0.0005 | 0.0029 ± 0.0011 | 0.0015 ± 0.0012 |
| Fe | µg/L | 84 ± 0 | 83 ± 3 | 99 ± 4 | 168 ± 0 | 81 ± 0 |
| Gd | µg/L | 0.081 ± 0.001 | 0.067 ± 0.001 | 0.067 ± 0.004 | 0.031 ± 0 | 0.064 ± 0.002 |
| Ho | µg/L | 0.0012 ± 0.0001 | 0.0019 ± 0.0001 | 0.0012 ± 0.0001 | 0.0015 ± 0.0001 | 0.0011 ± 0 |
| La | µg/L | 0.0062 ± 0.0001 | 0.007 ± 0.0006 | 0.006 ± 0.0007 | 0.0086 ± 0.0001 | 0.0054 ± 0.0002 |
| Li | µg/L | 105 ± 0 | 105 ± 1 | 111 ± 1 | 107 ± 2 | 105 ± 0 |
| Lu | µg/L | 0.0004 ± 0.0002 | 0.0008 ± 0.0001 | 0.0006 ± 0.0001 | 0.0006 ± 0.0001 | 0.0004 ± 0.0001 |
| Mn | µg/L | 34 ± 1 | 76 ± 6 | 38 ± 0 | 87 ± 1 | 33 ± 0 |
| Mo | µg/L | 25 ± 1 | 21 ± 0 | 30 ± 1 | 19 ± 1 | 26 ± 0 |
| Nd | µg/L | 0.007 ± 0.002 | 0.014 ± 0 | 0.008 ± 0 | 0.016 ± 0.001 | 0.007 ± 0.001 |
| Ni | µg/L | 4.6 ± 0.2 | 3.4 ± 0.1 | 4 ± 0.1 | 2.2 ± 0.2 | 8.3 ± 0.3 |
| Pb | µg/L | 0.2 ± 0.01 | 0.06 ± 0 | 0.12 ± 0.01 | 0.04 ± 0.01 | 0.12 ± 0.02 |
| Pr | µg/L | 0.0017 ± 0 | 0.0028 ± 0.0001 | 0.0019 ± 0.0001 | 0.0039 ± 0 | 0.0014 ± 0 |
| Rb | µg/L | 15 ± 0 | 14 ± 0 | 15 ± 1 | 15 ± 1 | 15 ± 0 |
| Re | µg/L | 0.081 ± 0 | 0.081 ± 0.002 | 0.085 ± 0.001 | 0.085 ± 0.004 | 0.083 ± 0.002 |
| Sb | µg/L | 0.69 ± 0.01 | 0.43 ± 0 | 0.66 ± 0 | 0.42 ± 0 | 0.78 ± 0 |
| Se | µg/L | 0.3 ± 0.15 | < 0.09 ± 0.01 | 0.11 ± 0.06 | < 0.09 ± 0.1 | 0.11 ± 0.06 |
| Sm | µg/L | 0.002 ± 0 | 0.004 ± 0.001 | 0.002 ± 0 | 0.005 ± 0 | 0.002 ± 0.001 |
| Sr | µg/L | 662 ± 18 | 692 ± 21 | 686 ± 24 | 730 ± 39 | 680 ± 11 |
| Tb | µg/L | 0.0007 ± 0 | 0.001 ± 0.0002 | 0.0007 ± 0 | 0.0009 ± 0.0001 | 0.0006 ± 0 |
| Te | µg/L | 0.031 ± 0.006 | 0.026 ± 0 | 0.036 ± 0.005 | 0.038 ± 0.005 | 0.036 ± 0.003 |
| Th | µg/L | 0.0006 ± 0.0002 | 0.0008 ± 0.0001 | 0.0005 ± 0.0001 | 0.0006 ± 0 | 0.0003 ± 0.0001 |
| Tl | µg/L | 0.002 ± 0 | 0.002 ± 0.002 | 0.002 ± 0.001 | < 0.001 ± 0 | 0.002 ± 0.001 |
| Tm | µg/L | 0.0004 ± 0.0001 | 0.0006 ± 0.0001 | < 0.0001 ± 0 | 0.0006 ± 0.0001 | 0.0003 ± 0.0002 |
| U | µg/L | 0.87 ± 0.04 | 0.54 ± 0.02 | 1.09 ± 0.05 | 0.47 ± 0.02 | 1.01 ± 0.05 |
| V | µg/L | 5.4 ± 0.2 | 2.4 ± 0.2 | 5.6 ± 0.5 | 2.1 ± 0.2 | 4.7 ± 0.3 |
| Y | µg/L | 0.018 ± 0.001 | 0.034 ± 0 | 0.017 ± 0 | 0.029 ± 0 | 0.014 ± 0.001 |
| Yb | µg/L | 0.0019 ± 0.0001 | 0.0041 ± 0.0009 | 0.002 ± 0.0002 | 0.0037 ± 0.0004 | 0.0019 ± 0.0003 |
| Zn | µg/L | 20 ± 1 | 5.3 ± 0.2 | 19 ± 1 | 4.3 ± 0.2 | 24 ± 2 |
| Zr | µg/L | 0.029 ± 0.001 | 0.026 ± 0.003 | 0.044 ± 0.001 | 0.026 ± 0.003 | 0.043 ± 0.002 |

**Table 4-5.** Continued.

| Element | Concen-tration Unit | Hayfield 2 Outlet 8/4/98 | Hayfield Inlet 8/10/98 | Hayfield 2 Outlet 8/10/98 | Hayfield Inlet 8/18/98 | Hayfield 2 Outlet 8/18/98 |
|---|---|---|---|---|---|---|
| Al | µg/L | 4.9 ± 1.4 | 11 ± 1 | 1.6 ± 0.2 | 7 ± 0.7 | 22 ± 1 |
| As | µg/L | 4.5 ± 0 | 3.2 ± 0 | 3.7 ± 0 | 4 ± 0 | 4.3 ± 0 |
| B | µg/L | 407 ± 0 | 455 ± 3 | 399 ± 3 | 388 ± 6 | 407 ± 4 |
| Ba | µg/L | 26 ± 1 | 22 ± 1 | 28 ± 0 | 20 ± 0 | 29 ± 0 |
| Be | µg/L | 0.01 ± 0.003 | < 0.008 ± 0.008 | 0.008 ± 0.003 | < 0.008 ± 0.002 | 0.015 ± 0.006 |
| Bi | µg/L | 0.012 ± 0.001 | 0.006 ± 0 | 0.003 ± 0.001 | 0.006 ± 0.002 | 0.003 ± 0 |
| Cd | µg/L | < 0.002 ± 0.003 | < 0.002 ± 0.006 | < 0.002 ± 0.005 | < 0.002 ± 0.003 | < 0.002 ± 0.005 |
| Ce | µg/L | 0.033 ± 0.003 | 0.019 ± 0.001 | 0.031 ± 0 | 0.02 ± 0 | 0.069 ± 0 |
| Co | µg/L | 0.32 ± 0.01 | 0.22 ± 0 | 0.32 ± 0.03 | 0.42 ± 0.05 | 0.49 ± 0 |
| Cr | µg/L | 0.7 ± 0.3 | 0.7 ± 0.2 | 0.4 ± 0.1 | 0.7 ± 0.2 | 0.7 ± 0.2 |
| Cs | µg/L | 0.069 ± 0.001 | 0.081 ± 0.002 | 0.064 ± 0.001 | 0.099 ± 0.002 | 0.053 ± 0.002 |
| Cu | µg/L | < 0.06 ± 0.06 | 0.63 ± 0.04 | < 0.06 ± 0.01 | 0.8 ± 0.05 | < 0.06 ± 0.1 |
| Dy | µg/L | 0.0048 ± 0.0008 | 0.0024 ± 0.0007 | 0.0041 ± 0.0003 | 0.0028 ± 0 | 0.0067 ± 0.001 |
| Er | µg/L | 0.0038 ± 0 | 0.002 ± 0.0007 | 0.0037 ± 0.0003 | 0.0022 ± 0.0002 | 0.0057 ± 0.0003 |
| Eu | µg/L | 0.0015 ± 0.0006 | 0.0014 ± 0.0004 | 0.0026 ± 0.0011 | 0.0012 ± 0.0004 | 0.0023 ± 0.0006 |
| Fe | µg/L | 71 ± 1 | 85 ± 0 | 91 ± 0 | 83 ± 0 | 107 ± 0 |
| Gd | µg/L | 0.028 ± 0.001 | 0.012 ± 0 | 0.057 ± 0.003 | 0.044 ± 0 | 0.03 ± 0 |
| Ho | µg/L | 0.0018 ± 0.0001 | 0.0011 ± 0.0001 | 0.0016 ± 0.0001 | 0.0011 ± 0.0001 | 0.002 ± 0.0001 |
| La | µg/L | 0.0079 ± 0.0005 | 0.0062 ± 0 | 0.0068 ± 0.0003 | 0.005 ± 0.0001 | 0.026 ± 0.001 |
| Li | µg/L | 105 ± 6 | 104 ± 0 | 110 ± 2 | 113 ± 2 | 108 ± 1 |
| Lu | µg/L | 0.0007 ± 0.0001 | 0.0005 ± 0.0001 | 0.0005 ± 0.0001 | 0.0004 ± 0.0001 | 0.001 ± 0.0003 |
| Mn | µg/L | 79 ± 1 | 28 ± 0 | 67 ± 2 | 34 ± 0 | 110 ± 1 |
| Mo | µg/L | 20 ± 0 | 23 ± 1 | 25 ± 1 | 27 ± 1 | 20 ± 1 |
| Nd | µg/L | 0.017 ± 0.001 | 0.01 ± 0.001 | 0.015 ± 0 | 0.008 ± 0.001 | 0.033 ± 0 |
| Ni | µg/L | 3.1 ± 0.3 | 2.6 ± 0.4 | 4 ± 0.4 | 4.4 ± 0.5 | 3.6 ± 0.2 |
| Pb | µg/L | 0.05 ± 0.01 | 0.08 ± 0 | 0.05 ± 0 | 0.14 ± 0.01 | 0.07 ± 0 |
| Pr | µg/L | 0.0035 ± 0.0004 | 0.0023 ± 0.0002 | 0.0032 ± 0.0001 | 0.002 ± 0.0001 | 0.0083 ± 0.0006 |
| Rb | µg/L | 15 ± 0 | 14 ± 0 | 15 ± 1 | 16 ± 0 | 14 ± 1 |
| Re | µg/L | 0.085 ± 0 | 0.082 ± 0.005 | 0.088 ± 0.001 | 0.086 ± 0.004 | 0.082 ± 0.003 |
| Sb | µg/L | 0.41 ± 0.01 | 0.66 ± 0 | 0.45 ± 0 | 0.67 ± 0.01 | 0.49 ± 0.01 |
| Se | µg/L | < 0.09 ± 0.11 | 0.16 ± 0.17 | 0.24 ± 0.02 | 0.35 ± 0.18 | < 0.09 ± 0.01 |
| Sm | µg/L | 0.004 ± 0 | 0.002 ± 0.001 | 0.003 ± 0.001 | 0.002 ± 0.001 | 0.007 ± 0.001 |
| Sr | µg/L | 687 ± 10 | 663 ± 5 | 733 ± 14 | 695 ± 1 | 686 ± 16 |
| Tb | µg/L | 0.0009 ± 0.0002 | 0.0008 ± 0 | 0.0009 ± 0 | 0.0006 ± 0.0001 | 0.0015 ± 0.0001 |
| Te | µg/L | 0.04 ± 0 | 0.027 ± 0.005 | 0.034 ± 0.002 | 0.028 ± 0.002 | 0.039 ± 0.001 |
| Th | µg/L | 0.0011 ± 0.0004 | 0.0005 ± 0.0003 | 0.001 ± 0.0005 | 0.0003 ± 0.0002 | 0.0006 ± 0.0002 |
| Tl | µg/L | < 0.001 ± 0.001 | 0.002 ± 0.002 | < 0.001 ± 0.001 | 0.002 ± 0.001 | 0.002 ± 0.001 |
| Tm | µg/L | 0.0007 ± 0.0001 | 0.0004 ± 0.0001 | 0.0005 ± 0.0001 | 0.0003 ± 0.0001 | 0.0009 ± 0.0001 |
| U | µg/L | 0.45 ± 0.01 | 1.06 ± 0.03 | 0.66 ± 0.04 | 0.65 ± 0.04 | 0.6 ± 0.02 |
| V | µg/L | 3.1 ± 0 | 5.8 ± 0.5 | 2.2 ± 0 | 5.1 ± 0.5 | 3.2 ± 0.2 |
| Y | µg/L | 0.025 ± 0 | 0.014 ± 0 | 0.027 ± 0.001 | 0.015 ± 0 | 0.035 ± 0 |
| Yb | µg/L | 0.0044 ± 0.0001 | 0.0021 ± 0.0005 | 0.0035 ± 0.0002 | 0.0026 ± 0.0003 | 0.0055 ± 0.0009 |
| Zn | µg/L | 15 ± 0 | 15 ± 1 | 10 ± 0 | 20 ± 2 | 4.4 ± 0.2 |
| Zr | µg/L | 0.028 ± 0.001 | 0.036 ± 0.004 | 0.025 ± 0.001 | 0.033 ± 0.002 | 0.05 ± 0.009 |

**Table 4-6**. Summary of duplicate trace element results for water samples collected from the Cobble wetlands inlet, Cobble 2 wetland outlet, and the Gila River at Bullard Avenue during June 1999, and from the Cobble wetlands inlet, Cobble 1 and Cobble 2 wetlands outlet, Hayfield wetlands inlet, Hayfield 1 and Hayfield 2 wetlands outlets, the Gila River at 115th and Bullard Avenues, and the 91st Avenue dewatering well during February 2000. [ND, not determined]

| Element | Concentration Unit | Cobble Inlet 6/23/99 | Cobble Inlet 6/23/99 | Cobble 2 Outlet 6/23/99 | Cobble 2 Outlet 6/23/99 | Bullard Avenue 6/23/99 | Bullard Avenue 6/23/99 |
|---|---|---|---|---|---|---|---|
| Al | µg/L | 9 ± 0.5 | 9.7 ± 0.3 | 2.4 ± 0.1 | 1.4 ± 0 | 103 ± 3 | 1.7 ± 0.3 |
| As | µg/L | 3.9 ± 0.1 | 5 ± 0 | 3.5 ± 0.2 | 5 ± 0.1 | 8.4 ± 0 | 8.3 ± 0 |
| B | µg/L | 468 ± 13 | 450 ± 30 | 476 ± 17 | 432 ± 7 | 589 ± 11 | 591 ± 10 |
| Ba | µg/L | 20 ± 0 | 19 ± 0 | 24 ± 1 | 23 ± 0 | 48 ± 1 | 46 ± 0 |
| Be | µg/L | < 0.01± 0 | < 0.01± 0.01 | < 0.01 ± 0.01 | < 0.01± 0 | < 0.01± 0.01 | < 0.01± 0 |
| Bi | µg/L | 0.014 ± 0 | 0.009 ± 0.003 | 0.045 ± 0.002 | 0.01 ± 0 | 0.0072 ± 0.0011 | 0.012 ± 0 |
| Cd | µg/L | 0.005 ± 0.001 | 0.031 ± 0.004 | 0.047 ± 0.005 | 0.005 ± 0.004 | 0.004 ± 0.01 | < 0.002 ± 0.007 |
| Ce | µg/L | 0.021 ± 0.001 | 0.017 ± 0 | 0.037 ± 0.001 | 0.022 ± 0.001 | 0.3 ± 0.01 | 0.011 ± 0 |
| Co | µg/L | 0.24 ± 0.01 | 0.34 ± 0.01 | 0.34 ± 0.01 | 0.22 ± 0.02 | 0.55 ± 0.01 | 0.44 ± 0.04 |
| Cr | µg/L | 0.6 ± 0.2 | 0.5 ± 0.1 | 0.5 ± 0.1 | 0.6 ± 0 | 1.1 ± 0.1 | 1.1 ± 0.1 |
| Cs | µg/L | 0.12 ± 0 | 0.13 ± 0 | 0.082 ± 0.003 | 0.088 ± 0.001 | 0.076 ± 0.002 | 0.062 ± 0.002 |
| Cu | µg/L | 1.1 ± 0 | 0.97 ± 0.09 | 0.58 ± 0.06 | 0.62 ± 0.25 | 2.6 ± 0.1 | 2.2 ± 0 |
| Dy | µg/L | 0.0024 ± 0.0007 | 0.0017 ± 0.0003 | 0.0041 ± 0.0007 | 0.0045 ± 0.0004 | 0.016 ± 0.001 | 0.0031 ± 0.001 |
| Er | µg/L | 0.002 ± 0.0013 | 0.0021 ± 0.0001 | 0.0032 ± 0.0005 | 0.0043 ± 0.0005 | 0.011 ± 0.001 | 0.0035 ± 0.0007 |
| Eu | µg/L | 0.0009 ± 0.0012 | < 0.0002 ± 0.0005 | 0.0006 ± 0.0011 | 0.0011 ± 0.001 | 0.0061 ± 0.0008 | 0.0008 ± 0.0018 |
| Fe | µg/L | 70 ± 20 | 88 ± 2 | 65 ± 3 | 58 ± 4 | 170 ± 10 | 7.8 ± 1 |
| Gd | µg/L | 0.11 ± 0 | 0.12 ± 0 | 0.043 ± 0.001 | 0.04 ± 0.002 | 0.058 ± 0.001 | 0.041 ± 0.001 |
| Hg | ng/L | ND | ND | ND | ND | ND | ND |
| Ho | µg/L | 0.0013 ± 0.0001 | 0.0011 ± 0.0001 | 0.0017 ± 0.0001 | 0.0018 ± 0.0002 | 0.0039 ± 0.0004 | 0.0019 ± 0.0001 |
| La | µg/L | 0.006 ± 0 | 0.004 ± 0 | 0.01 ± 0 | 0.006 ± 0 | 0.14 ± 0 | 0.006 ± 0 |
| Li | µg/L | 92 ± 1 | 96 ± 0 | 89 ± 0 | 91 ± 1 | 130 ± 10 | 130 ± 10 |
| Lu | µg/L | 0.0005 ± 0.0001 | 0.0006 ± 0 | 0.0009 ± 0.0001 | 0.0007 ± 0 | 0.0017 ± 0.0002 | 0.0011 ± 0.0001 |
| Mn | µg/L | 26 ± 0 | 27 ± 1 | 30 ± 1 | 11 ± 0 | 62 ± 1 | 2.2 ± 0 |
| Mo | µg/L | 21 ± 0 | 23 ± 0 | 17 ± 0 | 17 ± 0 | 17 ± 0 | 17 ± 0 |
| Nd | µg/L | 0.0064 ± 0.001 | 0.0076 ± 0.0003 | 0.017 ± 0.001 | 0.014 ± 0.002 | 0.14 ± 0 | 0.0099 ± 0.0017 |
| Ni | µg/L | 7.2 ± 0.4 | 6.2 ± 0.1 | 4.1 ± 0.4 | 4.7 ± 0.5 | 5.6 ± 0.6 | 5.3 ± 0.7 |
| Pb | µg/L | 0.16 ± 0 | 0.15 ± 0.01 | 0.096 ± 0.001 | 0.098 ± 0.002 | 0.21 ± 0.01 | 0.083 ± 0.002 |
| Pr | µg/L | 0.0019 ± 0.0001 | 0.0016 ± 0.0003 | 0.0037 ± 0.0003 | 0.0033 ± 0.0006 | 0.033 ± 0 | 0.0021 ± 0.0003 |
| Rb | µg/L | 14 ± 0 | 14 ± 0 | 13 ± 0 | 13 ± 0 | 12 ± 0 | 11 ± 0 |
| Re | µg/L | 0.091 ± 0 | 0.1 ± 0 | 0.13 ± 0 | 0.13 ± 0 | 0.11 ± 0 | 0.11 ± 0 |
| Sb | µg/L | 0.55 ± 0 | 0.56 ± 0.01 | 0.38 ± 0.02 | 0.4 ± 0 | 0.47 ± 0 | 0.47 ± 0.01 |
| Se | µg/L | 0.2 ± 0.2 | 1.2 ± 0.1 | 1 ± 0.1 | < 0.2 ± 0.2 | 0.4 ± 0.1 | 0.5 ± 0.2 |
| Sm | µg/L | 0.0013 ± 0.0004 | 0.0014 ± 0.0005 | 0.0033 ± 0.0011 | 0.0038 ± 0.0007 | 0.026 ± 0 | 0.0025 ± 0.0002 |
| Sr | µg/L | 780 ± 10 | 810 ± 10 | 830 ± 0 | 800 ± 10 | 1300 ± 0 | 1200 ± 0 |
| Ta | µg/L | < 0.003 ± 0.004 | < 0.002 ± 0.002 | < 0.002 ± 0.001 | < 0.003 ± 0.002 | < 0.003 ± 0.002 | < 0.003 ± 0.003 |
| Tb | µg/L | 0.0009 ± 0.0001 | 0.0006 ± 0 | 0.0009 ± 0 | 0.0012 ± 0.0001 | 0.0035 ± 0.0003 | 0.0011 ± 0.0003 |
| Te | µg/L | 0.035 ± 0.001 | 0.037 ± 0.015 | 0.029 ± 0.005 | 0.046 ± 0.001 | 0.05 ± 0.002 | 0.048 ± 0.005 |
| Th | µg/L | 0.0024 ± 0.0016 | < 0.0008 ± 0.0005 | 0.0011 ± 0.0006 | 0.0029 ± 0.0009 | 0.016 ± 0.001 | 0.0017 ± 0 |
| Tl | µg/L | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.003 | < 0.002 ± 0.002 | < 0.002 ± 0.002 |
| Tm | µg/L | 0.0002 ± 0.0001 | 0.0003 ± 0 | 0.0004 ± 0.0001 | 0.0008 ± 0.0001 | 0.0014 ± 0.0001 | 0.0005 ± 0.0001 |
| U | µg/L | 1.5 ± 0 | 1.6 ± 0 | 0.66 ± 0.01 | 0.66 ± 0 | 4.1 ± 0.1 | 4.1 ± 0 |
| V | µg/L | 5.4 ± 0.3 | 4.2 ± 0.1 | 1.2 ± 0.2 | 2.7 ± 0.1 | 8.9 ± 0.1 | 8.7 ± 0 |
| Y | µg/L | 0.017 ± 0 | 0.016 ± 0.001 | 0.029 ± 0.002 | 0.028 ± 0 | 0.092 ± 0 | 0.026 ± 0.001 |
| Yb | µg/L | 0.0027 ± 0.0004 | 0.0027 ± 0.0003 | 0.0036 ± 0.0004 | 0.0039 ± 0.0003 | 0.0094 ± 0.0007 | 0.0045 ± 0.0008 |
| Zn | µg/L | 14 ± 0 | 14 ± 0 | 6.8 ± 0.1 | 6.4 ± 0.2 | 9.2 ± 0.1 | 8.5 ± 0 |
| Zr | µg/L | 0.023 ± 0.001 | 0.022 ± 0.001 | 0.013 ± 0.001 | 0.017 ± 0.002 | 0.053 ± 0.002 | 0.023 ± 0.001 |

**Table 4-6**. Continued.

| Element | Concentration Unit | Cobble Inlet 2/14/00 | Cobble Inlet 2/14/00 | Cobble 1 Outlet 2/14/00 | Cobble 1 Outlet 2/14/00 | Cobble 2 Outlet 2/14/00 | Cobble 2 Outlet 2/14/00 |
|---|---|---|---|---|---|---|---|
| Al | µg/L | 6.7 ± 0.4 | 6.7 ± 0.1 | 3.0 ± 0.2 | 3.0 ± 0.2 | 7.5 ± 0.4 | 4.6 ± 0.4 |
| As | µg/L | 5.5 ± 0.4 | 5.4 ± 0.3 | 5.7 ± 0 | 5.1 ± 0.3 | 5.1 ± 0.3 | 4.7 ± 0.1 |
| B | µg/L | 606 ± 1 | 653 ± 71 | 554 ± 84 | 560 ± 40 | 569 ± 69 | 570 ± 20 |
| Ba | µg/L | 18 ± 1 | 18 ± 1 | 14 ± 1 | 14 ± 0 | 14 ± 1 | 14 ± 0 |
| Be | µg/L | < 0.007 ± 0.001 | < 0.007 ± 0.002 | < 0.007 ± 0.001 | < 0.007 ± 0.003 | < 0.007 ± 0.003 | < 0.007 ± 0.003 |
| Bi | µg/L | 0.009 ± 0.001 | 0.016 ± 0.003 | 0.009 ± 0.001 | 0.011 ± 0.001 | 0.005 ± 0.002 | 0.012 ± 0.009 |
| Cd | µg/L | 0.007 ± 0.017 | 0.009 ± 0.009 | < 0.003 ± 0.003 | < 0.003 ± 0.031 | 0.037 ± 0.012 | 0.025 ± 0.002 |
| Ce | µg/L | 0.013 ± 0.001 | 0.012 ± 0.001 | 0.016 ± 0.001 | 0.017 ± 0 | 0.035 ± 0.001 | 0.028 ± 0.001 |
| Co | µg/L | 0.027 ± 0.106 | 0.051 ± 0.075 | 0.19 ± 0.1 | 0.19 ± 0.09 | 0.30 ± 0.06 | 0.32 ± 0.1 |
| Cr | µg/L | 0.6 ± 0.1 | 0.5 ± 0 | 0.4 ± 0 | 0.4 ± 0.1 | < 0.4 ± 0 | 0.4 ± 0.1 |
| Cs | µg/L | < 0.03 ± 0.01 | < 0.03 ± 0.03 | < 0.03 ± 0.01 | < 0.03 ± 0.01 | < 0.03 ± 0.04 | < 0.03 ± 0.02 |
| Cu | µg/L | 1.9 ± 0.1 | 1.8 ± 0.1 | 1.6 ± 0.1 | 1.7 ± 0.1 | 1.1 ± 0.1 | 0.91 ± 0.03 |
| Dy | µg/L | 0.0015 ± 0.0002 | 0.002 ± 0.0004 | 0.0021 ± 0.0003 | 0.0023 ± 0.0003 | 0.0036 ± 0.0001 | 0.0032 ± 0.0004 |
| Er | µg/L | 0.0017 ± 0.0001 | 0.0018 ± 0.0002 | 0.0017 ± 0.0002 | 0.0018 ± 0.0003 | 0.0028 ± 0.0002 | 0.0025 ± 0.0007 |
| Eu | µg/L | < 0.0002 ± 0.0029 | < 0.0002 ± 0.0015 | < 0.0002 ± 0.0018 | < 0.0002 ± 0.0022 | 0.0013 ± 0.0005 | 0.0009 ± 0.0024 |
| Fe | µg/L | 82 ± 0 | 79 ± 1 | 40 ± 1 | 40 ± 1 | 81 ± 2 | 71 ± 2 |
| Gd | µg/L | 0.02 ± 0.002 | 0.019 ± 0.002 | 0.12 ± 0.01 | 0.12 ± 0.01 | 0.10 ± 0.01 | 0.099 ± 0.005 |
| Hg | ng/L | 1.3 ± 0.2 | 0.9 ± 0.3 | 0.6 ± 0.2 | 0.5 ± 0.1 | < 0.4 ± 0.1 | < 0.4 ± 0.2 |
| Ho | µg/L | 0.0008 ± 0.0001 | 0.0007 ± 0.0002 | 0.0007 ± 0.0002 | 0.0008 ± 0.0002 | 0.0012 ± 0.0001 | 0.0011 ± 0.0002 |
| La | µg/L | 0.005 ± 0 | 0.004 ± 0 | 0.005 ± 0 | 0.005 ± 0 | 0.014 ± 0.001 | 0.011 ± 0 |
| Li | µg/L | 66 ± 2 | 65 ± 1 | 63 ± 0 | 62 ± 1 | 59 ± 1 | 59 ± 0 |
| Lu | µg/L | 0.0005 ± 0.0001 | 0.0005 ± 0 | 0.0003 ± 0 | 0.0005 ± 0.0001 | 0.0005 ± 0.0001 | 0.0006 ± 0 |
| Mn | µg/L | 24 ± 2 | 24 ± 1 | 16 ± 1 | 16 ± 1 | 27 ± 2 | 28 ± 1 |
| Mo | µg/L | 11 ± 0 | 11 ± 0 | 19 ± 0 | 18 ± 1 | 17 ± 0 | 16 ± 0 |
| Nd | µg/L | 0.005 ± 0.001 | 0.006 ± 0.001 | 0.006 ± 0 | 0.007 ± 0.001 | 0.015 ± 0.001 | 0.012 ± 0.000 |
| Ni | µg/L | 3.7 ± 0.6 | 4.3 ± 0.3 | 5.8 ± 0.3 | 6.1 ± 0.2 | 6.5 ± 0.4 | 6.2 ± 0.4 |
| Pb | µg/L | 0.17 ± 0.01 | 0.17 ± 0.02 | 0.2 ± 0.01 | 0.21 ± 0 | 0.20 ± 0 | 0.20 ± 0.03 |
| Pr | µg/L | 0.0014 ± 0.0002 | 0.0013 ± 0.0002 | 0.0016 ± 0.0003 | 0.0016 ± 0.0001 | 0.0036 ± 0 | 0.0030 ± 0.0001 |
| Rb | µg/L | 13 ± 0 | 13 ± 0 | 13 ± 0 | 13 ± 0 | 13 ± 0 | 13 ± 0 |
| Re | µg/L | 0.059 ± 0.002 | 0.057 ± 0.003 | 0.064 ± 0.001 | 0.07 ± 0.001 | 0.058 ± 0.001 | 0.064 ± 0.001 |
| Sb | µg/L | 0.43 ± 0.01 | 0.43 ± 0.01 | 0.59 ± 0.01 | 0.57 ± 0.03 | 0.52 ± 0.01 | 0.52 ± 0.1 |
| Se | µg/L | 1.1 ± 0.6 | 0.9 ± 0 | 0.6 ± 0.2 | 1 ± 0.5 | 0.9 ± 0.2 | 1.4 ± 0.2 |
| Sm | µg/L | 0.0013 ± 0.0005 | 0.0013 ± 0.0001 | 0.0016 ± 0.0002 | 0.0018 ± 0.0002 | 0.0033 ± 0.0003 | 0.0026 ± 0.0005 |
| Sr | µg/L | 736 ± 5 | 721 ± 12 | 802 ± 19 | 791 ± 20 | 750 ± 20 | 791 ± 13 |
| Ta | µg/L | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0 | < 0.002 ± 0.001 | < 0.002 ± 0 |
| Tb | µg/L | 0.0006 ± 0.0001 | 0.0005 ± 0.0001 | 0.0005 ± 0.0002 | 0.0008 ± 0 | 0.0008 ± 0.0002 | 0.0010 ± 0 |
| Te | µg/L | 0.031 ± 0.001 | 0.026 ± 0.003 | 0.021 ± 0.004 | 0.025 ± 0.007 | 0.019 ± 0.005 | 0.025 ± 0.005 |
| Th | µg/L | 0.0011 ± 0.0004 | 0.0013 ± 0.0006 | 0.0023 ± 0.0016 | 0.001 ± 0.0005 | 0.0032 ± 0.001 | 0.0037 ± 0.0016 |
| Tl | µg/L | 0.005 ± 0.003 | 0.004 ± 0.003 | < 0.003 ± 0 | < 0.003 ± 0.002 | < 0.003 ± 0.002 | 0.023 ± 0.004 |
| Tm | µg/L | 0.0003 ± 0 | 0.0003 ± 0.0001 | 0.0003 ± 0 | 0.0003 ± 0 | 0.0004 ± 0.0001 | 0.0004 ± 0.0001 |
| U | µg/L | 2.6 ± 0.1 | 2.6 ± 0.1 | 2.3 ± 0.1 | 2.4 ± 0.1 | 2.2 ± 0.1 | 2.4 ± 0.1 |
| V | µg/L | 3.1 ± 0.2 | 3.1 ± 0.1 | 4.5 ± 0.2 | 4.4 ± 0.1 | 4.2 ± 0.1 | 4.0 ± 0 |
| Y | µg/L | 0.019 ± 0.001 | 0.017 ± 0.001 | 0.021 ± 0.001 | 0.022 ± 0.002 | 0.032 ± 0.003 | 0.031 ± 0.001 |
| Yb | µg/L | 0.0024 ± 0.0006 | 0.0024 ± 0.0003 | 0.002 ± 0.0005 | 0.0022 ± 0.0008 | 0.0029 ± 0.0002 | 0.0040 ± 0.0004 |
| Zn | µg/L | 22 ± 0 | 22 ± 0 | 22 ± 1 | 20 ± 0 | 16 ± 1 | 16 ± 1 |
| Zr | µg/L | 0.047 ± 0.001 | 0.044 ± 0.002 | 0.042 ± 0.001 | 0.04 ± 0.001 | 0.039 ± 0.003 | 0.036 ± 0.002 |

**Table 4-6**. Continued.

| Element | Concentration Unit | Hayfield Inlet 2/15/00 | Hayfield Inlet 2/15/00 | Hayfield 1 Outlet 2/15/00 | Hayfield 1 Outlet 2/15/00 | Hayfield 2 Outlet 2/15/00 | Hayfield 2 Outlet 2/15/00 |
|---|---|---|---|---|---|---|---|
| Al | µg/L | 7 ± 3 | 3 ± 4 | 14 ± 5 | 10 ± 4 | 3 ± 4 | 7 ± 4 |
| As | µg/L | 4.1 ± 0.1 | 4.8 ± 0.2 | 5.3 ± 0 | 5.4 ± 0.4 | 5.6 ± 0.1 | 5.3 ± 0.6 |
| B | µg/L | 510 ± 0 | 570 ± 10 | 570 ± 20 | 550 ± 20 | 560 ± 20 | 560 ± 50 |
| Ba | µg/L | 15 ± 0 | 15 ± 0 | 10 ± 0 | 9.5 ± 0.2 | 8.2 ± 0.4 | 8.7 ± 0.3 |
| Be | µg/L | < 0.01 ± 0.01 | 0.01 ± 0.01 | < 0.01 ± 0 | < 0.01 ± 0 | < 0.01 ± 0.01 | < 0.01 ± 0 |
| Bi | µg/L | 0.017 ± 0.002 | 0.017 ± 0.002 | 0.0059 ± 0.0022 | 0.0027 ± 0.0007 | 0.0042 ± 0.0021 | 0.0042 ± 0.0013 |
| Cd | µg/L | 0.04 ± 0.01 | 0.01 ± 0.03 | < 0.09 ± 0.09 | 0.06 ± 0.06 | 0.14 ± 0.06 | < 0.01 ± 0.01 |
| Ce | µg/L | 0.011 ± 0.001 | 0.011 ± 0 | 0.12 ± 0 | 0.1 ± 0 | 0.057 ± 0.005 | 0.09 ± 0.002 |
| Co | µg/L | 0.2 ± 0.02 | 0.20 ± 0.1 | 0.34 ± 0.01 | 0.32 ± 0.01 | 0.21 ± 0.01 | 0.22 ± 0 |
| Cr | µg/L | < 0.4 ± 0.4 | < 0.4 ± 0.6 | < 0.4 ± 0.2 | < 0.4 ± 0.2 | < 0.4 ± 0 | < 0.4 ± 0.6 |
| Cs | µg/L | 0.11 ± 0.01 | 0.12 ± 0 | 0.06 ± 0.02 | 0.03 ± 0.02 | 0.12 ± 0.01 | 0.02 ± 0.01 |
| Cu | µg/L | 1.8 ± 0 | 1.8 ± 0.1 | 1.7 ± 0 | 1.1 ± 0.2 | 1.6 ± 0.1 | 1.5 ± 0.1 |
| Dy | µg/L | 0.0013 ± 0.0002 | 0.0012 ± 0.0003 | 0.0068 ± 0.0005 | 0.0065 ± 0.0012 | 0.0042 ± 0.001 | 0.0057 ± 0.0002 |
| Er | µg/L | 0.0012 ± 0.0001 | 0.0012 ± 0.0002 | 0.0052 ± 0.0008 | 0.0039 ± 0.0004 | 0.004 ± 0.0009 | 0.0047 ± 0.0007 |
| Eu | µg/L | 0.0003 ± 0.0003 | 0.0002 ± 0.0005 | 0.0021 ± 0.0005 | 0.0022 ± 0.0006 | 0.0011 ± 0.0002 | 0.0018 ± 0.0003 |
| Fe | µg/L | 86 ± 15 | 84 ± 27 | 59 ± 6 | 53 ± 2 | 37 ± 2 | 57 ± 3 |
| Gd | µg/L | 0.073 ± 0.003 | 0.072 ± 0 | 0.086 ± 0.004 | 0.081 ± 0.002 | 0.062 ± 0.002 | 0.067 ± 0 |
| Hg | ng/L | ND | ND | ND | ND | ND | ND |
| Ho | µg/L | 0.0006 ± 0.0001 | 0.0006 ± 0.0001 | 0.0019 ± 0.0001 | 0.0016 ± 0.0002 | 0.0013 ± 0.0001 | 0.0015 ± 0.0003 |
| La | µg/L | 0.0035 ± 0.0009 | 0.0025 ± 0.0005 | 0.049 ± 0 | 0.041 ± 0 | 0.019 ± 0.001 | 0.035 ± 0 |
| Li | µg/L | 51 ± 2 | 53 ± 1 | 53 ± 2 | 53 ± 0 | 53 ± 4 | 53 ± 1 |
| Lu | µg/L | 0.0003 ± 0.0001 | 0.0003 ± 0 | 0.0008 ± 0.0002 | 0.0008 ± 0 | 0.0009 ± 0 | 0.0009 ± 0 |
| Mn | µg/L | 23 ± 1 | 21 ± 1 | 18 ± 1 | 14 ± 1 | 6.1 ± 0.5 | 7.2 ± 0.5 |
| Mo | µg/L | 13 ± 0 | 13 ± 0 | 14 ± 0 | 14 ± 0 | 16 ± 0 | 17 ± 0 |
| Nd | µg/L | 0.0060 ± 0.0015 | 0.0055 ± 0.0003 | 0.049 ± 0.004 | 0.044 ± 0.004 | 0.021 ± 0 | 0.036 ± 0.001 |
| Ni | µg/L | 6.2 ± 0.3 | 6.1 ± 0.1 | 6.2 ± 0.1 | 5.6 ± 0.2 | 5.6 ± 0.1 | 5.5 ± 0.1 |
| Pb | µg/L | 0.21 ± 0 | 0.21 ± 0 | 0.18 ± 0.01 | 0.13 ± 0.02 | 0.13 ± 0.01 | 0.13 ± 0.01 |
| Pr | µg/L | 0.0013 ± 0.0004 | 0.0012 ± 0.0002 | 0.013 ± 0 | 0.011 ± 0 | 0.0051 ± 0.0003 | 0.009 ± 0.0004 |
| Rb | µg/L | 11 ± 0 | 12 ± 0 | 12 ± 0 | 11 ± 0 | 11 ± 0 | 11 ± 0 |
| Re | µg/L | 0.090 ± 0.003 | 0.093 ± 0.004 | 0.061 ± 0.003 | 0.061 ± 0 | 0.059 ± 0.002 | 0.058 ± 0.001 |
| Sb | µg/L | 0.42 ± 0 | 0.44 ± 0.01 | 0.47 ± 0.01 | 0.46 ± 0.01 | 0.54 ± 0.01 | 0.55 ± 0.03 |
| Se | µg/L | 0.22 ± 0.05 | 0.42 ± 0.13 | 0.33 ± 0.12 | 0.32 ± 0.05 | 0.35 ± 0.14 | 0.37 ± 0.06 |
| Sm | µg/L | 0.0015 ± 0.0007 | 0.0012 ± 0.0008 | 0.0089 ± 0.001 | 0.0083 ± 0.0007 | 0.0077 ± 0.0004 | 0.0071 ± 0.0005 |
| Sr | µg/L | 700 ± 10 | 730 ± 10 | 750 ± 0 | 740 ± 10 | 710 ± 0 | 730 ± 0 |
| Ta | µg/L | < 0.001 ± 0 | < 0.001 ± 0.001 | < 0.001 ± 0.001 | < 0.001 ± 0 | 0.003 ± 0.002 | 0.003 ± 0.003 |
| Tb | µg/L | 0.0003 ± 0.0001 | 0.0004 ± 0 | 0.0015 ± 0.0001 | 0.0013 ± 0.0002 | 0.0008 ± 0.0001 | 0.0011 ± 0.0001 |
| Te | µg/L | 0.023 ± 0.008 | 0.016 ± 0.001 | 0.022 ± 0.009 | 0.017 ± 0.004 | 0.017 ± 0.003 | 0.019 ± 0.006 |
| Th | µg/L | 0.0023 ± 0.0011 | 0.0015 ± 0.0009 | 0.0066 ± 0.0018 | 0.0047 ± 0.0007 | 0.011 ± 0.009 | 0.005 ± 0.0013 |
| Tl | µg/L | < 0.01 ± 0.01 | < 0.01 ± 0.01 | < 0.01 ± 0 | < 0.01 ± 0 | < 0.01 ± 0.01 | < 0.01 ± 0.01 |
| Tm | µg/L | < 0.0001 ± 0.0001 | 0.0002 ± 0.0001 | 0.0007 ± 0.0001 | 0.0007 ± 0.0002 | 0.0006 ± 0.0001 | 0.0008 ± 0.0002 |
| U | µg/L | 1.9 ± 0 | 1.9 ± 0 | 1.8 ± 0 | 1.8 ± 0 | 2.5 ± 0 | 2.5 ± 0.1 |
| V | µg/L | 4.0 ± 0.5 | 4.5 ± 0.2 | 5.9 ± 0.3 | 5.6 ± 0.3 | 7 ± 0.2 | 6.5 ± 0 |
| Y | µg/L | 0.013 ± 0.001 | 0.031 ± 0 | 0.044 ± 0.001 | 0.043 ± 0.001 | 0.029 ± 0 | 0.039 ± 0.002 |
| Yb | µg/L | 0.0016 ± 0.0001 | 0.0019 ± 0.0004 | 0.0056 ± 0.0006 | 0.0048 ± 0.0004 | 0.0046 ± 0.0003 | 0.0052 ± 0.0004 |
| Zn | µg/L | 14 ± 1 | 14 ± 1 | 10 ± 0 | 9.9 ± 0.9 | 12 ± 0 | 12 ± 1 |
| Zr | µg/L | 0.058 ± 0.032 | 0.025 ± 0.002 | 0.047 ± 0.017 | 0.028 ± 0.004 | 0.041 ± 0.013 | 0.03 ± 0.004 |

**Table 4-6**. Continued.

| Element | Concentration Unit | Bullard Avenue 2/13/00 | Bullard Avenue 2/13/00 | 115th Avenue 2/13/00 | 115th Avenue 2/13/00 | 91st Avenue Well 2/16/00 |
|---|---|---|---|---|---|---|
| Al | µg/L | 48 ± 1 | 35 ± 0 | 15 ± 2 | 22 ± 2 | < 10 ± 11 |
| As | µg/L | 6.2 ± 0 | 7.3 ± 0.1 | 6.7 ± 0.9 | 6.8 ± 1 | 10 ± 1 |
| B | µg/L | 614 ± 7 | 604 ± 3 | 747 ± 35 | 760 ± 31 | 570 ± 10 |
| Ba | µg/L | 46 ± 1 | 46 ± 3 | 34 ± 1 | 35 ± 1 | 57 ± 1 |
| Be | µg/L | 0.009 ± 0 | < 0.007 ± 0.001 | < 0.007 ± 0.003 | 0.008 ± 0.002 | < 0.01 ± 0.01 |
| Bi | µg/L | 0.041 ± 0.03 | 0.007 ± 0.005 | 0.009 ± 0.002 | 0.017 ± 0.002 | 0.015 ± 0.001 |
| Cd | µg/L | 0.015 ± 0.01 | < 0.003 ± 0.009 | < 0.003 ± 0.007 | < 0.003 ± 0.003 | 0.02 ± 0.01 |
| Ce | µg/L | 0.13 ± 0 | 0.094 ± 0.004 | 0.031 ± 0.002 | 0.044 ± 0.002 | 0.011 ± 0 |
| Co | µg/L | 0.56 ± 0.11 | 0.44 ± 0.08 | 0.18 ± 0.19 | 0.14 ± 0.22 | 1.1 ± 0 |
| Cr | µg/L | 1.8 ± 0.1 | 1.8 ± 0.1 | < 0.4 ± 0.1 | 0.4 ± 0.1 | < 0.4 ± 1.6 |
| Cs | µg/L | < 0.03 ± 0.06 | < 0.03 ± 0.03 | < 0.03 ± 0.01 | < 0.03 ± 0.01 | 0.14 ± 0.02 |
| Cu | µg/L | 1.6 ± 0.2 | 1.7 ± 0.1 | 1.2 ± 0.1 | 1.2 ± 0 | 8.2 ± 0.1 |
| Dy | µg/L | 0.0088 ± 0.0008 | 0.0062 ± 0.0005 | 0.0033 ± 0 | 0.0045 ± 0.0002 | 0.0026 ± 0.0002 |
| Er | µg/L | 0.0067 ± 0.0004 | 0.0059 ± 0.0006 | 0.0041 ± 0.0004 | 0.0046 ± 0.0005 | 0.0089 ± 0.0003 |
| Eu | µg/L | 0.0041 ± 0.0034 | < 0.0002 ± 0.0027 | < 0.0002 ± 0.0049 | < 0.0002 ± 0.0012 | < 0.0001 ± 0.0002 |
| Fe | µg/L | 68 ± 3 | 50 ± 2 | 49 ± 1 | 57 ± 1 | 19 ± 6 |
| Gd | µg/L | 0.097 ± 0.009 | 0.1 ± 0 | 0.087 ± 0.009 | 0.09 ± 0.008 | 0.0036 ± 0.001 |
| Hg | ng/L | 1 ± 0.2 | <0.4 ± 0.2 | 0.8 ± 0.2 | <0.4 ± 0.5 | ND |
| Ho | µg/L | 0.0022 ± 0.0001 | 0.0018 ± 0 | 0.0015 ± 0.0001 | 0.0016 ± 0.0001 | 0.002 ± 0.0001 |
| La | µg/L | 0.063 ± 0.003 | 0.045 ± 0.002 | 0.014 ± 0.001 | 0.02 ± 0.002 | 0.009 ± 0.0004 |
| Li | µg/L | 113 ± 1 | 121 ± 7 | 165 ± 1 | 162 ± 1 | 160 ± 0 |
| Lu | µg/L | 0.0018 ± 0.0002 | 0.0016 ± 0.0001 | 0.0014 ± 0 | 0.0015 ± 0.0002 | 0.0052 ± 0.0001 |
| Mn | µg/L | 75 ± 0 | 77 ± 1 | 81 ± 6 | 84 ± 5 | 25 ± 1 |
| Mo | µg/L | 12 ± 0 | 13 ± 0 | 12 ± 0 | 12 ± 1 | 2.9 ± 0.1 |
| Nd | µg/L | 0.061 ± 0.003 | 0.043 ± 0.002 | 0.014 ± 0.001 | 0.02 ± 0.001 | 0.0058 ± 0.0006 |
| Ni | µg/L | 5 ± 0.2 | 5.3 ± 0.4 | 4.7 ± 0.1 | 5.3 ± 0.5 | ND |
| Pb | µg/L | 0.2 ± 0 | 0.18 ± 0.01 | 0.18 ± 0.01 | 0.18 ± 0.01 | 0.059 ± 0.006 |
| Pr | µg/L | 0.015 ± 0 | 0.011 ± 0 | 0.0035 ± 0.0001 | 0.0051 ± 0.0002 | 0.0017 ± 0.0004 |
| Rb | µg/L | 11 ± 0 | 11 ± 0 | 13 ± 0 | 12 ± 0 | 6 ± 0.1 |
| Re | µg/L | 0.082 ± 0 | 0.081 ± 0.002 | 0.077 ± 0.002 | 0.077 ± 0.002 | 0.09 ± 0.001 |
| Sb | µg/L | 0.36 ± 0.01 | 0.37 ± 0.01 | 0.37 ± 0 | 0.38 ± 0.01 | 0.056 ± 0.003 |
| Se | µg/L | 2.2 ± 0.2 | 1.2 ± 0.2 | 0.8 ± 0.3 | 0.5 ± 0.2 | < 0.09 ± 0.18 |
| Sm | µg/L | 0.011 ± 0 | 0.0086 ± 0.001 | 0.0034 ± 0.0006 | 0.0047 ± 0.0001 | 0.0021 ± 0 |
| Sr | µg/L | 1326 ± 1 | 1321 ± 1 | 1413 ± 27 | 1437 ± 15 | 580 ± 20 |
| Ta | µg/L | < 0.002 ± 0 | < 0.002 ± 0.001 | < 0.002 ± 0 | < 0.002 ± 0 | < 0.001 ± 0.001 |
| Tb | µg/L | 0.0017 ± 0.0001 | 0.0014 ± 0.0002 | 0.0011 ± 0.0003 | 0.001 ± 0.0003 | 0.0006 ± 0.0001 |
| Te | µg/L | 0.023 ± 0.007 | 0.017 ± 0.001 | 0.037 ± 0 | 0.035 ± 0 | 0.015 ± 0.007 |
| Th | µg/L | 0.011 ± 0.001 | 0.0063 ± 0.0004 | 0.0033 ± 0.0002 | 0.0047 ± 0.0011 | 0.0032 ± 0.0017 |
| Tl | µg/L | 0.007 ± 0.003 | 0.007 ± 0.004 | 0.009 ± 0.001 | 0.008 ± 0.004 | < 0.01 ± 0.01 |
| Tm | µg/L | 0.0011 ± 0 | 0.0009 ± 0.0001 | 0.0006 ± 0.0001 | 0.0008 ± 0.0001 | 0.002 ± 0.0001 |
| U | µg/L | 5.3 ± 0.1 | 5.3 ± 0.1 | 5.6 ± 0 | 5.7 ± 0 | 1.8 ± 0 |
| V | µg/L | 6.5 ± 0 | 6.6 ± 0.3 | 4.8 ± 0.1 | 5 ± 0 | 10 ± 0 |
| Y | µg/L | 0.06 ± 0.003 | 0.05 ± 0.002 | 0.039 ± 0.001 | 0.041 ± 0.001 | 0.041 ± 0.002 |
| Yb | µg/L | 0.0096 ± 0.0006 | 0.0076 ± 0.0004 | 0.0064 ± 0.0008 | 0.0064 ± 0.0007 | 0.02 ± 0.001 |
| Zn | µg/L | 11 ± 0 | 11 ± 0 | 12 ± 0 | 13 ± 1 | 0.66 ± 0.18 |
| Zr | µg/L | 0.074 ± 0.002 | 0.065 ± 0.001 | 0.041 ± 0 | 0.045 ± 0.002 | 0.007 ± 0 |

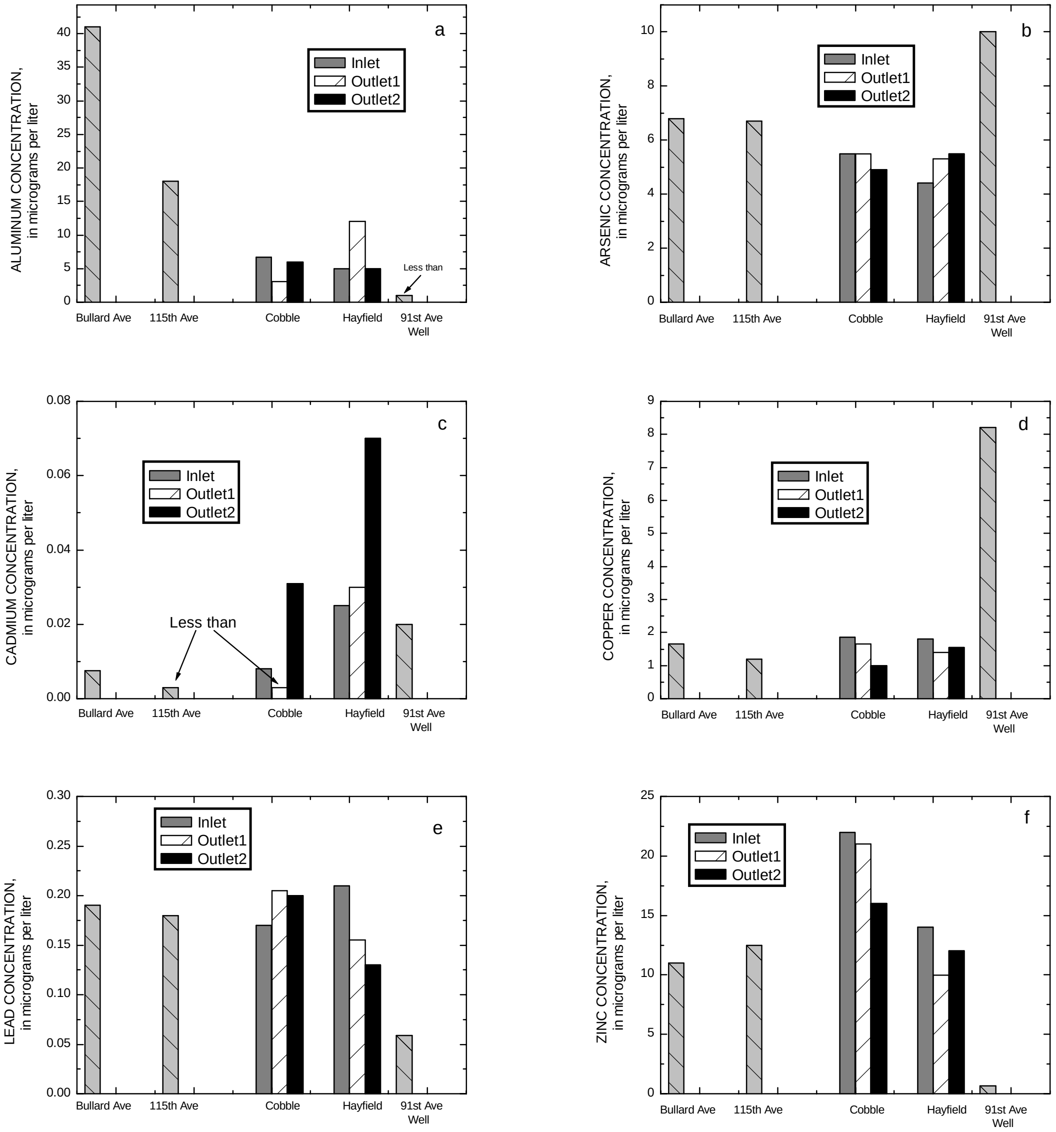

**Figure 4-5**. Plots of dissolved (a) aluminum, (b) arsenic, (c) cadmium, (d) copper, (e) lead, and (f) zinc concentrations in water samples collected from the Gila River at 115th and Bullard Avenues, the Cobble and Hayfield wetlands inlets and outlets, and the 91st Avenue dewatering well, February 2000.

### NUTRIENTS

Table 4-7 lists the results for dissolved nutrients including nitrate, nitrite, ammonium, and orthophosphate in samples collected at the H2 wetland in July and August 1998. Results show that nitrate and nitrite values are always higher in the inlet samples than the corresponding outlet samples. No significant change was observed for concentrations of ammonium between the inlet and outlet sites. Values for all orthophosphate determinations were reported to be greater than 0.7 milligrams of phosphorus per liter due to sample preservation problems.

## SEDIMENT

Results for duplicate elemental analyses of sediment samples collected from the inlet and outlet of the C2 wetland on June 23, 1999 are listed in table 4-8. In addition, results are reported for NIST Buffalo River Sediment Standard, SRM 2704 along with the reported certified values.

## BIOTA

### VEGETATION

Elemental composition data for *Schoenoplectus tabernaemontani* and *Schoenoplectus americanus* vegetation samples (culms) collected from the C2 wetland inlet and outlet, June 23, 1998 are reported in table 4-9. All results are reported on a dry-weight basis. Analyses of NIST Apple Leaves Standard, SRM 1515 (Taylor, 2001) are listed with certified values. Bar graphs showing typical vegetation data for 6 elements are shown in figure 4-6.

**Table 4-7**. Nutrient data for water samples collected from the Hayfield wetlands inlet and the Hayfield 2 wetland outlet during July to August 1998.

| Compound | Concentration Unit | Hayfield Inlet 7/24/98 | Hayfield 2 Outlet 7/24/98 | Hayfield Inlet 7/28/98 | Hayfield 2 Outlet 7/28/98 | Hayfield Inlet 8/4/98 |
|---|---|---:|---:|---:|---:|---:|
| $NO_3$ | mg N/L | 2.26 ± 0.02 | 0.041 ± 0.009 | 2.27 ± 0 | 0.009 ± 0.003 | 0.62 ± 0 |
| $NO_2$ | mg N/L | 0.071 ± 0.001 | 0.034 ± 0.001 | 0.08 ± 0.001 | 0.004 ± 0.001 | 0.076 ± 0.001 |
| $NH_4$ | mg N/L | 0.97 ± 0.01 | 1.1 ± 0 | 1.2 ± 0 | 1.2 ± 0 | 1.1 ± 0 |
| $PO_4$ | mg P/L | > 0.7 ± 0 | > 0.7 ± 0.77 | > 0.7 ± 0 | > 0.7 ± 0.39 | > 0.7 ± 0 |

| Compound | Concentration Unit | Hayfield 2 Outlet 8/4/98 | Hayfield Inlet 8/10/98 | Hayfield 2 Outlet 8/10/98 | Hayfield Inlet 8/18/98 | Hayfield 2 Outlet 8/18/98 |
|---|---|---:|---:|---:|---:|---:|
| $NO_3$ | mg N/L | 0.03 ± 0.001 | 1.7 ± 0.02 | 0.1 ± 0 | 1.45 ± 0.01 | 0.024 ± 0 |
| $NO_2$ | mg N/L | 0.008 ± 0.002 | 0.1 ± 0 | 0.031 ± 0.001 | 0.024 ± 0 | 0.047 ± 0.001 |
| $NH_4$ | mg N/L | 1.0 ± 0 | 1.1 ± 0 | 0.6 ± 0 | 0.75 ± 0.01 | 0.62 ± 0 |
| $PO_4$ | mg P/L | > 0.7 ± 1.65 | > 0.7 ± 0 | > 0.7 ± 0.75 | > 0.7 ± 0 | > 0.7 ± 0.75 |

**Table 4-8**. Trace-element composition data for duplicate sediment samples collected from the Cobble 2 wetland inlet and outlet, June 23, 1998. [Values reported on a dry-weight basis; µg/g, microgram per gram; ng/g, nanogram per gram; analysis of Buffalo River Sediment Standard, SRM 2704, is listed with certified values (Taylor, 2001); ND, not determined]

| Element | Concentration Unit | Cobble Inlet | Cobble Inlet | Cobble 2 Outlet | Cobble 2 Outlet | SRM 2704 Measured | SRM 2704 Certified |
|---|---|---:|---:|---:|---:|---:|---:|
| As | µg/g | < 10 ± 1 | ND | 17 ± 3 | < 20 ± 4 | 29 ± 2 | 23 ± 1 |
| Ba | µg/g | 690 ± 50 | ND | 830 ± 90 | 780 ± 60 | 440 ± 10 | 414 ± 12 |
| Be | µg/g | 1.5 ± 0 | 1.5 ± 0.1 | 2.2 ± 0.3 | 1.9 ± 0.3 | 1.7 ± 0 | ND |
| Bi | µg/g | 0.64 ± 0.07 | 0.64 ± 0.06 | 0.31 ± 0.05 | 0.36 ± 0.04 | 0.64 ± 0.08 | ND |
| Cd | µg/g | 0.1 ± 0 | 0.07 ± 0.02 | 0.17 ± 0.04 | 0.09 ± 0.07 | 3.5 ± 0.1 | 3.45 ± 0.22 |
| Ce | µg/g | 49 ± 3 | 47 ± 0 | 63 ± 1 | 67 ± 5 | 53 ± 6 | 72 |
| Co | µg/g | 10 ± 1 | 11 ± 1 | 16 ± 1 | 14 ± 1 | 13 ± 2 | 14 ± 0.6 |
| Cr | µg/g | 75 ± 5 | 81 ± 5 | 97 ± 4 | 91 ± 5 | 120 ± 10 | 135 ± 5 |
| Cs | µg/g | 4 ± 0 | 4 ± 0 | 4 ± 1 | 5 ± 0 | 4 ± 1 | 6 |
| Cu | µg/g | 37 ± 4 | 38 ± 3 | 44 ± 3 | 46 ± 3 | 100 ± 0 | 98.6 ± 5 |
| Dy | µg/g | 3.2 ± 0.3 | 2.9 ± 0 | 4.7 ± 0.1 | 3.9 ± 0.1 | 4.3 ± 0.4 | 6 |
| Er | µg/g | 1.9 ± 0.2 | 1.7 ± 0 | 2.8 ± 0.1 | 2.3 ± 0.1 | 2.7 ± 0 | ND |
| Eu | µg/g | 0.9 ± 0 | 0.9 ± 0 | 1.3 ± 0 | 1.3 ± 0 | 1.2 ± 0 | 1.3 |
| Ga | µg/g | 11 ± 0 | 12 ± 1 | 15 ± 0 | 13 ± 0 | 12 ± 2 | 15 |
| Gd | µg/g | 3.3 ± 0.2 | 3.3 ± 0.4 | 4.9 ± 0.1 | 4.5 ± 0.3 | 4.5 ± 0.8 | ND |
| Hg | ng/g | < 3 ± 4 | < 4 ± 4 | < 4 ± 5 | < 5 ± 4 | 1342 ± 39 | 1470 ± 70 |
| Ho | µg/g | 0.61 ± 0.05 | 0.56 ± 0 | 0.9 ± 0 | 0.76 ± 0.01 | 0.82 ± 0.09 | ND |
| La | µg/g | 24 ± 2 | 24 ± 0 | 31 ± 1 | 32 ± 3 | 26 ± 3 | 29 |
| Li | µg/g | 32 ± 4 | 30 ± 1 | 40 ± 3 | 37 ± 5 | 44 ± 3 | 47.5 ± 4.1 |
| Lu | µg/g | 0.3 ± 0.03 | 0.26 ± 0 | 0.4 ± 0.01 | 0.34 ± 0 | 0.37 ± 0.04 | 0.6 |
| Mn | µg/g | 350 ± 20 | 360 ± 20 | 640 ± 10 | 620 ± 40 | 560 ± 20 | 555 ± 19 |
| Mo | µg/g | 1.7 ± 0.1 | 1.8 ± 0.1 | 2.2 ± 0.2 | 2 ± 0.2 | 4.5 ± 0.4 | ND |
| Nd | µg/g | 23 ± 2 | 22 ± 0 | 31 ± 0 | 31 ± 2 | 26 ± 3 | ND |
| Ni | µg/g | 31 ± 3 | 34 ± 5 | 45 ± 2 | 43 ± 4 | 43 ± 8 | 44.1 ± 3 |
| Pb | µg/g | 20 ± 2 | 18 ± 0 | 23 ± 0 | 21 ± 1 | 170 ± 20 | 161 ± 17 |
| Pr | µg/g | 6.0 ± 0.4 | 6.0 ± 0.5 | 8.2 ± 0.2 | 8.1 ± 0.7 | 6.7 ± 0.7 | ND |
| Rb | µg/g | 91 ± 10 | 82 ± 4 | 95 ± 5 | 99 ± 7 | 90 ± 8 | 100 |
| Re | µg/g | 0.002 ± 0.002 | < 0.002 ± | < 0.002 ± | < 0.002 ± | 0.006 ± 0.001 | ND |
| Sb | µg/g | 1.1 ± 0 | 1.1 ± 0 | 1.4 ± 0 | 1.2 ± 0.1 | 3.9 ± 0.4 | 3.79 ± 0.2 |
| Sc | µg/g | 11 ± 1 | ND | 13 ± 1 | 14 ± 1 | 13 ± 1 | 12 |
| Se | µg/g | 9 ± 1 | 10 ± 0 | 11 ± 1 | 12 ± 0 | 11 ± 1 | 1.12 ± 0.1 |
| Sm | µg/g | 4.2 ± 0.3 | 4 ± 0.1 | 6 ± 0.1 | 5.5 ± 0 | 5.3 ± 0.7 | 6.7 |
| Sr | µg/g | 300 ± 30 | 310 ± 20 | 360 ± 20 | 350 ± 30 | 110 ± 10 | 130 |
| Ta | µg/g | 1.4 ± 0.2 | 1.3 ± 0.1 | 2.1 ± 0.2 | 1.8 ± 0.2 | 1.5 ± 0.1 | ND |
| Tb | µg/g | 0.5 ± 0 | 0.49 ± 0.01 | 0.8 ± 0 | 0.67 ± 0.01 | 0.71 ± 0.08 | ND |
| Te | µg/g | 0.15 ± 0.01 | 0.14 ± 0.04 | 0.15 ± 0.02 | 0.28 ± 0 | 0.25 ± 0.01 | ND |
| Th | µg/g | 7 ± 1 | 6 ± 0 | 9 ± 0 | 9 ± 0 | 9 ± 0.8 | 9.2 |
| Tl | µg/g | 0.4 ± 0 | 0.3 ± 0.1 | 0.4 ± 0.1 | 0.4 ± 0 | 0.8 ± 0.2 | 1.06 ± 0.1 |
| Tm | µg/g | 0.29 ± 0.01 | 0.25 ± 0.01 | 0.4 ± 0.01 | 0.33 ± 0.01 | 0.37 ± 0.04 | ND |
| U | µg/g | 3 ± 0.3 | 2.8 ± 0.1 | 2.8 ± 0.1 | 2.9 ± 0.2 | 3.5 ± 0.1 | 3.13 ± 0.1 |
| V | µg/g | 94 ± 5 | ND | 130 ± 0 | 130 ± 10 | 120 ± 9 | 95 ± 4 |
| Y | µg/g | 16 ± 1 | 15 ± 1 | 23 ± 1 | 20 ± 2 | 20 ± 2 | ND |
| Yb | µg/g | 1.9 ± 0.2 | 1.7 ± 0 | 2.8 ± 0 | 2.3 ± 0 | 2.5 ± 0.3 | 2.8 |
| Zn | µg/g | 68 ± 4 | 72 ± 0 | 86 ± 2 | 82 ± 7 | 410 ± 50 | 438 ± 12 |
| Zr | µg/g | 100 ± 9 | 100 ± 6 | 110 ± 4 | 110 ± 9 | 130 ± 14 | 300 |

**Table 4-9**. Trace-element composition data for softstem (*Schoenoplectus tabernaemontani*) and Olney's (*Schoenoplectus americanus)* bulrush samples collected from the Cobble 2 wetland inlet and outlet zones, June 23, 1998. [Values reported on a dry-weight basis; µg/g, microgram per gram; ng/g, nanogram per gram; wt%, weight percent; analysis of Apple Leaves Standard, SRM 1515, is listed with certified values (Taylor, 2001); ND, not determined]

| **Element** | **Concentration Unit** | **Cobble 2 Inlet *tabernaemontani*** | **Cobble 2 Inlet *americanus*** | **Cobble 2 Outlet *tabernaemontani*** | **Cobble 2 Outlet *americanus*** | **SRM 1515 Measured** | **SRM 1515 Certified** |
|---|---|---:|---:|---:|---:|---:|---:|
| Al | µg/g | 11 ± 3 | 49 ± 11 | 23 ± 8 | 17 ± 5 | 230 ± 10 | 286 ± 9 |
| As | µg/g | 0.25 ± 0.05 | 0.16 ± 0.03 | 0.18 ± 0.03 | 0.65 ± 0.17 | < 0.1 ± 0.1 | 0.04 ± 0.01 |
| B | µg/g | 8 ± 11 | 11 ± 1 | 9 ± 4 | 23 ± 2 | 27 ± 9 | 27 ± 2 |
| Ba | µg/g | 14 ± 1 | 15 ± 2 | 23 ± 1 | 8.6 ± 0.4 | 49 ± 2 | 49 ± 2 |
| Be | µg/g | < 0.09 ± 0.01 | < 0.09 ± 0.02 | < 0.09 ± 0.04 | < 0.09 ± 0.02 | < 0.09 ± 0.02 | ND |
| Bi | µg/g | < 0.01 ± 0 | < 0.01 ± 0 | < 0.01 ± 0 | < 0.01 ± 0.02 | < 0.01 ± 0 | ND |
| Ca | wt% | 0.4 ± 0.03 | 0.3 ± 0.04 | 0.37 ± 0.07 | 0.35 ± 0.05 | 1.5 ± 0.1 | 1.53 ± 0.02 |
| Cd | µg/g | 0.19 ± 0.06 | < 0.02 ± 0.07 | 0.2 ± 0.07 | 0.5 ± 0.03 | 0.06 ± 0.02 | 0.013 ± 0.002 |
| Ce | µg/g | 0.038 ± 0.01 | 0.12 ± 0.02 | 0.058 ± 0.01 | 0.058 ± 0.007 | 3.1 ± 0.1 | 3 |
| Co | µg/g | 0.03 ± 0.01 | 0.03 ± 0.01 | < 0.02 ± 0.01 | < 0.02 ± 0.01 | 0.03 ± 0.01 | 0.09 |
| Cr | µg/g | < 1 ± 1 | < 1 ± 1 | < 1 ± 1 | < 1 ± 1 | 1.1 ± 0.4 | 0.3 |
| Cs | µg/g | < 0.4 ± 0.4 | < 0.4 ± 0.1 | < 0.4 ± 0.3 | < 0.4 ± 0.4 | < 0.4 ± 0.1 | ND |
| Cu | µg/g | 1.8 ± 0.4 | 4 ± 0.9 | 1.6 ± 0.4 | 1.2 ± 0.5 | 5.4 ± 0.3 | 5.64 ± 0.24 |
| Dy | µg/g | < 0.005 ± 0.002 | < 0.005 ± 0.007 | < 0.005 ± 0.001 | < 0.006 ± 0.003 | 1.7 ± 0 | ND |
| Er | µg/g | < 0.006 ± 0.001 | < 0.006 ± 0.001 | < 0.006 ± 0.001 | < 0.006 ± 0.002 | 0.54 ± 0.01 | ND |
| Eu | µg/g | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | 0.24 ± 0.01 | 0.2 |
| Fe | µg/g | 65 ± 18 | 120 ± 10 | 26 ± 12 | 40 ± 6 | 87 ± 44 | 83 ± 5 |
| Gd | µg/g | < 0.004 ± 0.001 | < 0.004 ± 0.003 | < 0.004 ± 0.002 | < 0.004 ± 0.001 | 2.9 ± 0.1 | 3 |
| Hg | ng/g | 23 ± 0 | 13 ± 0 | 27 ± 1 | 19 ± 1 | 33 ± 1 | 44 ± 4 |
| Ho | µg/g | 0.0017 ± 0.0009 | 0.002 ± 0.001 | < 0.0009 ± 0.0008 | < 0.0009 ± 0.0002 | 0.27 ± 0 | ND |
| La | µg/g | 0.009 ± 0.0002 | 0.039 ± 0.009 | 0.02 ± 0.008 | 0.021 ± 0.005 | 20 ± 0 | 20 |
| Li | µg/g | 1.2 ± 0.1 | 1.1 ± 0.2 | 2.5 ± 0.4 | 3.2 ± 0.2 | < 0.1 ± 0.1 | ND |
| Lu | µg/g | < 0.001 ± 0.001 | 0.0014 ± 0.0013 | < 0.001 ± 0 | < 0.001 ± 0.001 | 0.021 ± 0.001 | ND |
| Mg | wt% | 0.14 ± 0.01 | 0.13 ± 0.02 | 0.11 ± 0.02 | 0.13 ± 0.02 | 0.28 ± 0.01 | 0.27 ± 0.01 |
| Mn | µg/g | 250 ± 20 | 53 ± 8 | 230 ± 10 | 100 ± 10 | 52 ± 3 | 54 ± 3 |
| Mo | µg/g | < 0.2 ± 0.4 | 0.6 ± 0.3 | 0.6 ± 0.3 | 0.4 ± 0.1 | < 0.2 ± 0.1 | 0.094 ± 0.013 |
| Na | wt% | 0.28 ± 0.03 | 0.38 ± 0.07 | 0.52 ± 0.1 | 0.8 ± 0.04 | 0.005 ± 0.003 | 0.0024 ± 0.0001 |
| Nd | µg/g | 0.009 ± 0.003 | 0.039 ± 0.009 | 0.017 ± 0.002 | 0.026 ± 0.004 | 16 ± 0 | 17 |
| Ni | µg/g | < 0.05 ± 0.1 | < 0.05 ± 0.24 | < 0.05 ± 0.11 | < 0.05 ± 0.05 | < 0.05 ± 0.14 | 0.91 ± 0.12 |
| P | µg/g | 3200 ± 200 | 2000 ± 300 | 2000 ± 400 | 1500 ± 300 | 1500 ± 100 | 1600 ± 100 |
| Pb | µg/g | 0.03 ± 0.04 | 0.14 ± 0.06 | 0.02 ± 0.01 | 0.04 ± 0.05 | 0.4 ± 0.04 | 0.47 ± 0.02 |
| Pr | µg/g | 0.0013 ± 0.001 | 0.012 ± 0.003 | 0.0024 ± 0.0029 | 0.0049 ± 0.0011 | 4.1 ± 0.2 | ND |
| Rb | µg/g | 7.6 ± 0.5 | 9.6 ± 1.5 | 6.1 ± 1.2 | 4.7 ± 0.7 | 9.6 ± 0.4 | 10.2 ± 1.5 |
| Re | µg/g | < 0.002 ± 0 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.002 | < 0.002 ± 0 | ND |
| S | wt% | 0.39 ± 0.03 | 0.34 ± 0.02 | 0.46 ± 0.06 | 0.7 ± 0.03 | 0.2 ± 0.03 | 0.18 |
| Sb | µg/g | < 0.02 ± 0.03 | < 0.02 ± 0.01 | < 0.02 ± 0.03 | < 0.02 ± 0.01 | < 0.02 ± 0.01 | 0.013 |
| Sc | µg/g | < 0.4 ± 0.1 | < 0.4 ± 0.2 | < 0.4 ± 0.2 | < 0.4 ± 0.3 | < 0.4 ± 0.3 | 0.03 |
| Se | µg/g | < 0.7 ± 0.3 | < 0.7 ± 0.7 | < 0.7 ± 0.3 | < 0.7 ± 0.6 | 0.9 ± 0.4 | 0.05 ± 0.01 |
| Si | wt% | 0.19 ± 0.04 | 0.16 ± 0.03 | 0.25 ± 0.01 | 0.087 ± 0.008 | 0.033 ± 0.003 | ND |
| Sm | µg/g | < 0.006 ± 0.002 | 0.012 ± 0.004 | 0.007 ± 0.006 | 0.008 ± 0.001 | 2.7 ± 0.1 | 3 |
| Sr | µg/g | 51 ± 4 | 56 ± 9 | 59 ± 12 | 45 ± 6 | 24 ± 1 | 25 ± 2 |
| Ta | µg/g | < 0.010 ± 0.006 | < 0.010 ± 0.002 | < 0.010 ± 0.007 | < 0.010 ± 0.003 | < 0.010 ± 0.007 | ND |
| Tb | µg/g | < 0.001 ± 0.001 | < 0.001 ± 0.001 | < 0.001 ± 0.001 | < 0.001 ± 0.001 | 0.36 ± 0 | 0.4 |
| Te | µg/g | < 0.06 ± 0.02 | < 0.06 ± 0.03 | < 0.06 ± 0 | < 0.06 ± 0.02 | < 0.06 ± 0.03 | ND |
| Th | µg/g | < 0.02 ± 0.01 | < 0.02 ± 0.01 | < 0.02 ± 0.02 | < 0.02 ± 0.01 | < 0.02 ± 0 | 0.03 |
| Tl | µg/g | < 0.02 ± 0.04 | < 0.02 ± 0.02 | < 0.02 ± 0.01 | < 0.02 ± 0.04 | < 0.02 ± 0.01 | ND |
| Tm | µg/g | < 0.0008 ± 0.0001 | < 0.0008 ± 0.0014 | < 0.0008 ± 0.0004 | < 0.0008 ± 0.0003 | 0.053 ± 0.001 | ND |
| U | µg/g | 0.01 ± 0.006 | 0.057 ± 0.023 | 0.014 ± 0.006 | 0.024 ± 0.025 | 0.007 ± 0.006 | 0.006 |
| V | µg/g | < 0.7 ± 0.3 | < 0.6 ± 0.2 | < 0.7 ± 0.2 | < 0.7 ± 0.5 | < 0.7 ± 0.6 | 0.26 ± 0.03 |
| Y | µg/g | 0.068 ± 0.007 | 0.1 ± 0.03 | 0.12 ± 0.02 | 0.077 ± 0.014 | 9.4 ± 0.1 | ND |
| Yb | µg/g | < 0.003 ± 0.001 | 0.004 ± 0.003 | < 0.003 ± 0.001 | < 0.003 ± 0.003 | 0.2 ± 0.02 | 0.3 |
| Zn | µg/g | 16 ± 5 | 25 ± 7 | 9.9 ± 2.9 | 8.2 ± 2.1 | 11 ± 1 | 12.5 ± 0.3 |
| Zr | µg/g | 0.67 ± 0.04 | 0.92 ± 0.27 | 1.5 ± 0.1 | 0.7 ± 0.04 | 0.06 ± 0.01 | ND |

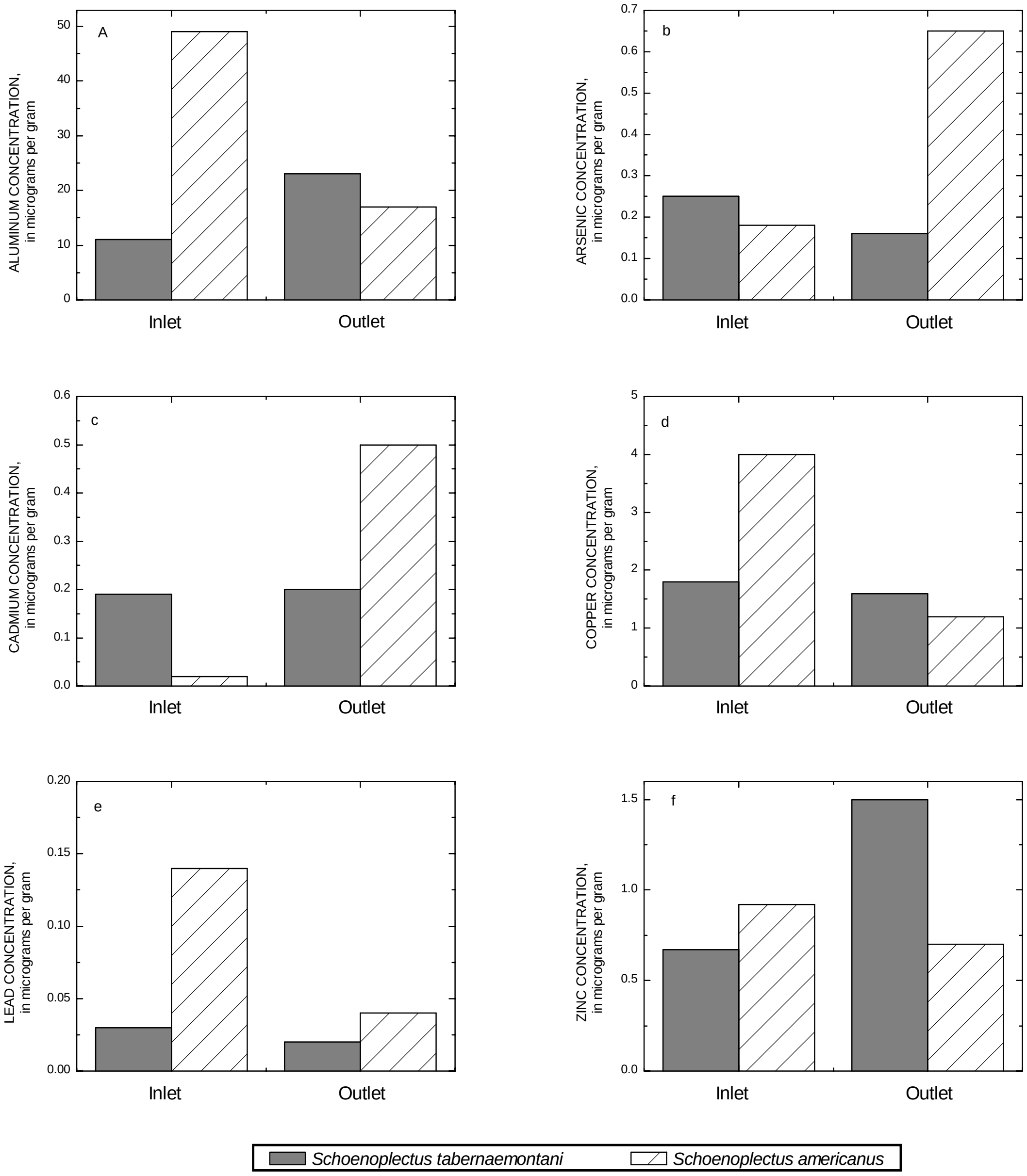

**Figure 4-6**. Plots of (a) aluminum, (b) arsenic, (c) cadmium, (d) copper, (e) lead, and (f) zinc concentrations (dry-weight basis) for softstem (*Schoenoplectus tabernaemontani)* and Olney's (*Schoenoplectus americanus)* bulrush samples collected at the inlet and outlet of the Cobble 2 wetland, June 23, 1998.

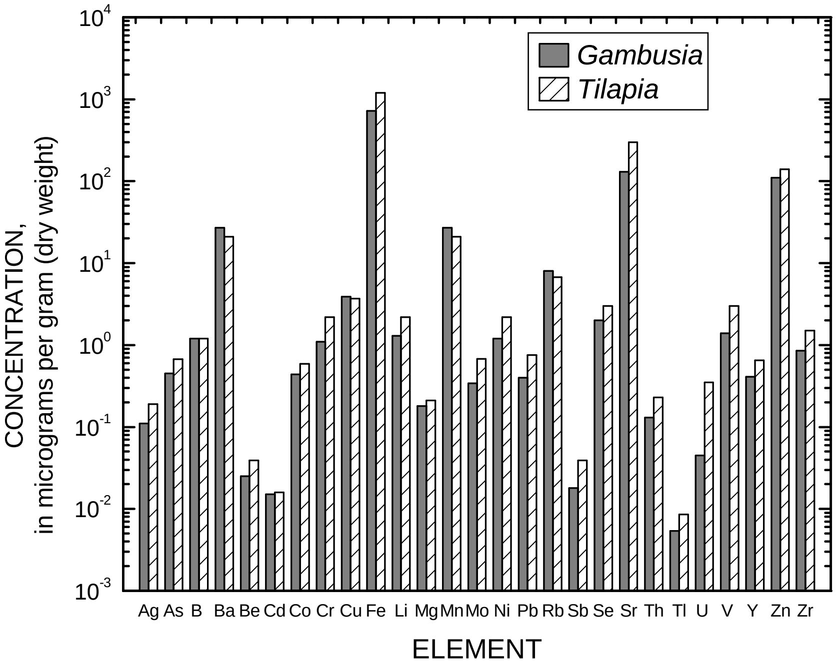

**Figure 4-7**. Plot of 27 selected trace-element concentrations for *Gambusia* and *Tilapia* whole-body tissue collected at the Hayfield 2 wetland, July 23, 1998.

## FISH TISSUE

Elemental composition data for two species of fish, *Gambusia* and *Tilapia*, collected from the H2 wetland on July 23, 1998, are listed in table 4-10. For *Gambusia,* whole-body data are reported in micrograms per gram (µg/g) on a dry-weight basis. *Tilapia* specimens were analyzed for both whole-body and dissected parts, including liver and filet tissue (table 2-15). Figure 4-7 shows a plot of 27 selected elements comparing the whole-body trace element composition of *Gambusia* and *Tilapia*. This figure demonstrates a high degree of similarity in composition between the two fish species.

Table 4-11 lists elemental data for *Gambusia* whole-body, and *Tilapia* filet and liver tissue collected from the Hayfield and Cobble wetlands, February 14, 2000. Data are reported in µg/g on a dry-weight basis. Replicate samples of both filet and liver tissue are listed as are data for NRC Dogfish Muscle Standard, DORM-1, and Dogfish Liver Standard, DOLT-1, SRM. Figure 4-8 shows plots for selected elements comparing concentrations in whole-body *Gambusia* and *Tilapia* filet and liver tissue. Replicate samples are designated to demonstrate variability between individual organisms.

**Table 4-10**. Trace-element composition data for *Gambusia* whole-body and *Tilapia* whole-body, filet, liver, and other tissue samples collected from the Hayfield 2 wetland, July 23, 1998. [Values reported on a dry-weight basis; µg/g, microgram per gram; wt%, weight percent]

| Element | Concentration Unit | *Gambusia* whole-body 1 | *Tilapia* whole-body 1 | *Tilapia* whole-body 2 | *Tilapia* filet 1 | *Tilapia* filet 2 |
|---|---|---|---|---|---|---|
| Al | µg/g | 530 ± 20 | 960 ± 10 | 680 ± 0 | 3 ± 0 | 27 ± 1 |
| As | µg/g | 0.45 ± 0.01 | 0.67 ± 0.01 | 0.45 ± 0 | 0.08 ± 0 | 0.19 ± 0.01 |
| B | µg/g | 1.2 ± 0.1 | 1.2 ± 0.1 | 1 ± 0 | 0.9 ± 0 | 0.5 ± 0 |
| Ba | µg/g | 27 ± 0 | 21 ± 0 | 12 ± 0 | 0.2 ± 0 | 1 ± 0 |
| Be | µg/g | 0.025 ± 0.002 | 0.039 ± 0.004 | 0.031 ± 0.002 | < 0.002 ± 0.001 | 0.004 ± 0 |
| Bi | µg/g | 0.031 ± 0 | 0.13 ± 0 | 0.18 ± 0.01 | 0.006 ± 0.001 | 0.023 ± 0.001 |
| Ca | wt% | 3.7 ± 0 | 6.3 ± 0 | 4.5 ± 0.1 | 0.11 ± 0 | 0.54 ± 0 |
| Cd | µg/g | 0.015 ± 0.001 | 0.016 ± 0.001 | 0.011 ± 0.001 | 0.0006 ± 0.0004 | < 0.0008 ± 0.0004 |
| Ce | µg/g | 1.5 ± 0 | 2.4 ± 0 | 1.8 ± 0 | 0.008 ± 0 | 0.072 ± 0 |
| Co | µg/g | 0.44 ± 0 | 0.59 ± 0.02 | 0.42 ± 0.01 | 0.02 ± 0 | 0.07 ± 0 |
| Cr | µg/g | 1.1 ± 0 | 2.2 ± 0 | 1.6 ± 0 | 0.2 ± 0.01 | 0.19 ± 0.11 |
| Cs | µg/g | 0.18 ± 0.01 | 0.29 ± 0.01 | 0.23 ± 0 | 0.11 ± 0.01 | 0.08 ± 0.02 |
| Cu | µg/g | 3.9 ± 0 | 3.7 ± 0 | 3.5 ± 0 | 0.7 ± 0 | 0.8 ± 0 |
| Dy | µg/g | 0.091 ± 0.002 | 0.14 ± 0 | 0.1 ± 0 | 0.0005 ± 0.0001 | 0.0043 ± 0.0002 |
| Er | µg/g | 0.036 ± 0 | 0.059 ± 0 | 0.043 ± 0 | 0.0003 ± 0.0001 | 0.002 ± 0.0003 |
| Eu | µg/g | 0.027 ± 0 | 0.043 ± 0.001 | 0.031 ± 0.002 | 0.0001 ± 0 | 0.0012 ± 0 |
| Fe | µg/g | 720 ± 40 | 1200 ± 100 | 930 ± 90 | 17 ± 2 | 61 ± 3 |
| Gd | µg/g | 0.1 ± 0 | 0.16 ± 0 | 0.12 ± 0 | 0.0007 ± 0.0001 | 0.0054 ± 0 |
| Ho | µg/g | 0.014 ± 0 | 0.022 ± 0.001 | 0.016 ± 0 | 0.0001 ± 0 | 0.0007 ± 0.0001 |
| La | µg/g | 0.69 ± 0 | 1 ± 0 | 0.77 ± 0 | 0.004 ± 0 | 0.035 ± 0.001 |
| Li | µg/g | 1.3 ± 0 | 2.2 ± 0 | 1.7 ± 0 | 0.05 ± 0.01 | 0.18 ± 0.02 |
| Lu | µg/g | 0.005 ± 0.0001 | 0.0079 ± 0.0005 | 0.0059 ± 0 | 0.0001 ± 0 | 0.0002 ± 0 |
| Mg | wt% | 0.18 ± 0 | 0.21 ± 0.01 | 0.16 ± 0 | 0.14 ± 0 | 0.16 ± 0 |
| Mn | µg/g | 27 ± 0 | 21 ± 1 | 20 ± 1 | 0.6 ± 0 | 1.9 ± 0.1 |
| Mo | µg/g | 0.34 ± 0 | 0.68 ± 0.02 | 0.57 ± 0.02 | 0.07 ± 0.02 | 0.09 ± 0.01 |
| Na | wt% | 0.36 ± 0 | 0.57 ± 0.02 | 0.42 ± 0.02 | 0.27 ± 0 | 0.4 ± 0.01 |
| Nd | µg/g | 0.67 ± 0.01 | 1 ± 0 | 0.76 ± 0 | 0.003 ± 0 | 0.033 ± 0 |
| Ni | µg/g | 1.2 ± 0 | 2.2 ± 0 | 1.5 ± 0.1 | 0.09 ± 0.02 | 0.58 ± 0 |
| P | wt% | 1.8 ± 0 | 3.1 ± 0 | 2.2 ± 0.1 | 0.76 ± 0.03 | 0.91 ± 0.01 |
| Pb | µg/g | 0.4 ± 0 | 0.76 ± 0 | 0.54 ± 0.01 | 0.008 ± 0 | 0.028 ± 0 |
| Pr | µg/g | 0.18 ± 0 | 0.28 ± 0.01 | 0.21 ± 0.01 | 0.001 ± 0 | 0.009 ± 0 |
| Rb | µg/g | 8 ± 0.1 | 6.7 ± 0 | 5.8 ± 0 | 11 ± 0 | 10 ± 0 |
| Re | µg/g | 0.001 ± 0 | < 0.001 ± 0 | < 0.001 ± 0.001 | < 0.001 ± 0 | 0.005 ± 0.001 |
| S | wt% | 1.6 ± 0 | 1.4 ± 0.1 | 1.1 ± 0 | 1.6 ± 0 | 2.2 ± 0.1 |
| Sb | µg/g | 0.018 ± 0.001 | 0.039 ± 0.001 | 0.031 ± 0.001 | 0.002 ± 0 | 0.004 ± 0 |
| Se | µg/g | 2 ± 0 | 3 ± 0 | 2.3 ± 0.1 | 3 ± 0.1 | 3.8 ± 0 |
| Si | wt% | 0.23 ± 0 | 0.23 ± 0 | 0.19 ± 0 | 0.03 ± 0 | 0.06 ± 0 |
| Sm | µg/g | 0.13 ± 0 | 0.2 ± 0 | 0.15 ± 0 | 0.0008 ± 0.0002 | 0.0061 ± 0.0002 |
| Sr | µg/g | 130 ± 0 | 300 ± 0 | 190 ± 0 | 3.7 ± 0.1 | 21 ± 0 |
| Tb | µg/g | 0.012 ± 0 | 0.019 ± 0 | 0.014 ± 0 | 0.0001 ± 0 | 0.0007 ± 0.0001 |
| Te | µg/g | < 0.02 ± 0.01 | < 0.02 ± 0.01 | < 0.01 ± 0.01 | < 0.02 ± 0.01 | < 0.03 ± 0 |
| Th | µg/g | 0.13 ± 0 | 0.23 ± 0 | 0.16 ± 0 | 0.001 ± 0 | 0.007 ± 0.001 |
| Tl | µg/g | 0.0054 ± 0.0002 | 0.0086 ± 0.0001 | 0.0068 ± 0.0001 | < 0.0002 ± 0.0001 | 0.0006 ± 0.0003 |
| Tm | µg/g | 0.0067 ± 0.0002 | 0.011 ± 0 | 0.0079 ± 0 | < 0.0001 ± 0 | 0.0003 ± 0.0001 |
| U | µg/g | 0.045 ± 0 | 0.35 ± 0 | 0.18 ± 0.01 | 0.002 ± 0 | 0.012 ± 0 |
| V | µg/g | 1.4 ± 0 | 3 ± 0 | 2.1 ± 0 | < 0.005 ± 0.001 | 0.08 ± 0.03 |
| Y | µg/g | 0.41 ± 0 | 0.65 ± 0.02 | 0.47 ± 0.01 | 0.002 ± 0 | 0.02 ± 0 |
| Yb | µg/g | 0.039 ± 0 | 0.062 ± 0.002 | 0.044 ± 0.001 | 0.0003 ± 0.0001 | 0.0019 ± 0.0002 |
| Zn | µg/g | 110 ± 0 | 140 ± 0 | 81 ± 0 | 18 ± 0 | 41 ± 1 |
| Zr | µg/g | 0.85 ± 0 | 1.5 ± 0.1 | 1.2 ± 0 | 0.009 ± 0 | 0.057 ± 0.001 |

**Table 4-10**. Continued.

| Ele-ment | Concen-tration Unit | *Tilapia* liver 1 | *Tilapia* liver 2 | *Tilapia* other 1 | *Tilapia* other 2 |
|---|---|---|---|---|---|
| Al | µg/g | 81 ± 0 | 170 ± 0 | 280 ± 0 | 1100 ± 0 |
| As | µg/g | 0.38 ± 0 | 0.58 ± 0 | 0.3 ± 0 | 0.78 ± 0.01 |
| B | µg/g | 1.6 ± 0.1 | 4.1 ± 0 | 1.7 ± 0.1 | 1.6 ± 0 |
| Ba | µg/g | 1.2 ± 0 | 2.7 ± 0 | 12 ± 0 | 21 ± 0 |
| Be | µg/g | 0.004 ± 0.003 | < 0.005 ± 0.009 | 0.014 ± 0 | 0.053 ± 0.002 |
| Bi | µg/g | 0.32 ± 0 | 0.26 ± 0 | 0.082 ± 0 | 0.38 ± 0 |
| Ca | wt% | 0.15 ± 0.03 | 0.37 ± 0.24 | 5.9 ± 0 | 5.2 ± 0 |
| Cd | µg/g | 0.046 ± 0.001 | 0.023 ± 0 | 0.0091 ± 0.0006 | 0.018 ± 0.001 |
| Ce | µg/g | 0.23 ± 0 | 0.47 ± 0.01 | 0.71 ± 0 | 3 ± 0.1 |
| Co | µg/g | 1.4 ± 0 | 0.79 ± 0.02 | 0.17 ± 0 | 0.75 ± 0.01 |
| Cr | µg/g | 0.39 ± 0.05 | 1.8 ± 0 | 0.82 ± 0.07 | 3 ± 0 |
| Cs | µg/g | 0.05 ± 0.01 | 0.11 ± 0.01 | 0.14 ± 0 | 0.37 ± 0.01 |
| Cu | µg/g | 216 ± 1 | 78 ± 1 | 2.6 ± 0 | 4.4 ± 0.1 |
| Dy | µg/g | 0.01 ± 0 | 0.021 ± 0 | 0.042 ± 0.001 | 0.17 ± 0 |
| Er | µg/g | 0.0045 ± 0.0005 | 0.0081 ± 0.0007 | 0.017 ± 0 | 0.072 ± 0.001 |
| Eu | µg/g | 0.0034 ± 0.0004 | 0.0068 ± 0.0002 | 0.013 ± 0 | 0.053 ± 0.001 |
| Fe | µg/g | 1700 ± 100 | 2600 ± 100 | 550 ± 30 | 1600 ± 100 |
| Gd | µg/g | 0.014 ± 0 | 0.028 ± 0.004 | 0.062 ± 0.022 | 0.2 ± 0 |
| Ho | µg/g | 0.0015 ± 0.0001 | 0.0034 ± 0.0001 | 0.0067 ± 0.0001 | 0.026 ± 0 |
| La | µg/g | 0.12 ± 0 | 0.21 ± 0 | 0.32 ± 0.01 | 1.3 ± 0 |
| Li | µg/g | 0.31 ± 0 | 0.57 ± 0.02 | 0.92 ± 0.02 | 2.7 ± 0.1 |
| Lu | µg/g | 0.0005 ± 0 | 0.0012 ± 0.0002 | 0.0026 ± 0.0001 | 0.0097 ± 0.0002 |
| Mg | wt% | 0.08 ± 0 | 0.12 ± 0.01 | 0.18 ± 0 | 0.23 ± 0 |
| Mn | µg/g | 10 ± 0 | 19 ± 0 | 16 ± 1 | 38 ± 2 |
| Mo | µg/g | 27 ± 0 | 12 ± 0 | 0.37 ± 0 | 0.79 ± 0.02 |
| Na | wt% | 0.83 ± 0 | 0.79 ± 0 | 0.54 ± 0 | 0.53 ± 0.02 |
| Nd | µg/g | 0.095 ± 0.002 | 0.19 ± 0 | 0.31 ± 0.01 | 1.3 ± 0 |
| Ni | µg/g | 2.1 ± 0 | 2.7 ± 0 | 0.65 ± 0.08 | 2.5 ± 0.1 |
| P | wt% | 0.91 ± 0.01 | 0.94 ± 0.15 | 3 ± 0 | 2.7 ± 0 |
| Pb | µg/g | 0.16 ± 0 | 0.24 ± 0.01 | 0.39 ± 0 | 0.93 ± 0 |
| Pr | µg/g | 0.025 ± 0 | 0.05 ± 0 | 0.083 ± 0 | 0.35 ± 0 |
| Rb | µg/g | 6.6 ± 0 | 5.5 ± 0 | 7.9 ± 0 | 8.7 ± 0.3 |
| Re | µg/g | 0.003 ± 0 | < 0.004 ± 0.001 | 0.003 ± 0.005 | 0.003 ± 0.003 |
| S | wt% | 1.7 ± 0 | 1.5 ± 0 | 1.5 ± 0.1 | 1.5 ± 0.1 |
| Sb | µg/g | 0.058 ± 0.001 | 0.036 ± 0.001 | 0.022 ± 0.002 | 0.047 ± 0.002 |
| Se | µg/g | 30 ± 0 | 15 ± 0 | 3.3 ± 0 | 3.3 ± 0.1 |
| Si | wt% | 0.6 ± 0 | 0.89 ± 0 | 0.47 ± 0 | 0.29 ± 0 |
| Sm | µg/g | 0.017 ± 0 | 0.035 ± 0.001 | 0.058 ± 0.002 | 0.25 ± 0 |
| Sr | µg/g | 8 ± 0.2 | 18 ± 0 | 270 ± 0 | 230 ± 10 |
| Tb | µg/g | 0.0014 ± 0.0001 | 0.003 ± 0.0002 | 0.0056 ± 0.0001 | 0.023 ± 0 |
| Te | µg/g | 0.06 ± 0.01 | < 0.06 ± 0.04 | < 0.02 ± 0 | < 0.01 ± 0.01 |
| Th | µg/g | 0.011 ± 0 | 0.013 ± 0.001 | 0.061 ± 0 | 0.26 ± 0 |
| Tl | µg/g | 0.0027 ± 0.0001 | 0.003 ± 0.0025 | 0.0034 ± 0.0008 | 0.012 ± 0 |
| Tm | µg/g | 0.0007 ± 0 | 0.0015 ± 0 | 0.0032 ± 0.0002 | 0.013 ± 0 |
| U | µg/g | 0.082 ± 0 | 0.1 ± 0 | 0.12 ± 0 | 0.32 ± 0.01 |
| V | µg/g | 0.72 ± 0.01 | 0.52 ± 0 | 1.5 ± 0 | 3.3 ± 0 |
| Y | µg/g | 0.046 ± 0.001 | 0.1 ± 0 | 0.2 ± 0 | 0.79 ± 0.01 |
| Yb | µg/g | 0.004 ± 0.0001 | 0.0098 ± 0.0001 | 0.019 ± 0.001 | 0.075 ± 0.002 |
| Zn | µg/g | 110 ± 0 | 110 ± 0 | 86 ± 0 | 110 ± 0 |
| Zr | µg/g | 0.04 ± 0.003 | 0.004 ± 0.004 | 0.54 ± 0.01 | 2.1 ± 0 |

**Table 4-11**. Trace-element composition data for *Gambusia* whole-body tissue collected from the Cobble 2 wetland, and *Tilapia* filet and liver tissue collected from the Hayfield 1 wetland, February 14, 2000. [Values reported on a dry-weight basis; µg/g, microgram per gram; ng/g, nanogram per gram; wt%, weight percent; analysis of Dogfish Muscle Standard, DORM-1, and Dogfish Liver Standard, DOLT-1, are listed with certified values (Taylor, 2001); ND, not determined]

| Element | Concentration Unit | *Gambusia* whole-body | *Tilapia* filet 1 | *Tilapia* filet 3 | *Tilapia* filet 4 | *Tilapia* filet 5 | *Tilapia* filet 6 |
|---|---|---|---|---|---|---|---|
| Al | µg/g | 22 ± 5 | < 0.8 ± 1.6 | < 1 ± 1 | < 0.9 ± 1 | < 0.3 ± 1.1 | < 0.9 ± 1.7 |
| As | µg/g | 0.46 ± 0.11 | 0.3 ± 0.22 | 0.49 ± 0.24 | 0.46 ± 0.2 | 0.12 ± 0.06 | 0.4 ± 0.14 |
| B | µg/g | < 9 ± 6 | < 9 ± 3 | < 10 ± 0 | < 10 ± 11 | 6 ± 2 | < 10 ± 3 |
| Ba | µg/g | 9.4 ± 0 | < 0.06 ± 0.07 | < 0.09 ± 0.01 | 0.76 ± 0.07 | 0.04 ± 0.02 | 0.4 ± 0.08 |
| Be | µg/g | < 0.3 ± 0.1 | < 0.3 ± 0.1 | < 0.4 ± 0.3 | < 0.3 ± 0.3 | < 0.09 ± 0.05 | < 0.3 ± 0.2 |
| Bi | µg/g | < 0.005 ± 0.008 | < 0.005 ± 0.009 | < 0.007 ± 0.015 | < 0.006 ± 0.01 | < 0.002 ± 0.002 | 0.024 ± 0.034 |
| Ca | wt% | 5.3 ± 0.2 | 0.07 ± 0.019 | 0.12 ± 0.01 | 1 ± 0.1 | 0.022 ± 0.002 | 1 ± 0.1 |
| Cd | µg/g | < 0.07 ± 0.06 | < 0.07 ± 0 | < 0.09 ± 0.1 | < 0.07 ± 0.11 | < 0.02 ± 0.02 | < 0.07 ± 0.07 |
| Ce | µg/g | 0.092 ± 0.004 | < 0.003 ± 0.007 | < 0.004 ± 0.005 | < 0.003 ± 0.005 | 0.004 ± 0.002 | 0.012 ± 0.008 |
| Co | µg/g | < 0.05 ± 0.06 | < 0.05 ± 0.02 | < 0.07 ± 0.08 | < 0.06 ± 0.06 | < 0.02 ± 0.01 | < 0.06 ± 0.02 |
| Cr | µg/g | < 2 ± 1 | < 2 ± 0 | 4 ± 4 | < 2 ± 0 | < 0.7 ± 0.3 | < 2 ± 1 |
| Cs | µg/g | < 1 ± 0 | < 1 ± 1 | < 2 ± 0 | < 2 ± 0 | < 0.5 ± 0 | < 2 ± 0 |
| Cu | µg/g | 8.3 ± 0.5 | 3.2 ± 1 | 4.3 ± 0.5 | 3.6 ± 1.8 | 0.5 ± 0.1 | 2.2 ± 0.3 |
| Dy | µg/g | 0.007 ± 0.008 | < 0.007 ± 0.003 | < 0.010 ± 0.006 | < 0.008 ± 0.006 | < 0.002 ± 0.002 | < 0.008 ± 0.002 |
| Er | µg/g | < 0.01 ± 0.01 | < 0.01 ± 0 | < 0.02 ± 0.01 | < 0.01 ± 0.01 | < 0.004 ± 0.002 | < 0.01 ± 0 |
| Eu | µg/g | < 0.003 ± 0 | < 0.003 ± 0.001 | < 0.005 ± 0.002 | < 0.004 ± 0.003 | < 0.003 ± 0.001 | < 0.004 ± 0.003 |
| Fe | µg/g | 180 ± 20 | < 5 ± 3 | 13 ± 3 | 19 ± 17 | 3 ± 1 | 13 ± 1 |
| Gd | µg/g | < 0.009 ± 0.008 | < 0.007 ± 0.003 | < 0.01 ± 0 | < 0.009 ± 0.003 | < 0.003 ± 0.001 | < 0.009 ± 0.004 |
| Hg | ng/g | 64 ± 0 | 8 ± 1 | 8 ± 3 | 15 ± 2 | 6 ± 2 | 14 ± 3 |
| Ho | µg/g | < 0.002 ± 0.001 | < 0.002 ± 0.001 | < 0.002 ± 0.002 | < 0.002 ± 0.002 | < 0.0006 ± 0.0006 | < 0.002 ± 0 |
| K | wt% | 1.2 ± 0.1 | 1.3 ± 0.1 | 1.6 ± 0.1 | 1.5 ± 0.2 | 0.35 ± 0.03 | 1.5 ± 0.1 |
| La | µg/g | 0.045 ± 0.001 | < 0.003 ± 0.003 | < 0.004 ± 0.001 | < 0.003 ± 0.001 | 0.002 ± 0.001 | 0.007 ± 0.002 |
| Li | µg/g | 0.3 ± 0 | 0.2 ± 0.2 | < 0.3 ± 0.3 | 0.6 ± 0.1 | 0.1 ± 0.1 | < 0.2 ± 0 |
| Lu | µg/g | < 0.002 ± 0 | < 0.002 ± 0.001 | < 0.003 ± 0.001 | < 0.002 ± 0.001 | < 0.0007 ± 0.0001 | < 0.002 ± 0.001 |
| Mg | wt% | 0.19 ± 0.01 | 0.073 ± 0.02 | 0.13 ± 0 | 0.13 ± 0.01 | 0.019 ± 0.002 | 0.12 ± 0.01 |
| Mn | µg/g | 18 ± 1 | 0.14 ± 0.1 | 0.91 ± 1.06 | 1.1 ± 0.7 | 0.18 ± 0.07 | 1.7 ± 1.2 |
| Mo | µg/g | < 0.1 ± 0.1 | < 0.1 ± 0.1 | < 0.2 ± 0.4 | < 0.1 ± 0.1 | < 0.04 ± 0.22 | < 0.1 ± 0.2 |
| Na | wt% | 0.37 ± 0.02 | 0.36 ± 0.1 | 0.51 ± 0.01 | 0.44 ± 0.03 | 0.13 ± 0.01 | 0.54 ± 0.05 |
| Nd | µg/g | 0.038 ± 0.011 | < 0.01 ± 0 | < 0.02 ± 0.01 | < 0.01 ± 0.01 | < 0.004 ± 0.002 | < 0.01 ± 0.01 |
| Ni | µg/g | < 0.2 ± 0.4 | 1.1 ± 0.2 | < 0.3 ± 0.3 | 0.3 ± 0 | < 0.06 ± 0.05 | < 0.2 ± 0.3 |
| P | wt% | 2.91 ± 0.06 | 0.53 ± 0.11 | 0.76 ± 0.06 | 0.96 ± 0.05 | 0.14 ± 0.03 | 0.94 ± 0.04 |
| Pb | µg/g | 0.05 ± 0.15 | < 0.04 ± 0.01 | < 0.05 ± 0.15 | < 0.04 ± 0 | < 0.01 ± 0 | < 0.04 ± 0.06 |
| Pd | µg/g | 0.014 ± 0.003 | < 0.01 ± 0 | < 0.02 ± 0.01 | 0.015 ± 0.015 | < 0.004 ± 0.003 | < 0.01 ± 0.01 |
| Pr | µg/g | 0.013 ± 0.002 | 0.003 ± 0.001 | < 0.004 ± 0.003 | < 0.003 ± 0 | < 0.0009 ± 0.0008 | < 0.003 ± 0.002 |
| Rb | µg/g | 11 ± 1 | 6.3 ± 1.7 | 9 ± 0.2 | 7.9 ± 0.3 | 1.8 ± 0.2 | 9.5 ± 0.9 |
| Re | µg/g | < 0.006 ± 0.003 | < 0.006 ± 0.002 | < 0.008 ± 0.003 | < 0.006 ± 0.002 | < 0.002 ± 0.001 | < 0.006 ± 0.002 |
| S | wt% | 1.17 ± 0.09 | 0.82 ± 0.08 | 1.3 ± 0.05 | 1.23 ± 0.16 | 0.23 ± 0.02 | 1.18 ± 0.16 |
| Sb | µg/g | < 0.04 ± 0.02 | < 0.04 ± 0.05 | < 0.06 ± 0.02 | < 0.05 ± 0.01 | < 0.01 ± 0.01 | < 0.05 ± 0.01 |
| Se | µg/g | 5.2 ± 0.4 | 3.9 ± 2 | 6.1 ± 1.4 | 2.1 ± 0.1 | 1 ± 0.2 | 5.2 ± 1.2 |
| Si | wt% | < 0.02 ± 0.02 | < 0.02 ± 0.01 | < 0.04 ± 0.02 | < 0.03 ± 0 | < 0.009 ± 0.002 | < 0.03 ± 0.02 |
| Sm | µg/g | 0.011 ± 0.003 | < 0.007 ± 0.003 | < 0.01 ± 0.01 | < 0.008 ± 0.012 | < 0.003 ± 0.001 | < 0.008 ± 0.001 |
| Sr | µg/g | 170 ± 10 | 1.9 ± 0.5 | 3.5 ± 0.6 | 37 ± 2 | 0.5 ± 0.1 | 40 ± 3 |
| Ta | µg/g | 0.019 ± 0.015 | < 0.01 ± 0 | 0.027 ± 0.008 | 0.041 ± 0.003 | 0.013 ± 0.002 | 0.016 ± 0.004 |
| Tb | µg/g | < 0.002 ± 0 | < 0.002 ± 0.001 | < 0.003 ± 0.001 | 0.002 ± 0.003 | < 0.0007 ± 0.0002 | < 0.002 ± 0.001 |
| Te | µg/g | < 0.1 ± 0 | < 0.1 ± 0.1 | < 0.2 ± 0.2 | < 0.1 ± 0.1 | < 0.04 ± 0.02 | < 0.1 ± 0 |
| Th | µg/g | < 0.008 ± 0.015 | < 0.008 ± 0.009 | < 0.01 ± 0 | < 0.009 ± 0.007 | < 0.003 ± 0.001 | < 0.009 ± 0.012 |
| Tl | µg/g | < 0.06 ± 0.01 | < 0.06 ± 0.14 | < 0.08 ± 0.02 | < 0.07 ± 0.07 | < 0.02 ± 0.05 | < 0.07 ± 0.06 |
| Tm | µg/g | < 0.002 ± 0.001 | < 0.002 ± 0.002 | < 0.003 ± 0.001 | < 0.002 ± 0 | < 0.0007 ± 0.0003 | < 0.002 ± 0.001 |
| U | µg/g | 0.035 ± 0.011 | < 0.006 ± 0.01 | < 0.009 ± 0.003 | 0.009 ± 0.001 | < 0.002 ± 0.003 | 0.023 ± 0.003 |
| V | µg/g | < 0.8 ± 0.1 | < 0.8 ± 0.8 | < 1 ± 1 | < 0.9 ± 0.9 | < 0.3 ± 0.1 | 1.1 ± 1.5 |
| Y | µg/g | 0.028 ± 0.008 | < 0.003 ± 0 | 0.008 ± 0.003 | 0.011 ± 0.009 | 0.001 ± 0.002 | 0.01 ± 0.003 |
| Yb | µg/g | < 0.008 ± 0.001 | < 0.008 ± 0.003 | < 0.01 ± 0 | < 0.008 ± 0.008 | < 0.003 ± 0 | < 0.008 ± 0.001 |
| Zn | µg/g | 180 ± 0 | 27 ± 6 | 42 ± 4 | 57 ± 10 | 8 ± 1 | 49 ± 8 |
| Zr | µg/g | 0.13 ± 0.02 | 0.05 ± 0.01 | 0.07 ± 0.01 | 0.07 ± 0 | 0.04 ± 0.01 | 0.08 ± 0.01 |

**Table 4-11**. Continued.

| Element | Concentration Unit | *Tilapia* filet 8 | *Tilapia* filet 10 | *Tilapia* liver 1 | *Tilapia* liver 5 | *Tilapia* liver 6 | *Tilapia* liver 7 |
|---|---|---|---|---|---|---|---|
| Al | µg/g | < 1.0 ± 1.3 | < 4 ± 3 | 42 ± 3 | 200 ± 50 | 96 ± 4 | 13000 ± 1000 |
| As | µg/g | 0.56 ± 0.28 | 1.8 ± 1.5 | 0.23 ± 0.05 | 0.37 ± 0.13 | 1.7 ± 0.3 | 3.8 ± 1.4 |
| B | µg/g | < 10 ± 6 | < 40 ± 70 | < 6 ± 1 | < 7 ± 1 | < 20 ± 20 | 82 ± 45 |
| Ba | µg/g | < 0.07 ± 0.07 | < 0.3 ± 0.1 | 0.85 ± 0.08 | 9.3 ± 2.4 | 2.2 ± 0 | 140 ± 10 |
| Be | µg/g | < 0.3 ± 0.3 | < 1 ± 1 | < 0.2 ± 0.1 | < 0.2 ± 0.2 | < 0.6 ± 0.6 | 1.8 ± 0.8 |
| Bi | µg/g | < 0.006 ± 0.009 | < 0.03 ± 0.01 | 0.046 ± 0.004 | 0.22 ± 0.05 | 0.24 ± 0.02 | 1.7 ± 0.3 |
| Ca | wt% | 0.1 ± 0.02 | 0.35 ± 0.06 | 0.43 ± 0.01 | 0.13 ± 0.03 | 0.8 ± 0.02 | 0.56 ± 0.09 |
| Cd | µg/g | < 0.08 ± 0.06 | < 0.3 ± 0.3 | < 0.05 ± 0.02 | < 0.05 ± 0.06 | < 0.2 ± 0.1 | < 0.4 ± 0.3 |
| Ce | µg/g | 0.005 ± 0.004 | < 0.02 ± 0.02 | 0.06 ± 0.007 | 0.39 ± 0.11 | 0.33 ± 0.05 | 24 ± 1 |
| Co | µg/g | < 0.06 ± 0.02 | < 0.3 ± 0.2 | 0.07 ± 0.02 | 0.19 ± 0.07 | 0.52 ± 0.06 | 4.7 ± 0.7 |
| Cr | µg/g | 3 ± 2 | < 10 ± 0 | < 1 ± 1 | < 2 ± 1 | < 5 ± 4 | 30 ± 12 |
| Cs | µg/g | < 2 ± 1 | < 7 ± 2 | < 1 ± 0 | < 1 ± 1 | < 4 ± 0 | 19 ± 2 |
| Cu | µg/g | 2.5 ± 0.6 | 18 ± 2 | 45 ± 0 | 51 ± 13 | 280 ± 30 | 47 ± 3 |
| Dy | µg/g | < 0.008 ± 0.005 | < 0.04 ± 0.02 | < 0.005 ± 0.001 | 0.007 ± 0.002 | < 0.02 ± 0 | 1.2 ± 0 |
| Er | µg/g | < 0.01 ± 0.01 | < 0.06 ± 0.02 | < 0.008 ± 0.004 | < 0.008 ± 0.004 | < 0.03 ± 0.02 | 0.057 ± 0.02 |
| Eu | µg/g | < 0.004 ± 0.002 | < 0.02 ± 0.02 | < 0.002 ± 0.001 | 0.004 ± 0.002 | < 0.008 ± 0.005 | 0.34 ± 0.01 |
| Fe | µg/g | 19 ± 5 | 31 ± 14 | 310 ± 10 | 930 ± 40 | 1600 ± 0 | 14000 ± 1000 |
| Gd | µg/g | < 0.01 ± 0.009 | < 0.04 ± 0.04 | < 0.006 ± 0.002 | 0.015 ± 0.005 | 0.021 ± 0.02 | 1.4 ± 0 |
| Hg | ng/g | 15 ± 3 | 8 ± 2 | 8 ± 4 | 14 ± 9 | 63 ± 6 | 54 ± 16 |
| Ho | µg/g | 0.003 ± 0.002 | < 0.008 ± 0.005 | < 0.001 ± 0.001 | 0.003 ± 0.001 | 0.005 ± 0.002 | 0.24 ± 0 |
| K | wt% | 1.9 ± 0 | 5 ± 0.2 | 0.28 ± 0.02 | 0.28 ± 0.08 | 1.7 ± 0.2 | 1.1 ± 0.3 |
| La | µg/g | 0.006 ± 0.004 | < 0.01 ± 0.01 | 0.024 ± 0.003 | 0.15 ± 0.04 | 0.16 ± 0.01 | 11 ± 1 |
| Li | µg/g | 0.3 ± 0.2 | < 1.0 ± 0.6 | < 0.1 ± 0 | 0.3 ± 0.1 | 0.5 ± 0.1 | 17 ± 2 |
| Lu | µg/g | < 0.002 ± 0.001 | < 0.010 ± 0.009 | < 0.001 ± 0.001 | < 0.001 ± 0.001 | < 0.005 ± 0.003 | 0.078 ± 0.012 |
| Mg | wt% | 0.11 ± 0.01 | 0.29 ± 0.03 | 0.047 ± 0.002 | 0.06 ± 0.015 | 0.24 ± 0.03 | 0.52 ± 0.05 |
| Mn | µg/g | 1.3 ± 1.3 | 2.5 ± 5.3 | 1.6 ± 0 | 6.2 ± 1.5 | 6.4 ± 1.3 | 110 ± 10 |
| Mo | µg/g | < 0.1 ± 0.2 | < 0.6 ± 1.4 | 4.2 ± 0.1 | 2.8 ± 0.5 | 26 ± 0 | 4.2 ± 1.5 |
| Na | wt% | 0.57 ± 0.08 | 1.6 ± 0.1 | 0.21 ± 0.01 | 0.21 ± 0.05 | 1.2 ± 0.1 | 0.43 ± 0.05 |
| Nd | µg/g | 0.014 ± 0.007 | < 0.06 ± 0.03 | 0.021 ± 0.003 | 0.11 ± 0.03 | 0.1 ± 0.02 | 9.7 ± 1 |
| Ni | µg/g | 0.3 ± 0 | < 0.9 ± 0.2 | 0.4 ± 0.1 | 0.8 ± 0 | 1.8 ± 0.4 | 18 ± 1 |
| P | wt% | 0.83 ± 0.12 | 2.08 ± 0.02 | 0.34 ± 0.08 | 0.2 ± 0.06 | 1.24 ± 0.24 | 0.61 ± 0.07 |
| Pb | µg/g | 0.08 ± 0.15 | < 0.2 ± 0.7 | 0.03 ± 0.02 | 0.39 ± 0.12 | 0.44 ± 0.07 | 10 ± 1 |
| Pd | µg/g | 0.017 ± 0.024 | < 0.06 ± 0.04 | 0.009 ± 0.002 | 0.027 ± 0.007 | 0.033 ± 0.028 | 0.17 ± 0.06 |
| Pr | µg/g | 0.006 ± 0.003 | 0.019 ± 0.014 | 0.006 ± 0.002 | 0.032 ± 0.006 | 0.037 ± 0.016 | 2.7 ± 0.1 |
| Rb | µg/g | 10 ± 0 | 25 ± 3 | 1.8 ± 0.1 | 1.7 ± 0.4 | 10 ± 1 | 25 ± 2 |
| Re | µg/g | < 0.007 ± 0.001 | < 0.03 ± 0.01 | < 0.004 ± 0 | < 0.004 ± 0.001 | < 0.01 ± 0.01 | < 0.03 ± 0.01 |
| S | wt% | 1.41 ± 0.07 | 3.54 ± 0.42 | 0.2 ± 0 | 0.18 ± 0.03 | 1.2 ± 0.11 | 0.55 ± 0.1 |
| Sb | µg/g | < 0.05 ± 0.02 | < 0.2 ± 0.2 | < 0.03 ± 0.01 | < 0.03 ± 0.03 | < 0.1 ± 0 | < 0.3 ± 0.2 |
| Se | µg/g | 4.7 ± 1.7 | 18 ± 1 | 4.8 ± 0.8 | 4.3 ± 1.1 | 33 ± 2 | 10 ± 4 |
| Si | wt% | < 0.03 ± 0.01 | < 0.1 ± 0 | < 0.02 ± 0.01 | 0.02 ± 0.01 | 0.07 ± 0.06 | 2.47 ± 0.6 |
| Sm | µg/g | < 0.008 ± 0.003 | < 0.04 ± 0.06 | < 0.005 ± 0.001 | 0.034 ± 0.003 | 0.034 ± 0.033 | 1.6 ± 0.3 |
| Sr | µg/g | 3.1 ± 0.8 | 9.7 ± 2.5 | 18 ± 0 | 13 ± 3 | 31 ± 3 | 81 ± 7 |
| Ta | µg/g | 0.019 ± 0.008 | 0.12 ± 0.02 | 0.009 ± 0.002 | 0.018 ± 0.01 | < 0.03 ± 0.03 | 0.17 ± 0.05 |
| Tb | µg/g | < 0.002 ± 0.002 | < 0.010 ± 0.004 | < 0.001 ± 0.001 | 0.002 ± 0.001 | < 0.005 ± 0.001 | 0.24 ± 0 |
| Te | µg/g | < 0.1 ± 0 | 0.62 ± 0.04 | < 0.08 ± 0.01 | < 0.09 ± 0.01 | < 0.3 ± 0 | < 0.7 ± 0.5 |
| Th | µg/g | < 0.009 ± 0.005 | < 0.04 ± 0.05 | < 0.006 ± 0.009 | 0.015 ± 0.014 | 0.034 ± 0.03 | 1.9 ± 0.2 |
| Tl | µg/g | < 0.07 ± 0.1 | < 0.3 ± 0.2 | < 0.04 ± 0.02 | < 0.04 ± 0.06 | < 0.1 ± 0.2 | < 0.4 ± 0.6 |
| Tm | µg/g | < 0.002 ± 0 | < 0.01 ± 0.01 | < 0.001 ± 0 | < 0.002 ± 0.001 | < 0.005 ± 0.002 | 0.09 ± 0.014 |
| U | µg/g | < 0.007 ± 0.004 | < 0.03 ± 0.06 | 0.044 ± 0.006 | 0.21 ± 0.06 | 0.2 ± 0 | 2 ± 0.3 |
| V | µg/g | < 0.9 ± 1.1 | < 4 ± 5 | < 0.6 ± 0.2 | 1.3 ± 0.9 | 2.7 ± 2 | 26 ± 2 |
| Y | µg/g | 0.004 ± 0.005 | 0.021 ± 0.015 | 0.016 ± 0.002 | 0.074 ± 0.023 | 0.088 ± 0.007 | 6.3 ± 0.2 |
| Yb | µg/g | < 0.009 ± 0.005 | < 0.04 ± 0 | < 0.005 ± 0.003 | < 0.006 ± 0.004 | < 0.02 ± 0.01 | 0.59 ± 0.01 |
| Zn | µg/g | 49 ± 7 | 130 ± 0 | 23 ± 1 | 30 ± 1 | 200 ± 0 | 110 ± 10 |
| Zr | µg/g | 0.04 ± 0.02 | 0.23 ± 0.04 | 0.25 ± 0.15 | 1.1 ± 0 | 0.33 ± 0.03 | 14 ± 1 |

**Table 4-11**. Continued.

| Element | Concentration Unit | *Tilapia* liver 10 | DOLT-1 standard 1 | DOLT-1 standard 2 | DOLT-1 certified | DORM-1 standard 1 | DORM-1 certified |
|---|---|---|---|---|---|---|---|
| Al | µg/g | 4700 ± 200 | < 0.6 ± 2.3 | < 0.5 ± 0.7 | ND | < 0.6 ± 1.3 | ND |
| As | µg/g | 2.1 ± 0.4 | 8.6 ± 0.8 | 9 ± 0 | 10.1 ± 1.4 | 14 ± 0 | 17.7 ± 2.1 |
| B | µg/g | < 30 ± 10 | 14 ± 3 | 17 ± 9 | ND | 30 ± 1 | ND |
| Ba | µg/g | 76 ± 1 | 0.07 ± 0.03 | 0.06 ± 0 | ND | 0.1 ± 0.02 | ND |
| Be | µg/g | < 0.9 ± 0.6 | < 0.2 ± 0.1 | < 0.2 ± 0.2 | ND | < 0.2 ± 0.1 | ND |
| Bi | µg/g | 0.87 ± 0.05 | 0.006 ± 0.022 | < 0.003 ± 0.004 | ND | < 0.004 ± 0 | ND |
| Ca | wt% | 0.8 ± 0.02 | 0.06 ± 0.008 | 0.057 ± 0.004 | ND | 0.096 ± 0.01 | ND |
| Cd | µg/g | < 0.2 ± 0.1 | 3.7 ± 0.4 | 4 ± 0.1 | 4.2 ± 0.3 | 0.05 ± 0.04 | 0.09 ± 0.01 |
| Ce | µg/g | 12 ± 0 | 0.007 ± 0.004 | 0.01 ± 0.002 | ND | 0.006 ± 0.002 | ND |
| Co | µg/g | 2.7 ± 0.4 | 0.14 ± 0.03 | 0.11 ± 0 | 0.157 ± 0.037 | < 0.04 ± 0.05 | 0.049 ± 0.014 |
| Cr | µg/g | 14 ± 8 | < 1 ± 0 | < 1 ± 1 | 0.4 ± 0.07 | 3 ± 1 | 3.6 ± 0.4 |
| Cs | µg/g | < 5 ± 1 | < 1 ± 1 | < 0.9 ± 0.3 | ND | 170 ± 10 | ND |
| Cu | µg/g | 270 ± 20 | 20 ± 0 | 18 ± 1 | 20.8 ± 1.2 | 4.8 ± 0.5 | 5.22 ± 0.33 |
| Dy | µg/g | 0.61 ± 0.04 | < 0.005 ± 0.004 | < 0.004 ± 0.004 | ND | < 0.005 ± 0.001 | ND |
| Er | µg/g | 0.27 ± 0.06 | < 0.008 ± 0.002 | < 0.007 ± 0.004 | ND | < 0.008 ± 0.003 | ND |
| Eu | µg/g | 0.16 ± 0 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | ND | < 0.002 ± 0.002 | ND |
| Fe | µg/g | 7500 ± 600 | 820 ± 10 | 750 ± 50 | 712 ± 48 | 61 ± 7 | 63.6 ± 5.3 |
| Gd | µg/g | 0.74 ± 0.04 | < 0.006 ± 0.002 | < 0.005 ± 0.004 | ND | < 0.006 ± 0.004 | ND |
| Hg | ng/g | 151 ± 15 | -- | 262 ± 42 | 225 ± 37 | -- | 798 ± 74 |
| Ho | µg/g | 0.087 ± 0.001 | < 0.001 ± 0.001 | 0.001 ± 0.001 | ND | < 0.001 ± 0 | ND |
| K | wt% | 1.8 ± 0.3 | 0.99 ± 0.12 | 0.97 ± 0.05 | 1.01 ± 0.1 | 1.6 ± 0.1 | 1.59 ± 0.1 |
| La | µg/g | 5.5 ± 0 | 0.006 ± 0.001 | 0.007 ± 0.001 | ND | 0.008 ± 0.002 | ND |
| Li | µg/g | 6 ± 0.3 | 0.1 ± 0.1 | < 0.1 ± 0 | ND | 0.2 ± 0 | ND |
| Lu | µg/g | 0.026 ± 0.008 | < 0.001 ± 0 | < 0.001 ± 0 | ND | < 0.001 ± 0.001 | ND |
| Mg | wt% | 0.42 ± 0.01 | 0.11 ± 0.01 | 0.1 ± 0.01 | 0.11 ± 0.015 | 0.12 ± 0.01 | 0.121 ± 0.013 |
| Mn | µg/g | 66 ± 5 | 9 ± 1 | 8.6 ± 0.1 | 8.7 ± 0.5 | 2.5 ± 1.4 | 1.3 ± 0.3 |
| Mo | µg/g | 13 ± 0 | 0.83 ± 0.37 | 0.74 ± 0.14 | ND | < 0.08 ± 0.06 | ND |
| Na | wt% | 1.2 ± 0.2 | 0.66 ± 0.08 | 0.66 ± 0.04 | 0.73 ± 0.07 | 0.77 ± 0.05 | 0.8 ± 0.06 |
| Nd | µg/g | 5.3 ± 0.2 | < 0.008 ± 0.003 | 0.011 ± 0.006 | ND | 0.008 ± 0.006 | ND |
| Ni | µg/g | 7.2 ± 0.6 | 0.4 ± 0.1 | 0.4 ± 0.1 | 0.26 ± 0.06 | 0.9 ± 0.1 | 1.2 ± 0.3 |
| P | wt% | 1.29 ± 0.21 | 1.19 ± 0.2 | 1.12 ± 0.3 | ND | 1.01 ± 0.24 | ND |
| Pb | µg/g | 9.3 ± 0.6 | 1.8 ± 0.2 | 1.1 ± 0.1 | 1.36 ± 0.29 | 0.28 ± 0.13 | 0.4 ± 0.12 |
| Pd | µg/g | 0.097 ± 0.024 | < 0.008 ± 0.004 | < 0.007 ± 0.006 | ND | < 0.008 ± 0.005 | ND |
| Pr | µg/g | 1.4 ± 0 | < 0.002 ± 0.001 | < 0.002 ± 0.001 | ND | < 0.002 ± 0.001 | ND |
| Rb | µg/g | 18 ± 0 | 3.7 ± 0.4 | 3.5 ± 0.2 | ND | 5.9 ± 0.5 | ND |
| Re | µg/g | < 0.02 ± 0 | < 0.004 ± 0 | < 0.004 ± 0 | ND | < 0.004 ± 0.001 | ND |
| S | wt% | 1.15 ± 0.07 | 1.63 ± 0.07 | 1.53 ± 0.17 | ND | 0.99 ± 0.11 | ND |
| Sb | µg/g | 0.53 ± 0.34 | < 0.03 ± 0.02 | < 0.03 ± 0.02 | ND | < 0.03 ± 0.01 | ND |
| Se | µg/g | 18 ± 3 | 5.8 ± 1.2 | 5.3 ± 0.7 | 7.34 ± 0.42 | 1.1 ± 0.1 | 1.62 ± 0.12 |
| Si | wt% | 0.38 ± 0.02 | 0.02 ± 0.03 | < 0.02 ± 0.01 | ND | < 0.02 ± 0 | ND |
| Sm | µg/g | 0.96 ± 0.06 | < 0.005 ± 0.007 | 0.006 ± 0.005 | ND | < 0.005 ± 0.003 | ND |
| Sr | µg/g | 70 ± 2 | 4.3 ± 0.5 | 4.4 ± 0.2 | ND | 5.4 ± 0.4 | ND |
| Ta | µg/g | 0.041 ± 0.035 | 0.025 ± 0.006 | 0.011 ± 0.003 | ND | 0.013 ± 0.001 | ND |
| Tb | µg/g | 0.093 ± 0.004 | < 0.001 ± 0.001 | < 0.001 ± 0.001 | ND | < 0.001 ± 0.001 | ND |
| Te | µg/g | < 0.4 ± 0.4 | < 0.08 ± 0.04 | < 0.07 ± 0.03 | ND | < 0.08 ± 0.02 | ND |
| Th | µg/g | 0.81 ± 0.03 | < 0.006 ± 0.002 | < 0.005 ± 0.003 | ND | < 0.006 ± 0.003 | ND |
| Tl | µg/g | < 0.2 ± 0.1 | < 0.04 ± 0.09 | < 0.04 ± 0.03 | ND | < 0.04 ± 0.03 | ND |
| Tm | µg/g | 0.031 ± 0.008 | < 0.001 ± 0 | < 0.001 ± 0 | ND | < 0.001 ± 0 | ND |
| U | µg/g | 1.2 ± 0 | 0.023 ± 0.005 | 0.023 ± 0.002 | ND | < 0.004 ± 0.001 | ND |
| V | µg/g | 9.8 ± 4.9 | 0.7 ± 0.2 | < 0.5 ± 0.3 | ND | < 0.6 ± 0.2 | ND |
| Y | µg/g | 3 ± 0.1 | 0.003 ± 0.002 | 0.004 ± 0.002 | ND | 0.003 ± 0.001 | ND |
| Yb | µg/g | 0.21 ± 0.05 | < 0.005 ± 0.001 | < 0.005 ± 0.003 | ND | < 0.005 ± 0.005 | ND |
| Zn | µg/g | 190 ± 20 | 93 ± 0 | 91 ± 13 | ND | 19 ± 3 | ND |
| Zr | µg/g | 6 ± 0.1 | 0.05 ± 0.01 | 0.05 ± 0.01 | ND | 0.04 ± 0.03 | ND |

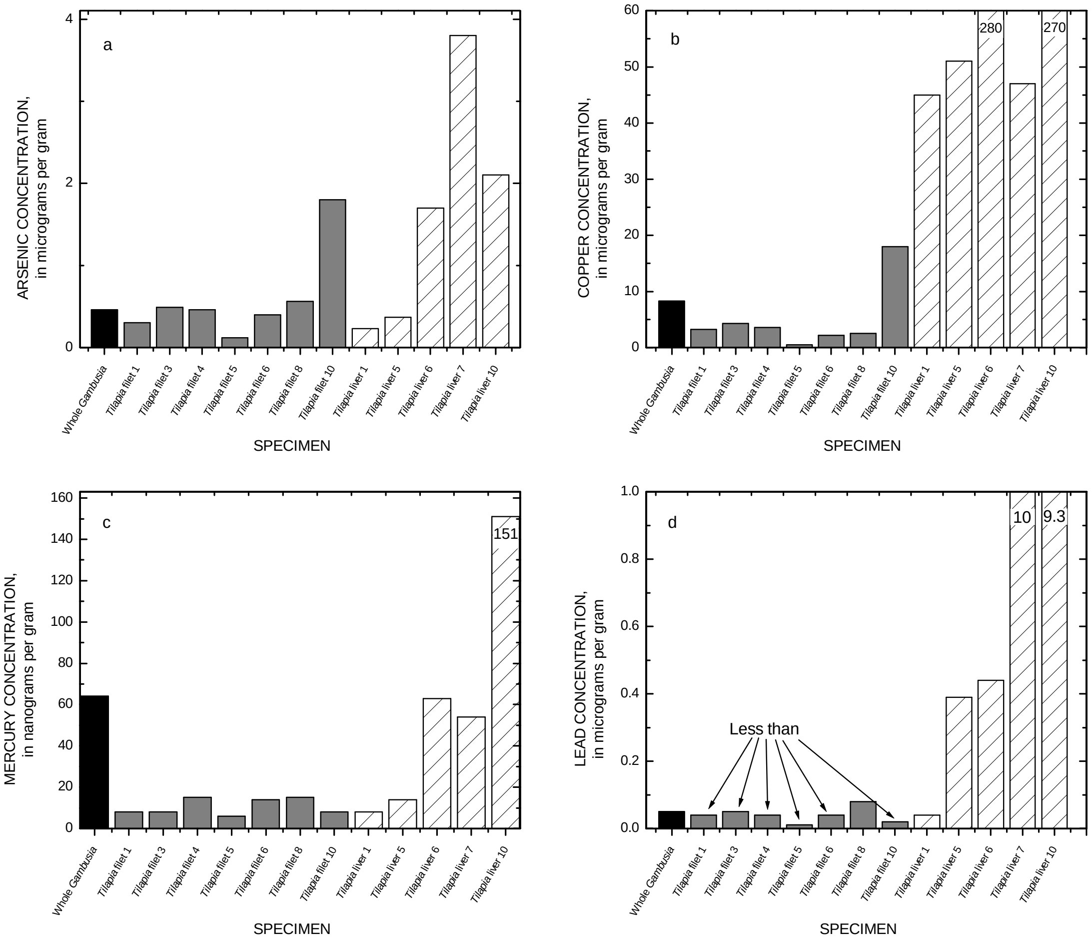

**Figure 4-8**. Plots of (a) arsenic, (b) copper, (c) mercury, and (d) lead concentrations (dry weight) in whole-body *Gambusia* and selected body parts of *Tilapia* specimens collected from the Cobble and Hayfield wetlands, February 14, 2000.

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