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Chronic Effects of Ammonia-Stripped Oil Shale Retort Water on Fishes, Birds, and Mammals

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Commercial oil shale development of the Green River Formation in Colorado, Utah, and Wyoming will probably take place within the next decade. Equal volumes of oil and retort water are expected to be produced using in situ oil shale processing (FARRIER et al. 1978). Research has been done on the acute toxicity of retort water to fish (ANDERSON et al. 1980) and mammals (HEPLER et al. 1979). The acute effect on fish is gill hyperplasia, primarily from the irritating effect of ammonia. Retort water did not appear toxic to dogs, rats, or guinea pigs under the acute test conditions imposed. No research has been done on the long-term chronic effect of retort water on any of these animals.

A variety of schemes has been proposed for the treatment of retort water, most of which involve the removal of ammonia. Numerous potentially harmful compounds remain after many of the treatment processes thus far proposed, including ammonia stripping. Some of these compounds, benzene and benzopyrene, for example, are known to be carcinogenic to many animals (DAVIES et al. 1971, DE LUSTIG AND MATOS 1971, FERON 1972, BLAIR et al. 1973). Other compounds, valeroactone, for example, may cause pronounced physiological changes (DEICHMANN et al. 1945).

The present study was an attempt to find the effects of chronic low-level exposure of fish and wildlife to partially treated oil shale retort water. Rainbow trout (*Salmo gairdneri* Richardson), fathead minnows (*Pimephales promelas* Rafinesque), coturnix quail (*Coturnix coturnix* Temminck and Schlegel), and golden hamsters (*Mesocricetus auratus* Water) were exposed, through various routes, to low levels of ammonia-stripped retort water, and cytological and/or histological changes monitored.

Ammonia-stripped retort water was used because any scheme adopted for treatment of retort water will probably involve primary removal of the majority of the ammonical nitrogen.

MATERIALS AND METHODS

Retort Water

Oxy-6 retort water was obtained from the Laramie Energy Technology Center. A chemical characterization of this water is shown in Table 1. It was stripped of 80% of the ammonia (to less than

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200 ppm) by boiling for one hour. The stripped retort water (SRW) was incorporated into food of the various test animals during pelletization. SRW was also dripped into the water of the fishes by means of a Mariotti bottle and mixing box, and added to the drinking water of the quail and hamsters.

TABLE 1

Chemical characterization of Oxy-6 retort water (Division of Environmental Sciences, Laramie Energy Technology Center, unpublished data).

Parameter	Mean[a] (mg/L except where noted)
Total Solids	8,960
Total Dis. Solids	8,900
TOC	2,890
TIOC	1,040
TC	4,040
COD	14,000
pH (std. pH units)	8.84
Alkalinity ($CaCO_3$)	7,190
Oil and Grease	391
Thiocyanate	53
Thiosulfate	<0.1
Tetrathionate	<0.1-0.4
Sodium	126
Potassium	10.8
Calcium	1.3
Magnesium	0.95
Phosphate	INT[b]
Chloride	370-490
Fluoride	29-32
Sulfate	1,380-1,480
Carbonate	1,300-1,700
Aluminum	<1.0
Arsenic	4.0-15
Barium	<0.5
Boron	18
Cadmium	<0.1
Chromium	<0.1
Copper	<0.1
Cyanide	2.3
Iron	0.45
Lead	<0.5
Manganese	<0.1
Zinc	<0.05-0.15
Mercury	0.0016
Nickel	<0.1
Nitrate (NO_3-N)	3,160
Selenium	0.16
Silver	0.1

TABLE 1

(continued)

Parameter	Mean[a] (mg/L except where noted)
TKN	1,180
Phenols	47
Conductivity	13,000μmhos/cm
Ammonia (NH_3-N)	1,320

[a]Means are based on the analysis of 21 samples, except for oil and grease, TOC, TIOC, Arsenic, and Selenium, which were based on fewer samples.

[b]Interference.

Fishes

Rainbow trout eggs were acquired from the Colorado Division of Wildlife, and fathead minnows obtained from the Department of Zoology and Physiology, University of Wyoming. All fishes were cultured in well water with a constant flow of 2 L/min, and fed according to the procedure outlined by DEUEL et al. (1952). They were divided into 10 groups consisting of high dose exposures (250 ppm) and low dose exposures (125 ppm) of SRW, plus experimental controls. The exposure levels were lowered to 100 ppm and 50 ppm, respectively, after 85% mortality occurred in the high dose rainbow trout group (#1). Chronology and the various levels of SRW exposures to fish are given in Table 2.

Hamsters

Golden hamster breeding stock, obtained from Charles River Lakeview, Newfield, New Jersey, produced offspring that were used in this study. Ten hamsters were given drinking water with 25% v/v SRW and Purina Laboratory Animal Chow with 10% v/w SRW. The exposure was begun at birth and continued for a period of 10 months. A second group of 10 hamsters, with no exposure to SRW, served as the experimental control group. The hamsters were separated by sex and kept in cages containing no more than 5 animals each. They were fed once a day and offered water *ad libitum*.

Quail

Sixty 3-day old coturnix quail were acquired from The Peregrine Fund, Fort Collins, Colorado. Drinking water with 25% v/v SRW and Purina Game Bird Maintenance Chow with 10% v/w SFW were given to 40 quail over a 10 month period. A group of 20 experimental control quail were kept in cages containing 10 birds per cage. They were

TABLE 2

Chronology and levels of SRW to fish. Age of animals at the beginning of exposure is indicated.

Species	Group Number	Number of Animals	Age (days)	Exposure Period (Months) 0–1	Exposure Period (Months) 1–10
Rainbow Trout	1	270	45	250 ppm[a]	100 ppm water, 10% v/w-food
	2	40	45	125 ppm	50 ppm-water, 10% v/w-food
	3	270	21	125 ppm[b]	
	4	40	35	100 ppm-water, 10% v/w-food	100 ppm-water, 10% v/w-food
	5	40	21	50 ppm-water, 10% v/w-food	50 ppm-water, 10% v/w-food
	6	40	45	10% v/w-food	10% v/w-food
	7	40	45	Nontreated control	Nontreated control
Fathead Minnow	8	40	105	250 ppm	100 ppm-water; 10% v/w food
	9	40	105	125 ppm	50 ppm-water; 10% v/w food
	10	40	105	Nontreated control	Nontreated control

[a]85% Mortality

[b]100% mortality

fed once a day and offered water *ad libitum*.

Tissue Sections

Animals were sacrificed from each group after 10 months exposure to SRW. Five fish were sacrificed from groups 1, 2, 5 and 6; and 10 fish from groups 4, 7, 8, 9, and 10 (Table 2). Five hamsters were sacrificed from each hamster group. Twenty quail were sacrificed from the SRW-treated group and 10 from the control group.

Liver, kidney, spleen, pancreas, and intestine were taken from each animal. In addition, gills were taken from fishes, lung from hamsters and quail, proventriculus from quail, and other tissues as indicated. All tissues were embedded in parafin, sectioned, and stained with hemotoxylin and eosin. Special stains were also used for glycogen and fat in the livers of selected animals from each group. Light microscope techniques were used to examine stained tissue sections.

RESULTS

Normal activity, behavior and appearance continued among all animals being exposed to SRW in food and water. Necropsy, gross examination and histology of 20 fathead minnows, 30 rainbow trout, 20 coturnix quail, and 5 golden hamsters revealed no pathological change attributed to contact and/or ingestion of Oxy-6 SRW. Cut and stained sections of 20 sexually mature fathead minnow testes or ovary had normal spermatogenesis or egg development. Both quail and hamsters continued normal reproductive patterns during the period of exposure. Two rainbow trout, one from the experimental control group (#7) and one from a group exposed to SRW (#2), each had a small (1.0 mm by 1.5 mm) area of liver hyperplasia. These areas of change were considered to have been caused by the diet or the environmental water supply, and not the SRW.

DISCUSSION

Results of this study indicate that ammonia-stripping may be an important treatment step in reducing the potential harmful effects of retort water to fish and wildlife. ANDERSON et al. (1980) determined the 96 h TC_{50} of whole retort water to be at 0.41% dilution (4.1 ml/L) for fathead minnows and 0.56% dilution (5.6 ml/L) for rainbow trout. The acute oral LD_{50} of 33.0 ml/kg and 37.5 ml/kg were determined for rats and rabbits, respectively, exposed to whole retort water by HEPLER et al. (1979). The lack of chronic exposure effects of 25% SRW in drinking water during the present 10 month study may be explained by the fact that many of the volatile organic components of retort water are removed along with ammonia during the stripping process. The potentially harmful compounds remaining are apparently not present in concentrations high enough to cause histological changes under the test conditions imposed.

This study was designed to be a preliminary search for possible adverse effects of SRW to various animals. Similar studies should also be done on retort waters from oil shale retorting processes other than the Oxy-6 process, since their chemical compositions may vary significantly. In addition, further research is needed to determine the possible adverse effects of SRW to second generation animals.

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