STATE SELENIUM WORK GROUP

Selenium Information Tour

Kendrick/Casper-Alcova Irrigation District
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Department of Environmental Quality
University of Wyoming College of Agriculture/
Cooperative Extension Service
U.W. Botany Department
Wyoming Water Research Center
Wyoming Governor's Office
State Department of Agriculture
State Department of Health and Social Services
Wyoming State Engineer's Office
Wyoming Geological Survey
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Cooperative Extension Service
College of Agriculture
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INTRODUCTION TO SELENIUM[1]

Selenium is a naturally occurring elemental metal that is both an essential nutrient and a potential poison. In the past it has generated commercial interest. The electrical conductivity of selenium varies with light intensity. Its photoelectric properties enable it to be used in electronic eyes, light meters, and electrical rectifiers. The steel industry uses the metal to produce stronger, corrosion resistant products. Selenium is used as a rubber vulcanizer, in dandruff control shampoo and as an alloy to improve the machinability of copper. Red, pink and ruby colored glass obtains its tint from Selenium.

Metallic selenium is odorless and tasteless. The gaseous, methylated forms have an odor similar to garlic. Selenium is highly poisonous. It is used in insecticides and paints applied to ship hulls to prevent growth of barnacles.

In Wyoming, the geologic occurrence of selenium is widespread. It is naturally found in volcanic tuff, coal deposits and some shales. Selenium weathered from rocks and found in soils is taken up by plants which consequently may be ingested by animals. Thus, much of the interest in Wyoming has centered around its known or potential toxicity to animals. It has been of concern to residents of Wyoming as its presence in some of the state's vegetation and water has resulted in adverse effects to animals in specific localities.

The concentration at which selenium becomes toxic in a plant depends on the form of selenium,the presence of oxalates, alkalodes, or other natural products, the type of animal ingesting the plant, and the quantity of vegetation consumed. Mildly toxic effects can generally be observed if a quantity of plants containing five part per million of selenium are ingested. One milk vetch from the Powder River Basin contained approximately 15,000 parts per million of selenium. There have been many reports of livestock deaths in the state, some of which may have been associated with selenium poisoning. Trelease and Beath reported that during the summer of 1907 and 1908 more than 15,000 sheep died after grazing in an area north of Medicine Bow with an abundant growth of seleniferous vegetation. In 1919, 275 sheep died overnight after grazing in an area with seleniferous vegetation near Rock River. Selenium may have been a factor in some of those deaths. However, no detailed pathology was reported at the time of death, and other toxic factors may have been prevalent. Very few livestock deaths have been attributed to selenium in the last 40 years, perhaps due to a better understanding of the problem and better management practices.

Selenium is an essential micronutrient and is required for vitamin E metabolism. Nationwide, selenium deficiency in livestock is a far more common occurrence than selenium toxicity. Livestock in the midwest and eastern U.S. are often fed selenium supplements because the element is often lacking in locally raised forage. Selenium deficiency is also a localized problem in Wyoming livestock.

Irrigation drainwater has recently become the focus of studies to determine the extent of adverse effects on fish and wildlife resources in habitats receiving irrigation drainage in the western United States. Concern for the effects of drainwater quality on natural resources was prompted by Fish and Wildlife Service studies in 1983 at the Kesterson National Wildlife Refuge in the Central Valley of California. High concentrations of selenium and other trace elements in impounded drainwater at Kesterson were associated with reproductive failure and embryo deformities and mortality in several waterfowl species. This discovery prompted more detailed investigations of drainwater contaminant impacts on fish and wildlife species. Which in turn preceded termination of Federal drainwater service to irrigated croplands in the Western San Joaquin Valley containing high concentrations of selenium in soils and ground water. Drainwater service was discontinued by the Department of the Interior (DOI) to comply with provisions of the Migratory Bird Treaty Act.

Higher than desirable levels of selenium have recently been found in bird eggs, waterfowl and shore birds taken from the Kendrick/Casper-Alcova Irrigation Project and shore birds collected from the Laramie plains. There is sketchy evidence that selenium intoxication has occurred in elk and moose in northwestern Wyoming.

Selenium poisoning in humans is rare. The current Federal drinking water standard for human consumption is 10 parts per billion, however, the concentration at which selenium becomes toxic in water is not well defined. Human selenium intoxication has been reported in the western United States.

[1]Revised July 20, 1988

CHEMICAL & GEOLOGICAL PROPERTIES OF SELENIUM

In order to better understand the origin, distribution, and toxicity of selenium, a basic knowledge of its chemistry is required. Chemically similar to sulfur, it associates and sometimes replaces it. Elemental selenium, which is considered to be a semi-metal, has five forms (allotropes) recognized at room temperature. Those forms of elemental selenium range from metallic to crystalline. Elemental selenium has three primary oxidation states which are Se^{+6} (selenate), Se^{+4} (selenite), and Se^{-2} (selenide). The oxidation state that selenium is in partially determines its solubility and potential for mobility in the environment. There are numerous compounds of selenium available, with the compounds present in inorganic, organic, and gaseous forms.

The selenides of selenium occur in both metallic and gaseous forms. The metallic selenides are relatively stable, and most forms are not water soluble. The gaseous selenides are very mobile and somewhat water soluble. Hydrogen selenide gas is very toxic, in fact, much more toxic than hydrogen sulfide.

Selenides can be oxidized to selenites, which are rather stable. Below a pH of 8, selenite ions are readily adsorbed to iron hydroxides, clays, and organic substances. Selenites of alkalies are soluble, while those of iron are not. At a pH of 8, there is a reduced tendency for the selenite ion to adsorb, and the selenium can become available. At a pH of 11, the selenite is not adsorbed at all.

Selenates are soluble and are not adsorbed by iron. The selenate ion occurs in dry, oxidizing, alkaline environments, generally with a pH of 7.5 or greater. Worldwide, the selenate ion is not common, but is present in many areas of Wyoming due to the prevalence of alkaline soil types and the arid climate of the state. Selenates are very mobile forms of selenium, and are usually readily available for uptake by plants and animals.

The significance of the chemistry of selenium becomes apparent when the origin and primary depositional environments of selenium are known. Selenium is primarily volcanic in origin, being incorporated in volcanic ash, magma, and gas. The selenium released through volcanic activity is primarily in the selenide form. Upon exposure to the environment, the selenide is oxidized to either elemental selenium or the selenite state, at which point it can migrate until absorbed on clay particles, iron hydroxides, or organic particles. These particles are often found in streams and oceans. Those bodies of water then become effective transport mechanisms or depositional sites for the selenium. As a result, volcanically derived selenium has a tendency to be concentrated in marine shales, certain continental shales, tuffaceous deposits, certain sandstones, and coal.

Some of the volcanically derived selenium that is not transported by the above mechanisms can be concentrated through other means. Ground water can move and concentrate some of the soluble forms of selenium in porous media such as sandstone. Certain types of vegetation concentrate selenium, which can result in the localized enrichment of soils.

Wyoming has been exposed to many periods of tectonism, resulting in the uplift of seleniferous bedrock. While part of the selenium is bound into the bedrock, some is already in a soluble form and can be readily released into the environment. As much of Wyoming is arid and alkaline with an oxidizing environment, some of the selenium that is bound into the bedrock can also be mobilized through the weathering process. Certain forms of bacteria, fungi, and other microorganisms can convert selenium that is insoluble, even after weathering, into more soluble and mobile forms. The net result is that much of the selenium that occurs in bedrock can be made available for uptake by plants or be transported by either surface or ground water. Those are the primary routes through which selenium reaches animals and humans.

A few areas in Wyoming have been sampled and analyzed for selenium in detail. Most areas of the state, however, have had spotty sampling from which broad generalizations can be made about the occurrence and distribution of selenium in geologic formations, soils, and vegetation. Broad generalizations cannot be made about the occurrence and distribution of selenium in the waters of the state at the present time due to insufficient data.

The limited information that is available on selenium in the geologic formations, soils, and vegetation in the state can be divided into two classifications. The first data set is one of vegetation analyses from which the geochemistry of the bedrock and the soil supporting the vegetation is inferred. Associations have been found between specific geologic formations and the selenium content of the vegetation the formations can support in localized areas. Not all portions of the geologic formations flagged using this procedure may be seleniferous, however. The available information indicates that the formations have the potential to be seleniferous and support seleniferous vegetation in localized areas. The geologic formations flagged using this procedure are classified by comparing the potential toxicity of the vegetation they can support in localized areas. The potential vegetation toxicities are divided into highly toxic, moderately toxic, and mildly toxic categories. Vegetation that is highly toxic may be lethal to grazing animals. Vegetation that is moderately toxic can result in observable toxic effects on animals that consume it. Vegetation that is mildly toxic has the potential to cause observable toxic effects, if the vegetation is consumed over long periods of time. The geologic formations that have the potential to support the three categories of toxic vegetation in localized areas are contained on the following list:

Geologic Formations That Support Vegetation That May Be Highly Toxic To Grazing Animals In Localized Areas

Browns Park Formation	Niobrara Formation
Wagon Bed Formation	Hilliard Shale
Pierre Shale	Baxter Shale
Steele Shale	Morrison Formation
Cody Shale	Phosphoria Formation

Geologic Formations That Support Vegetation That May Be Moderately Toxic To Grazing Animals In Localized Areas

Chadron Member-White River Formation	Frontier Formation
Bridger Formation	Greenhorn Formation
Aycross Formation	Belle Fourche Shale
Wilkins Peak and Tipton Shale Members-Green River Formation	Mowry Shale
Wind River Formation	Muddy Sandstone Member - Thermopolis Shale
Fort Union Formation	Cloverly Formation
Medicine Bow Formation	Sundance Formation
Blair Formation	Gypsum Spring Formation
Carlile Shale	Alcova Limestone Member -Chugwater Formation

Geologic Formations That Support Vegetation That May Be Mildly Toxic To Grazing Animals In Localized Areas

Miocene Rocks	Thermopolis Shale
Arikaree Formation	Gannett Group
Lance Formation	Chugwater Formation
Lewis Shale	Dinwoody Formation
Mesaverde Formation	Goose Egg Formation
Aspen Shale	Amsden Formation

The second data set is composed of chemical analyses of bedrock without analyses of vegetation. The average concentration of selenium in crustal shale is estimated at 0.6 parts per million by Turekian and Wedepohl (1961). Because average concentrations of elements in shale are often used for geochemical comparisons, values above 0.6 parts per million selenium in bedrock are flagged in this study. A list of the geologic formations flagged using this criteria are listed below, along with a range of selenium concentrations for each formation.

Geologic Formations Where Selenium Is Locally Present At Concentrations Exceeding 0.6 Parts Per Million (PPM)

Wasatch Formation (0-1900 ppm)
Rock Springs Formation (0-2.7 ppm)
Battle Springs Formation (0-768.0 ppm)
Adaville Formation (0-1.19 ppm)
Hanna Formation (0-5.16 ppm)
Bacon Ridge Sandstone (0-7.46 ppm)
Ferris Formation (0-2.19 ppm)
Bear River Formation (0-7.0 ppm)
Harebell Formation (0-1.78 ppm)
Inyan Kara Group (0-900.0 ppm)
Meeteetse Formation (0-1.4 ppm)
Thaynes Limestone (0-1.5 ppm)
Almond Formation (0-2.45 ppm)

For a detailed explanation of the classification scheme used, and for more information on each of the geologic formations, including a map of their outcrop areas, refer to the "Guide to Potentially Seleniferous Areas in Wyoming" by J. Case and J. Cannia, Geological Survey of Wyoming Open Report 88-1, 1988 (included in the back pocket of this brochure).

All of the historic selenium related problems in Wyoming have occurred in vegetation growing on soils derived from the geologic formations flagged in this report. Soils derived from the Wagon Bed Formation, Pierre Shale, Steele Shale, Cody Shale, and Niobrara Formation have all supported vegetation linked to livestock deaths in specific areas.

There are certain ponds, lakes, and streams in Wyoming where selenium is present in concentrations that may be harmful to fish, waterfowl, and range animals. The ponds, lakes, and streams that have the greatest potential for the presence of selenium are those that are located on or flow through the geologic formations listed in the report. Irrigation in areas underlaid by the flagged geologic formations can also present some unique problems. Irrigation can locally raise ground water tables. In doing so, soluble forms of selenium in the water, bedrock, or soils can be brought closer to the surface. Irrigation can also result in the flushing of selenium from bedrock and soils. In some cases the flushed selenium can be incorporated with irrigation return flows. Studies are presently underway in the Casper area (Kendrick/Casper-Alcova Irrigation Project) and Riverton area to determine the effects of irrigation on selenium availability and migration.

Selenium has been a problem in portions of Wyoming in the past, and will continue to be a problem in select areas for years to come. Through public education and coordinated research efforts in the scientific community, future problems will hopefully be minimized.

SELENIUM EFFECTS ON HUMANS

Selenium can cause problems in humans if its level is too high or too low. There is generally no problem with humans not getting enough selenium because it naturally occurs in daily foodstuffs such as seafoods, meat, milk products, and grains. The harmful (or toxic) potential from selenium is related to its chemical form and solubility (which is the most important determinant). Humans absorb selenium compounds essentially only through the upper part of the intestinal tract. What one eats and drinks that contains selenium determines how much will enter your body. Over 90 percent of selenites may be absorbed by humans and are widely distributed in the organs, with the highest accumulation initially in the liver and kidney. Appreciable levels can also develop in blood, brain, heart muscle, body muscle, and the testicle. In addition, selenium is transferred across the placenta to the fetus and also appears in breast milk.

Approximately 14 to 40 percent of selenium absorbed in one day will be excreted in the urine in the next week. The rest of that day's selenium will be 50 percent excreted in the next 103 days. Taking in a high level of selenium each day will result in higher and higher levels of selenium in human tissues.

The Environmental Protection Agency has established levels of selenium in water considered to be safe for human consumption. These levels are currently being revised and new levels for safe drinking water should be available within the next year. Safe levels depend on whether or not you are an adult or a child and how long you are exposed to any given level.

People need to be aware that high levels of selenium can cause health problems. The main sources of selenium for people are drinking water, animal products, and garden products if irrigated with selenium-containing water, or if the soil is high in the element.

The easiest and quickest way to find out if there is any potential hazard is to test your drinking water and, if that is elevated, then have a soils test made for content of selenium in the garden.

Contact your County UW Cooperative Extension Office for assistance in water and soil sampling. Your county agent can assist you in getting more specific information on the health effects of selenium.

SELENIUM IN SOILS AND PLANTS

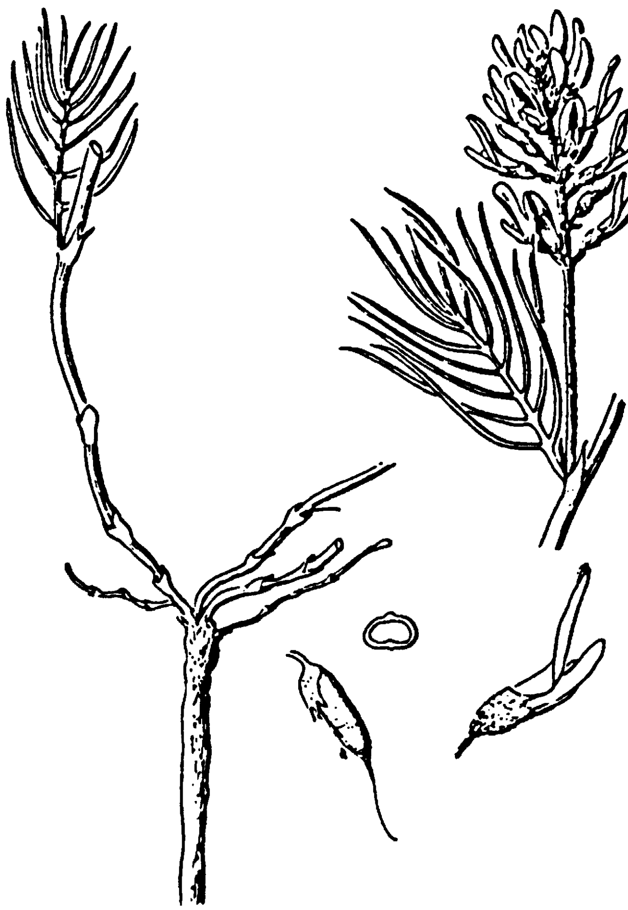
Small quantities of selenium are necessary for the nutrition of animals and humans; however, in most arid, as well as certain non-arid areas of the world, high levels of selenium in soil, plants and water represent a threat to wildlife, domestic animals and humans.

Soil selenium originates from geological material as it weathers. Selenium in rocks probably exists in relatively insoluble forms (metal selenides and elemental selenium). When these materials contact oxygen during weathering, they may be transformed to more soluble forms of selenium (selenites and selenates). These transformations are apparently carried out, at least partially, by soil bacteria and fungi. Selenium is usually deeply situated in soils and weathered rock. Certain plants, known generally as selenium converter (or indicator) plants, are capable of penetrating deeply into soils, taking up selenium compounds and transporting these into above ground stems and leaves. Selenium converter plants apparently have a role in transforming the relatively insoluble forms of selenium (metal selenides and elemental selenium) into soluble forms (selenites and selenates). Soil microorganisms which associate with plant roots, probably play a role in this transformation.

There are several species of plants in Wyoming which are well-known as selenium converters. These include two-groove milk vetch (*Astragalus bisulcatus*), tine-leaved milk vetch (*Astragalus pecinatus*) and woody aster (*Aster xylorrhiza*) (illustrations on page 6 and 7). Often these are known as primary converters because of their apparent role in converting (transforming) selenium as described above. Primary converter plants, unlike most plants, apparently require selenium as a nutrient for certain of their metabolic processes. When these plants die, decomposition of their leaves and stems result in deposition of selenium in surface soils.

Water and wind redistribute this surface deposited selenium across landscapes and within soil horizons. These redepositional processes tend towards deposition of selenium in depressions and low lying areas. Redeposition within soil may be restricted in zones of low rainfall, but likely selenium will be deposited in clay horizons or in horizons where calcium carbonate and gypsum accumulate.

Redistribution of selenium with eroding soil particles or with irrigation and ground water results in selenium deposition in streams, lakes and sediments. Selenium in such environments has been known to have severe impact on idigenous birds and other life forms.



A. pectinatus

Astragalus pectinatus Dougl. ex Hook. Fl. Bor. Am. 1:142. 1831, as a synonym; ex G. Don, Gen. Syst. 2:257. 1832.

Phaca pectinata Hook.Fl. Bor. Am. 1:141. 1831. *Tragacantha pectinata* Kuntze, Rev. Gen. 2:947. 1891. *Ctenophyllum pectinatum* Rydb. Bull. Torrey Club 32:663. 1906. *Cnemidophacos pectinatus* Rydb. N. Am. Fl. 24,5:288. 1929. (*Drummond,* "pastures of the Saskatchawan")

Rather fleshy, somewhat malodorus, grayish-strigillose perennial with numerous erect, stiff stems 2-5 dm. tall, from a heavy taproot; base of stems usually partially subterranean, ascending and rhizomelike, without blades but with membranous sheathing stipules as much as 1 cm. long; aerial portion of the stems with essentially sessile leaves 5-9 cm. long, the stipules heavily veined 5-9 mm. long, acute-tipped, often bilobed, the lower ones connate, the upper ones free; leaflets 9-15, linear, 2-6 cm. long, not articulated (and the upper ones confluent) with the rachis; peduncles little if any longer than the subtending leaves; racemes rather loosely to compactly 10- to 30-flowered; pedicels stout, 2-5 mm. long; flowers ochroleucous, spreading to ascending-erect, 18-23 mm. long; calyx black-strigose, 6-9 mm. long, the linear teeth 1.5-3 mm. long; banner upcurved, 2-3 mm. longer than the wings but not much reflexed from them; wings sharply upcurved, 2-4 mm. longer than the very obscurely beaked keel; pod pendulous, sessile, fleshy and nearly solid but drying to woody, oblong-ovoid, 10-20 mm. long, nearly terete, 5-7 mm. in diameter, 1-celled, abruptly narrowed to a conspicuous, acute, sharply upcurved beak 4-6 mm. long, the sutures very prominent but neither one sulcate. N= 11.

Great Plains region, E. slope of the Rocky Mts., from Alta. through Mont. to S.E. Colo., E. to Sask. and Kans., often on lowland or strongly alkaline soil. June-July.

A. bisulcatus

Astragalus bisulcatus (Hook.) Gray, Pac. R.R Rep. 12:42. 1860.

Phaca bisulcata Hook. Fl. Bor. Am. 1:145. 1831. *Tragacantha bisulcata* Kuntze, Rev. Gen. 2:943. 1891. *Diholcos bisulcatus* Rydb. Bull. Torrey Club 32:664. 1906. (*Drummond*, "plains of the Saskatchewan")

Sparsley soft-strigillose, greenish, caespitose perennial from a thick branched crown; stems several, thick, spreading to erect, 4-10 dm. tall; leaves 4-8 (10) cm. long, short-petiolate; stipules lanceolate, 3-6 mm. long, the basal ones connate; leaflets 11-27, lanceolate to elliptic or oblong-elliptic, mostly 15-25 mm. long, 3-8 mm. broad; peduncles stout, from about as long to twice as long as the leaves; racemes closely 30- to 150-flowered, lengthening and more open in fruit; pedicels 1-2 mm. long; flowers purplish to (occasionally) pale lavendar or nearly white, 11-15 mm. long; calyx 6-9 mm. long, the teeth linear-lanceolate, subequal to the strongly gibbous based, grayish- or blackish-strigillose tube; banner erect; wings and keel subequal; pod pendulous, stipitate, the stipe about equal to the calyx tube, the body linear-oblong, nearly straight, membranous, glabrous, 15-22 mm. long, strongly obcompressed, 1.5-2 mm. wide and nearly twice as thick, sulcate on either side of the upper (ventral) suture, 1-celled, neither suture intruded. N = 12.

Sagebrush desert and grassland, especially where somewhat alkaline; mostly on the E. slope of the Rocky Mts., from Alta. to N.M., E. to Nebr., W. to C. Beaverhead Co., Mont., and to Clark Co., Ida. June-July.

Primary converters are apparently responsible for removing deeply situated selenium and transporting it to surface and near surface locations. Further, their presence on sites is interpreted as an indicator that the site is seleniferous. Another class of plants, secondary converters, are presumed to take up selenium from surface soils, maintaining that selenium in soluble forms and keeping it at or near the soil surface. Secondary converters include numerous species of plants, and may include some plants used for food for humans and livestock. For example, there is some indication that alfalfa (*medicago satina*) may be a secondary converter. Also, some garden plants, when grown on seleniferous soils, take up selenium.

Soil microorganisms have a further function in selenium transformations. Several bacteria and some fungi have been shown to convert selenium to hydrogenated and methylated forms. These compounds, hydrogen selenide and methyl selenium, are very toxic and are also volatile.

The picture of selenium depicted here is vague in some sectors and likely distorted in others. More information is needed regarding the nature of plant selenium uptake as well as more information pertaining to selenium uptake by particular plants. The role of soil microorganisms in selenium transformations also requires further elucidation. In addition, redistribution of selenium across landscapes and in soil profiles by wind and water needs to be quantified.

SELENIUM EFFECTS FISH AND WILDLIFE

In 1985, a Task Group on Irrigation Drainage was established with expertise from several DOI agencies to evaluate in the western states for additional areas other than the Kesterson area in California where contaminants from irrigation drainage might impact fish and wildlife as well as human health. The Task Group identified 19 locations in 13 states where reconnaissance studies were needed to determine if drainage from DOI irrigation projects was adversely affecting migratory bird or endangered species habitats. The Kendrick/Casper-Alcova Irrigation Project area near Casper, Wyoming, was included as one of these locations identified for reconnaissance investigations in 1986-87.

A Study Team was formed in 1986 to plan, conduct, and interpret reconnaissance investigations of trace elements in surface and ground water, sediment, and fish and wildlife associated with irrigation drainage in the Kendrick/Casper-Alcova Irrigation Project area. The Fish and Wildlife Service has been an active member of this Team responsible for developing and implementing the reconnaissance study of trace elements in fish, wildlife, and other biota from areas associated with drainwater from the irrigation project. This effort has been coordinated with other agencies on the Study Team including the U.S. Geological Survey and the U.S. Bureau of Reclamation, plus associated state agencies including the Wyoming Department of Environmental Quality and the Wyoming Game and Fish Department.

The principal objective of reconnaissance studies of biota at the Kendrick/Casper-Alcova Irrigation Project was to characterize trace element concentrations in representative species of fish and migratory birds and their diet organisms in habitats associated with irrigation drainwater in the Project area. These concentrations could then be compared with trace element levels known to cause adverse biological effects of comparable species based on experimental data.

To accomplish this objective, eight study sites were chosen to represent the diversity of aquatic habitats associated with the Kendrick/Casper-Alcova Irrigation Project, seven of which are known or suspected to receive irrigation return flow from the Project. Four sites (Rasmus Lee Lake, Goose Lake, Thirty-three Mile Reservoir, and Illco Pond) represented standing waters within the drainage area of the Project, and all receive some return flow from irrigated lands. The remaining sites were on the North Platte River between Alcova Reservoir and Casper, Wyoming. Only the North Platte River site near Alcova Reservoir was outside the irrigation drainage area of the Project.

As available, fish, migratory birds and bird eggs, aquatic invertebrates, and aquatic vascular plants and algae were collected from each standing water site for analysis of trace element concentrations. Juvenile migratory birds were sampled in preference to adults, because juveniles are less mobile so their accumulation of contaminants is usually more representative of concentrations in particular locations. Fish and aquatic invertebrates were collected at each site in the North Platte River.

Results of trace element analysis of biological samples from the Kendrick/Casper-Alcova Irrigation Project area indicated relatively low concentrations in fish and aquatic invertebrates from the North Platte River. There were no discernable trends in concentration from upstream to downstream sampling sites.

Trace element levels in biological samples from standing water in the study area were indicative of habitats containing high concentrations of selenium and boron to some extent. Boron content in migratory bird livers from Rasmus Lee Lake and Illco Pond was in the range documented to have negative studies by the Fish and Wildlife Service's Patuxent Wildlife Research Center. Boron concentrations in aquatic plants from Rasmus Lee Lake, Thirty-three Mile Reservoir, and Illco Pond were near the range causing reproductive effects in the diet of mallard ducks.

Selenium levels were consistently high in migratory bird livers and eggs collected from Rasmus Lee Lake, Goose Lake, and Illco Pond. Selenium concentrations in these bird samples were at or above levels known to cause productive problems in migratory waterfowl, including significant embryo deformities. The selenium concentrations in the liver of an adult American avocet from Rasmus Lee Lake and in an eared grebe egg from Goose Lake are among the highest levels reported from North American Waterfowl. Selenium levels in fish and aquatic invertebrate samples from standing water locations at the exceeded concentrations known to cause adverse effects on reproduction in fish and in waterfowl that feed on invertebrates.

High selenium concentrations in lakes and ponds at the Kendrick/Casper-Alcova Irrigation Project may be associated with irrigation drainage into these waters. However, the contribution of trace elements from irrigation return flow compared to that from naturally high concentrations in soils and surface and ground waters in the Project area has not been documented.

Results from the 1986-87 reconnaissance of trace element levels in the Kendrick/Casper-Alcova Irrigation Project prompted the selection of this Project for an intensive study by DOI to determine the full extent of trace element problems for fish, wildlife, and human health. This study is in progress and will continue into 1990 to provide detailed information on the distribution and biological effects of selenium and other elements in soils, surface and ground water, and fish and wildlife habitats. As part of this effort, the Fish and Wildlife Service will be emphasizing studies to document migratory bird use and reproductive success in the area in relation to trace element concentrations. The principal intent of these detailed investigations is to provide information useful to operational solutions to trace element enrichment problems associated with irrigation drainage in the area.

Selenium in Water and Bottom Sediment

A reconnaissance sampling of water, bottom sediment, and biota in the area of the Kendrick/Casper-Alcova Irrigation District was conducted during 1986-87 under the auspices of the DOI irrigation drainage program. The following discussion of water and bottom sediment was condensed from the report by Peterson and others (1988) describing results of the reconnaissance.

Soils in the study area are derived principally from Cretaceous formations of marine origin. The Cody Shale and smaller outcrops of the underlying Frontier Formation and Mowry and Thermopolis Shales, the overlying Mesaverde Formation, and the equivalent Niobrara Formation and Steele Shale predominate. Quaternary alluvium occurs along the larger streams and in the northern part of the area (Crist, 1974).

Elevated concentrations of selenium in surface and ground water, rocks, and soils of the Kendrick/Casper-Alcova Irrigation District were described in detail by Crist (1974). Selenium concentrations in 253 surface water samples ranged from less than 10 to 1,200 µg/L (micrograms per liter); the median concentration was 20 µg/L. The selenium concentrations in ground water samples had a large temporal and spatial variance. Of 597 ground water samples, the concentrations ranged from less than 10 to 6,500 µg/L, and the median selenium concentration was 30 µg/L. Water soluble selenium concentrations of 179 rock and soil samples ranged from less than 0.010 to 4.2 µg/g (micrograms per gram of sample), and the median concentration was 0.050 µg/g. No specific rock type or locale within the study area was determined to contain a consistently large selenium concentration.

During the reconnaissance investigation, water samples were collected at 10 surface water sites and 5 ground water sites. Concentrations of dissolved selenium in 11 of 24 water samples exceeded 10 µg/L, the national standard for maximum allowable in public supply; however, the 11 samples are not from public-supply sources. Selenium concentrations in six surface water samples exceeded the maximum concentration of 50 µg/L for livestock watering recommended by the National Academy of Sciences and National Academy of Engineering (1973). The selenium concentrations ranged from less than 1 to 300 µg/L; the median concentration was 7.5 µg/L. The maximum concentration of 300 µg/L was measured in a water sample collected from Oregon Trail Drain on Oct. 16, 1986. The largest concentrations generally were found in samples of the four principal tributaries which drain the project area. Concentrations of dissovled selenium in two water samples from Rasmus Lee Lake were 12 and 30 µg/L.

In the North Platte River, which supplies drinking water for several municipalities, concentrations of dissolved selenium ranged from less than 1 to 4 µg/L. Both dissolved-selenium concentrations and selenium discharge in water of the North Platte River increased in the downstream direction. The increase in selenium concentration in the North Platte River from Alcova to downstream from Casper was from less than 1 to 2 µg/L in August, and from 1 to 4 µg/L in October. On the two dates during the investigation that samples were collected, much of the increase in selenium concentration and discharge was due to contributions from the four principal tributaries that drain the Kendrick/Casper-Alcova Irrigation District. On August 14, the dissolved selenium discharge was 14.6 kg/d (kilograms per day) in the North Platte River downstream from Casper ; the sum of the selenium discharges of the four tributaries was 7.5 kg/d. On October 17, the selenium discharge in the North Platte River downstream from Casper was 16.6 kg/d; the sum of the discharges of the four tributaries was 11.0 kg/d. The selenium discharge in the North Platte River at Alcova, upstream from the project, was 3.3 kg/d for the October sampling. Thus, for the October 17 discharge of 16.6 kg/d in the North Platte River downstream from Casper, 14.3 kg/d can be accounted for by summing the selenium discharge of the North Platte River at Alcova and the selenium discharges of the four tributaries.

Bottom sediment samples collected at nine sites were analyzed for trace elements and some of the major ions. Selenium concentrations of bottom sediment samples ranged from 0.9 to 25 µg/g. The largest selenium concentrations were measured in the bottom sediments of Poison Spring Creek (25 µg/g), Rasmus Lee Lake (17 µg/g), and Casper Creek (16 µg/g). Bottom sediment samples from the North Platte River and Bates Creek contained 1.2 µg/g or less of selenium. Selenium concentrations of bottom sediment samples at all of the sites in this investigation were greater than the geometric mean selenium concentrations of 0.23 µg/g in soils of the western conterminous United States and 0.45 µg/g in soils from the northern Great Plains, as reported by Shacklette and Boerngen (1984). The concentrations of uranium at all of the sites and the concentrations of chromium, lithium, and nickel in bottom sediments from Poison Spider Creek, Oregon Trail Drain, and Casper Creek also were greater than geometric mean concentrations reported by Shacklette and Boerngen (1984).

KEY LITERATURE

Adriano, D.C. 1986. Selenium. In: Trace Elements in the Terrestrial Environment. Springer-Verleg N.Y.,pp.391-419.

Bainbridge, D. and V. Wegrgzn. 1988 (In Press). Selenium in California. California Water Quality Control Board.

Crist, M.A., 1974, Selenium in Waters In and Adjacent to the Kendrick Project, Natrona County, Wyoming: U.S. Geological Survey Water Supply Paper 2023, 39 p.

Fisher, S.E. Jr., F.F. Munshower and F. Parady. 1987. Selenium. In: R.D. Williams and G.E. Schumann (eds.) Reclaiming Mine Soils and Overburden in the Western United States. Analytical Parameters and Procedures. Soil Conservation Society of America. pp 109-134.

Hitchcock, C.L., A. Cronquist, M. Ownsbey and J.W. Thompson. 1961. Vascular Plants of the Pacific Northwest, University of Washington Press.

National Academy of Sciences of Engineering, 1973, Water Quality Criteria 1972: Washington D.C., U.S. Government Printing Office, Ecological Research Series, EPA-R3-73-033, 594 p.

Peterson, D.A., Jones, W.E. and Morton, A.G., 1988, Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated With Irrigation Drainage in the Kendrick Reclamation Project Area, Wyoming, 1986-87: U.S. Geological Survey Water-Resources Investigations Report 87-4255, 57 p.

Shacklette, H.T., and Boerngen, J.G., 1984, Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States: U.S. Geological Survey Professional Paper 1270, 105 p.

Trelease, S.F. and O.A. Beathe. 1949. Selenium -- Its Geological Occurrence and Its Biological Effects in Relation to Botany, Chemistry, Agriculture, Nutrition and Medicine. Champlain Printers, New York, 292 p.

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