ORANGE COUNTY
NITROGEN AND SELENIUM
MANAGEMENT PROGRAM (NSMP)

BMP Data Needs

FINAL

November 15, 2005

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1 INTRODUCTION

Under Task 1 of the NSMP Year 1 Work Plan, existing data will be analyzed and field monitoring will be conducted to identify the spatial patterns of selenium and other constituents in groundwater, surface water, and soils, and their functional relationships, especially in terms of high and low flow regimes. The intent of the Year 1 sampling effort is to characterize existing water quality, both ambient background water quality and the water quality of discharges to surface waters. Data gathered under the Year 1 Work Plan will inform the overall NSMP implementation.

Under Task 2 of the Year 1 Work Plan, an effort will be conducted to identify and evaluate Best Management Practices (BMPs) and treatment technologies to be applied in the Newport Bay watershed to reduce selenium and nitrogen levels in order to meet permit and CTR criteria. Task 2.1 of the Year 1 Work Plan consists of coordination between the monitoring, BMP evaluation, and database development tasks to ensure that those conducting monitoring and database development efforts understand the data needs of the BMP development and evaluation effort.

Water quality data will be necessary to assess the applicability and efficiency of various treatment methods. In addition, understanding the typical discharge frequency, timing, magnitude and duration of various sources will provide a basis for implementation recommendations.

2 PURPOSE

The purpose of this Technical Memorandum (TM) is to identify the data necessary to develop and evaluate potential selenium and nitrogen Best Management Practices (BMPs) and treatment technologies for application in the Newport Bay watershed.

The specific goals of this TM are to:

a) Ensure that the consulting team members developing the sampling plans under Task 1 of the Year 1 Work Plan have a complete understanding of the water quality information that will be needed to conduct BMP evaluations under Task 2 of the Year 1 Work Plan
b) Outline for the Working Group what data the consulting team will be collecting (through both field testing and literature reviews)

This TM describes the data that will be needed from the field monitoring effort in order to evaluate and select BMPs and treatment technologies, as well as data that will be gathered from existing sources (desktop data) to assist in the evaluation under Task 2. Finally, this TM presents a brief summary of the information that will be sought through the treatment methods survey under Task 2.2.

3 SELENIUM SOURCES

A study by Hibbs and Lee (2000) found that shallow groundwater is a significant source of selenium in the Newport Bay watershed, and that selenium concentrations vary spatially in the watershed. Similarly, the volumes of groundwater discharges to surface waters vary throughout the watershed, but the three major reaches in the watershed (Peters Canyon Wash and both Reaches 1 and 2 of San Diego Creek) all contain significant amounts of groundwater flows (EPA, 2002). Groundwater enters surface water channels through natural seepage and man-made discharges from activities such as construction dewatering and dewatering wastes from subterranean seepage. The evaluation and ultimate selection of BMP treatment methods must consider the variability of flows and selenium as well as selenium species (i.e. different forms of selenium) concentrations in the watershed.

The chemistry and toxicity of selenium are complex, and present challenges to BMP design and management. Selenium interacts with various heavy metals (especially arsenic and mercury), vitamins A, C, and E, sulfur-containing amino acids, and paraquat herbicides (Ohlendorf 1989, 2003). These interactions can be antagonistic or synergistic when related to uptake and metabolic effects, thereby either increasing or decreasing the toxic effects of selenium or the other chemical. At appropriate dietary levels, selenium generally, but not always, protects animals from toxic effects of arsenic and certain other metals. For example, ducks fed selenium and arsenic in combination had an antagonistic effect whereby arsenic reduced the accumulation of selenium, the impact of selenium on hatching success, and embryo deformities (Stanley et al. 1994).

The geochemical species of selenium (oxidation state) and some associated compounds (i.e., nitrate, sulfate) determine how readily the selenium becomes bioavailable and enters the food web (e.g., Zehr and Oremland, 1987). For example, an abundance of oxidized compounds like nitrate and sulfate may retard the microbial reduction of selenate and selenite in sediment. However, once formed, insoluble, reduced forms such as elemental selenium or metal selenides are essentially not bioavailable. In contrast, the soluble oxyanion compounds of selenate and selenite are readily assimilated (Masscheleyn and Patrick, 1993).

The chemical oxidation state and forms of selenium also present a challenge when considering treatment options. Different treatment methods are more effective for different forms of selenium. The most common form of selenium in groundwater of the Newport Bay watershed is selenate (Meixner and Hibbs, et al. 2004), which is a highly soluble salt, preventing effective removal by simple filtration, coagulation, or settling. Selenate is also one of the least bioavailable forms of selenium, compared to forms such as selenite and organoselenium (Luoma et al. 1992). The potential for selenate to convert to more bioavailable forms is also a concern. However, other forms of selenium are easier to remove from solution, so selenium-removal BMPs often rely upon biochemical processes that chemically reduce (transform) selenium from the selenate form to less oxidized forms. Selenite has a greater tendency to adsorb to particles than selenate, and further conversion of selenite to elemental selenium yields even more effective removal, as elemental selenium is extremely insoluble (NPDES TAC and NSMP Working Group, 2005). Physical and chemical properties of selenium are summarized in Table 1 below.

Table 1. Chemistry and Significance of Selenium Forms (NPDES TAC and NSMP Working Group, 2005).

Oxidation State	Selenium Form	Key Characteristics	Importance to Selenium Cycling
Se^{+6}	Selenate (SeO_4^{2-})	Extremely soluble, with a very low affinity for sorption to particles.	Reported to be the main form in groundwater in the San Diego Creek watershed (Meixner and Hibbs et al. 2004). Lowest bioaccumulation and / or biotransformation by microorganisms and algae. Uptake is inhibited by sulfate.
Se^{+4}	Selenite (SeO_3^{2-})	Moderately soluble with a much greater affinity for sorption to particles than selenate.	Principal form of concern because it accumulates in phytoplankton ~10-fold more readily than selenate. Uptake is not inhibited by sulfate.
Se^{0}	Elemental Selenium	Insoluble reddish precipitate, monoclinic form and gray precipitate in common hexagonal form.	Removed from water by precipitation. Low solubility and bioavailability lessen ecological risk compared to selenite and selenate.
Se^{-2}	Inorganic selenide (Se^{2-})	Forms insoluble precipitates with metals in the same way that sulfide does.	Removed from water by precipitation.
	Cellular Organoselenium (a.k.a., particulate)	Most common is selenium substituted for sulfur in amino acids (e.g., selenomethionine).	Accumulation of selenium-substituted amino acids through the diet is the major cause of reproductive problems in birds and fish.
	Dissolved Organoselenium (a.k.a., organoselenide)	Dissolved organic compounds (e.g., selenomethionine) released from decaying cellular tissues.	Decay of cells creates a regenerative pool of bioavailable selenium that can be acquired by other microorganisms. Lower ecological risk than particulate organoselenium, because diet is more important than direct uptake from water column.
	Dimethylselenide, dimethyldiselenide	Produced by microbes, plants, and animals.	Provides gaseous escape from sediments and surface waters into the atmosphere.

The freshwater or saltwater nature of various habitats within the Newport Bay watershed may play a factor in selenium toxicity. Some studies suggest that salinity tolerance may influence effects of selenium in wildlife. Salinity tolerance has been found to be a large factor in embryo sensitivity to selenium exposure. Birds that prefer nonmarine saline wetlands are more tolerant of selenium than those that prefer freshwater wetlands (USDI 1998). For example, embryos of American avocets tolerate selenium much better than do those of black-necked stilts, and snowy plover embryos are more tolerant than those of killdeer. Overall, dabbling ducks (such as the mallard) are considered more sensitive than black-necked stilts (a moderately sensitive species), and the stilt is more sensitive than the avocet. These differences in sensitivity may be important in evaluating the potential effects of selenium in the creek versus Newport Bay and in designing BMPs to achieve maximum effect.

4 INITIAL LIST OF IDENTIFIED BMPs

The following BMPs have been identified for initial consideration and evaluation through a preliminary review of the literature:

4.1 Physical Treatment

- Reverse Osmosis
- Nanofiltration
- Evaporation Ponds
- Enhanced Evaporation Systems
- Salinity-Gradient Solar Ponds

4.2 Biological Treatment

- Anaerobic Bacterial Removal
- Algal – Bacterial Removal
- Agroforestry
- Constructed Wetlands
- Growth of selenium tolerant crops

4.3 Chemical (Engineered) Treatment

- Ferrous Hydroxide

5 FIELD WORK DATA NEEDS

The evaluation of BMPs will require consideration of water quality data, as well as information related to the timing, magnitude, and duration of discharges from anthropogenic and natural sources.

5.1 Water Quality

The identified treatment technologies use different processes to remove selenium and nitrogen. The applicability and efficiency of some processes may be limited or enhanced by other constituents present in the water column, such as nutrients, salts, and organic matter. In order to provide adequate data for the range of BMPs to be evaluated, the following water quality data should be collected under Task 1 of the Year 1 Work Plan for an initial representative sampling of all potential discharge sources:

- **Selenium speciation**
  - Selenate (Se^{6+})
  - Selenite (Se^{4+})
  - Selenide (Se^{2-})
  - Elemental Selenium (Se^{0})
  - Total selenium
- **Nitrogen**
  - Nitrate (NO_3^-)
  - Nitrite (NO_2^-)
  - Ammonia (NH_3)
  - Organic Nitrogen

    - Total Kjeldahl Nitrogen (TKN)
- **Phosphorus**
    - Ortho-Phosphate
    - Total Phosphorus
- **pH**
- **Total Dissolved Solids (TDS)**
- **General Minerals**
    - Calcium
    - Magnesium
    - Potassium
    - Sodium
    - Chloride
    - Iron
    - Manganese
    - Sulfate (SO_4^{2-})
- **Alkalinity**
- **Hardness**
- **TDS**
- **Biological Oxygen Demand (BOD)**
- **Total Organic Carbon (TOC)**
- **Total Suspended Solids (TSS)**
- **Temperature**

It is recognized that not all of these water quality constituents will be equally important for each source discharge and BMP. For example, indicator bacteria have not been included in the previous list of water quality constituents, because these do not impact treatment of selenium and nitrogen. However, actual BMP performance monitoring in Year 2 of the work plan will include indicator bacteria to ensure that any potential BMP does not inadvertently contribute to an increase or generation of undesirable bacteria levels. It is likely that subsets of analytes from the above list will be selected for different monitoring applications and BMP evaluations. Initial samples with more complete analyte lists will be used as a screening tool, followed by focused monitoring using smaller analyte lists.

In order to assess the relative contribution of discharges to surface water channels, concentrations of parameters listed above should be collected upstream of discharges, concurrent with field sampling of discharges.

The intent of the Year 1 sampling effort is to characterize existing water quality, both ambient background water quality and the water quality of discharges into the watershed. This information will be used in defining the specifications / characteristics of water that any BMP would be treating, if used locally. It will also help inform decisions on which discharges are likely to be most effectively treated by which BMPs (e.g. if existing discharges and water quality conditions are highly variable, then potential BMPs would need to be adaptable to a wide range of conditions). The Year 1 sampling will not be used to gather BMP effluent or performance information.

5.2 Discharge Flow Rate and Duration

In addition to the water quality characteristics of discharges, the following information should be collected concurrent with field sampling:

- Flow rate of the discharge at the time of sampling
- Estimated duration of the discharge (e.g., number of hours of well development discharge, duration of storm event, etc.)

In addition, seasonal and annual flows must be estimated to effectively compare BMPs and subbasin loads. Since groundwater is the major source of selenium, it will be important to consider the seasonality of flows. Flow rates should be estimated at more frequent intervals than water quality sampling as a cost-effective way of determining subbasin-specific hydraulic loads. Staff gauges or weirs will be the most cost-effective way of frequently monitoring flow, with or without concurrent water quality measurements.

In order to assess the relative contribution of discharges to surface water channels, flow rates in surface water channels should be collected upstream of discharges, concurrent with field sampling at discharges.

6 DESKTOP DATA NEEDS

In addition to the water quality monitoring data to be reviewed and collected under Task 1, the evaluation of BMPs will require the development of information to characterize the shallow groundwater basin, as well as typical discharge characteristics and currently implemented water quality management practices. Currently, the extent of the groundwater basin is determined by sinking wells or opening trenches. Data from each activity that results in the ability to determine the groundwater elevation and quality should be included in the database. The following discharge data should be developed for the various sources of selenium and nitrogen:

6.1 Well Development and Operation (including periodic purging, casing maintenance, and transmissivity maintenance)

- Typical ranges of discharge rates and duration of discharges
- Typical season of well development discharges
- Current industry standard BMPs, including county permitting requirements
- Information on whether the well is isolated from the selenium-containing strata
- Soils/groundwater mapping
- General locations of potential new well development sites, relative to groundwater selenium conditions

6.2 Aquifer Testing

- Typical ranges of discharge rates and duration of discharges
- Typical season(s) of aquifer testing discharges
- Current aquifer testing practices
- Locations of aquifer test wells, relative to receiving waters and soils/groundwater conditions

6.3 Construction and Post-Construction Dewatering

- Typical ranges in discharge rates and duration of discharges

- Typical season of construction discharges
- Rates of long-term discharges that occur due to dewatering but after construction has been completed
- Current industry standard BMPs, including county permitting requirements
- Rates of discharge from passive dewatering systems (e.g. French Drains)

6.4 Seepage

- Typical discharge rates and duration of discharges
- Typical season of seepage discharges
- Relationship to groundwater elevations

6.5 Natural Sources

- Rainfall associated erosion of selenium containing soils in the foothills and other natural areas

7 TREATMENT TECHNOLOGY DATA

Under Task 2.2, a literature review and technology survey will be conducted to ensure that BMP development is based on the most up-to-date information possible. In addition to a literature review of physical, chemical, and biological removal methods, site visits will be conducted at the locations of current BMP or technology installations to gather information about proprietary processes for selenium removal. Key information to be gathered to aid in evaluating various treatment BMP methods or technologies includes the following:

- Range of operating flows at which the technology has been proven
- Range of selenium and nitrogen removal rates for varying inflow concentrations
- Capital and operations and maintenance costs as a function of size
- Land requirements
- Energy requirements
- Modular capabilities of treatment units
- Start-up and shut-down considerations
- Life span of the treatment media
- Other constituents that may affect selenium removal efficiencies
- Treatment process effects on selenium speciation
- Process waste streams and associated permitting requirements
- Applicability and feasibility of implementation for discharges regulated by the Order
- Applicability and feasibility for general use in this watershed

8 REFERENCES

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