EMSL-LV-0539-25

FRESHWATER ALGAE OF THE NEVADA TEST SITE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Environmental Monitoring and Support Laboratory
Las Vegas, Nevada 89114

June 1979

Prepared under
Memorandum of Understanding
No. EY-76-A-08-0539
for the
U.S. DEPARTMENT OF ENERGY

AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

PRICE: PAPER COPY $4.50 MICROFICHE $3.00

EMSL-LV-0539-25

FRESHWATER ALGAE OF THE NEVADA TEST SITE

by

W. D. Taylor and K. R. Giles

Environmental Monitoring and Support Laboratory
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

June 1979

Prepared under
Memorandum of Understanding
No. EY-76-A-08-0539
for the
U.S. DEPARTMENT OF ENERGY

ABSTRACT

Fifty-two species of freshwater algae were identified in samples collected from the eight known natural springs of the Nevada Test Site. Although several species were widespread, 29 species were site specific. Diatoms provided the greatest variety of species at each spring. Three-fifths of all algal species encountered were diatoms. Well-developed mats of filamentous green algae (Chlorophyta) were common in many of the water tanks associated with the springs and accounted for most of the algal biomass. Major nutrients were adequate, if not abundant, in most spring waters--growth being limited primarily by light and physical habitat. There was some evidence of cesium-137 bioconcentration by algae at several of the springs.

CONTENTS

LIST OF FIGURE AND TABLES

INTRODUCTION

The Nevada Test Site (NTS) encompasses approximately 3,500 square kilometers of desert area, ranging from the high flat plateaus to dry lake beds. This entire area is subject to high winds, sudden temperature changes, and sporadic precipitation. The annual mean precipitation at any specific location depends to a large extent on the elevation (Quiring, 1968).

Although historically several of the springs on the NTS provided the only water available to settlers and travelers in the area (remains of old wood and stone structures still stand by several of the springs), today they are isolated from all but a few personnel employed at the NTS. A four-wheel drive vehicle is needed to gain access to several of the springs which further isolates them from human perturbations.

Interest in the eight natural springs known to exist within the boundaries of the NTS has increased due to a reduction in availability of water because of deterioration of the spring sites (Giles, 1976). The springs are the only known sources of water for wildlife in the area, especially during the critical hot summer months. Giles' study was undertaken to determine the manpower and materials required to improve or reclaim the springs for the continued support of wildlife. Renovations made in 1975 were described in another report (Smith et al., 1978a). Maintenance of the springs have continued on a routine basis (Smith et al., 1978b).

More comprehensive information on the historical development of the NTS springs, the use by wildlife, and the hydrology of the area is available in other publications (U.S. Geological Survey, 1971; Hayward et al., 1963; Jorgensen and Hayward, 1965; Worman, 1969). Drouet (1960), and Shields and Drouet (1962), in studies of terrestrial algae of the NTS, list 16 terrestrial and 15 aquatic species of algae, the aquatic species being found in the vicinity of Cane Spring. However, during the present study, only two of these species were encountered.

The primary purpose of this study was to characterize the poorly known algal communities and environmental conditions in the natural springs of the NTS. In addition, analyses of spring water and algae for gamma-emitting radionuclides and tritium were performed on selected spring samples as some algae are known to concentrate radioactive materials to levels many times greater than background concentrations.

DESCRIPTION OF SPRINGS

The locations of the eight natural springs known to exist on the NTS are shown in figure 1. The individual spring descriptions are modified from Giles (1976) only in cases where changes have occurred at the spring site or where additional information was added in connection with the subject of this study.

CANE SPRING

Location: East slope of the Skull Mountain, Area 27; Long. 116°06' W., Lat. 36°48' N., T. 13 S., R. 52 E., Sec 26.

Three old, unoccupied buildings and a large willow tree mark the location of Cane Spring. Water is accessible from a circular dugout in the hillside, from a deep tunnel excavated to improve waterflow, and from a 120-liter plastic tank kept full year-round with water piped a short distance from the spring. Spring water seeps down to a low marshy area which is overgrown with cattails, aquatic grasses, and other vegetation. Except for the dugout the area has full sun exposure.

CAPTAIN JACK SPRING

Location: Southwest of Area 12 Campsite near conjunction of Areas 2, 12, and 17; Long. 116°10' W., Lat. 37°10' N., T. 9 W., R. 52 E., Sec. 19.

Most of the water from this spring is diverted through a plastic pipe to a small metal tank where the water was made more readily accessible to wildlife. At the time of sampling the surface of the water in the tank was completely covered with a thick mat of filamentous algae. The spring and tank are in a narrow canyon, thereby limiting direct sunlight during large parts of the day.

GREEN SPRING (also known as Reitmann Spring)

Location: Area 7; Long. 116°00' W., Lat. 37°05' N., T. 9 S., R. 53 E.

This spring is an open pool containing about 23 liters of water year-round. Loss of water from the pool is through evaporation, transpiration, and from wild animals drinking it. The margin of the pool is overgrown with *Carex* sp. and grasses. The pool is littered with decomposing organic debris.

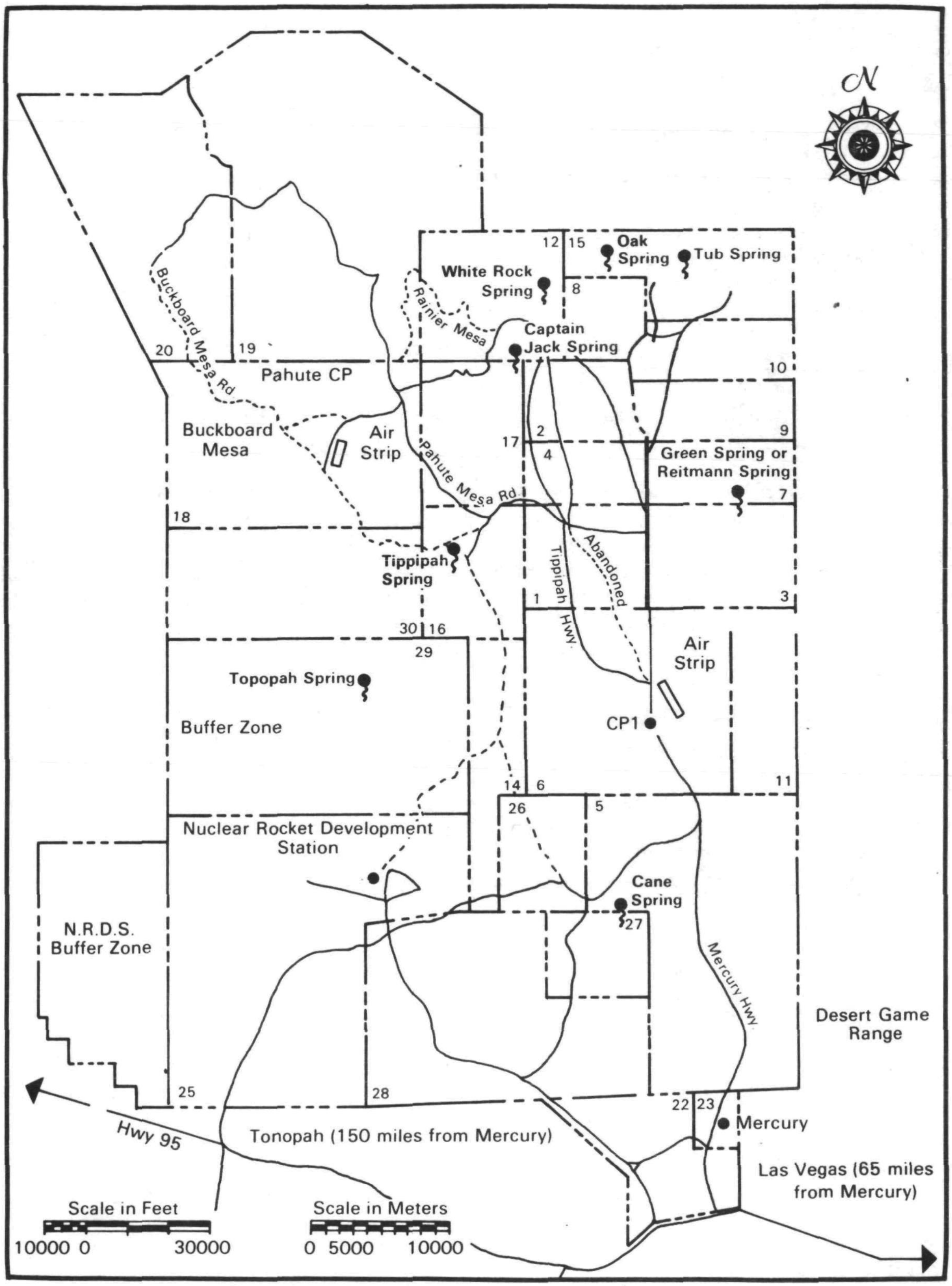

Figure 1. Location of natural springs (spring symbol) on the Nevada Test Site (from Giles, 1976)

OAK SPRING

Location: Area 15; Long. 116°04' W., Lat. 37°15' N., T. 8 S., R. 53 E., Sec. 20.

This spring was apparently developed to provide water for mining operations. There is evidence of a pipeline running to living quarters and a corral about 1.6 kilometers south of the spring. The opening at the spring is small (about 0.5 meters in diameter). Water was piped a short distance to a 120-liter tank. A sheet metal ladder is present in the tank presumably to provide a mechanism of escape for any small animal that might otherwise be trapped and drown. The steps of the ladder function as growing surfaces for dense masses of algae.

TIPPIPAH SPRING

Location: Northeast of the Shoshone Mountain, Area 16; Long. 116°12' W., Lat. 37°03' N., T. 10 S., R. 51 E., Sec. 26.

The remains of two stone buildings and other ranch structures are evidence of a once abundant supply of water from this spring. At the time of sampling there was a small pool 20 to 30 centimeters in depth at the back of a tunnel extending about 10 meters into the hillside. Rock and dirt falling from the roof are gradually filling the entrance to this tunnel. Very limited light reaches the water.

TOPOPAH SPRING

Location: Southwest of the foot of the Shoshone Mountain, Area 29; Long. 116°16' W., Lat. 36°56' N., T. 12 S., R. 51 E., Sec. 5.

The tunnel which once existed at the spring has been completely filled in with dirt and rock from the roof of the tunnel. At the time of sampling, only a small pool, tucked in under a rock overhang, was present. The pool was about 1 meter in diameter with a maximum depth of 8 centimeters.

TUB SPRING

Location: Area 15; Long. 116°02' W., Lat. 37°14' N., T. 8 S., R. 52 E., Sec. 13.

Apparently this spring was developed during the operation of a mine located 1.6 kilometers southwest of the spring. It was also probably used by ranchers grazing cattle and horses in the area prior to the establishment of the NTS.

The spring consists of a tunnel dug about 10 meters into the hillside which contains 0.5 to 1 meter of water year-round. The water is pooled within the tunnel by a small earthen dam at the entrance. Water is delivered from the dam via a 7.6-centimeter pipe to a small tank (approximately 120 liters) located nearly 30 meters below the dam.

WHITE ROCK SPRING

Location: East of the Rainier Mesa, Area 12; Long. 116°08' W., 37°12' N., T. 9. S., R. 52 E., Sec. 4.

This spring consists of two tunnels dug into the rock on either side of a narrow canyon. Each tunnel has a small concrete dam across the entrance, providing a fairly abundant year-round water supply which is then piped to a stock tank between the tunnels. Direct sunlight entering the caves is limited to a few hours each day, while the tank receives full daylight exposure.

MATERIALS AND METHODS

SAMPLE COLLECTION

The springs were visited twice in 1976. During the first visit on May 4, samples were collected for algal identification and immediately preserved in a 3 percent Formalin® solution. Algal collections consist of grab samples taken from several locations around each spring. For specific descriptions of the samples collected at each spring see table 1. Also, during the first visit, a 1-liter (1) container was filled with water at each spring for gamma-emitting radionuclide and tritium analyses. Preservation of these samples was unnecessary.

On the second visit (June 16) two 130-milliliter (ml) grab samples of water were collected at each spring for nutrient analysis. Each sample was immediately preserved with a 0.25-ml mercuric chloride ($HgCl_2$) solution (0.25 grams $HgCl_2$/1 of water). Also during this visit about 400 grams (wet weight) of algal material were collected at each spring for analysis of gamma-emitting radionuclides. Again no preservatives were needed. Finally, a 4-liter grab sample of water was collected at Green, White Rock, and Cane Springs and submitted within 24 hours to an independent laboratory for additional chemical analyses.

SAMPLE ANALYSIS

Algal identifications were made from wet mounts and heat-cleared, Hyrax-mounted diatom slides with a standard binocular compound-light microscope. Dark and light field-phase-contrast equipment was used when necessary for diatom identifications.

Nutrient analyses were performed by the Environmental Monitoring and Support Laboratory-Las Vegas using automated procedures as described by Mullins et al. (1975). The nutrient samples were analyzed for total phosphorus, dissolved orthophosphorus, ammonium nitrogen, nitrate nitrogen, total kjeldahl nitrogen (all reported in micrograms (μg) per liter), and total

®Registered Trademark

TABLE 1. WATER TEMPERATURE, pH, SAMPLE TYPES, AND OTHER OBSERVATIONS OF THE NEVADA TEST SITE SPRINGS SAMPLED ON MAY 4, 1976

SPRING	WATER TEMPERATURE (°C)	WATER pH	NOTES
Cane	11	6.5	Samples from benthic flocculum* immediately downstream from the tanks, scrapings from tank, and surface scum floating inside the cave.
Captain Jack	16	6.5	Grab samples from spring source and the tank. A mat of filamentous algae covered the surface of the tank.
Green	20	6.4	A detritus grab sample was taken from the small pool. Water at the pool was exposed to direct sunlight throughout most of the day.
Oak	15.2	6.5	Algae were sucked off the horizontal surfaces of a sheet metal ladder with a baster. The ladder extended throughout the depth of the tank. A grab sample was collected of floating filamentous algae and moss.
Tippipah	10.8	6.5	Sludge was collected from a pool which was located in the tunnel approximately 5 meters from the entrance.
Topopah	11	6.6	Algae was scraped from damp mud, rocks, and sucked out of a small puddle.
Tub	23	8.0	A number 25 plankton net was dipped 10 times into the tank. The only visible algae was scraped from the outlet of the pipe filling the tank. Tank had full sun exposure throughout the day.
White Rock	12.5	6.4	Samples were scrapings of rocks and mud from both cave entrances and a grab sample of the floating algal mat in the tank.

*Benthic flocculum is the thin layer of debris often found suspended in the water just off the bottom.

alkalinity as calcium carbonate ($CaCO_3$) (reported in milligrams (mg) per liter). Analyses of water and algae samples for gamma-emitting radionuclides and tritium were performed using methods described in Johns (1975). Tritium analyses were reported in picocuries (pCi) per liter, and gamma-emitting analyses were reported in pCi per kilogram (kg) wet weight.

Temperature and pH were measured during algae sample collection using a laboratory mercury thermometer and narrow range pHydrion® paper.

The 4-liter water samples collected at Green, White Rock, and Cane Springs were analyzed for calcium, magnesium, sodium, potassium, sulfate, chloride, boron, silica, arsenic, lead, selenium, barium, chromium, cadmium, manganese, fluoride, and zinc, all reported in mg/l. The laboratory used methods presented in APHA (1971) for these analyses.

®Registered Trademark

RESULTS AND DISCUSSION

WATER CHEMISTRY

All of the springs within the boundaries of the NTS discharge water from perched zones of saturation in tuff and rhyolite (Schoff and Moore, 1964). Moore (1961) also determined that discharges ranged from less than 4 to 11 liters per minute. Although direct measurements were not made during the present study, discharge rates have not changed appreciably since 1961. Schoff and Moore (1964) classified the water from Topopah, Tippipah, Captain Jack, Green, and White Rock Springs as the "sodium-potassium" type. Our data for White Rock and Green Springs are similar, indicating no major change in water chemistry in the past 10 years (table 2). Current data for the other springs are not available. The Schoff and Moore's (1964) study classified Cane, Oak, and Tub Springs as the "mixed" chemical type, i.e., with the sodium and potassium content nearly equaling the calcium and magnesium content. The data for Cane Spring indicated a slight shift to a 65 percent sodium-potassium and 35 percent calcium-magnesium condition since 1964 (table 2). With the exception of Tub Spring (pH = 8.0), all of the springs were slightly acid (pH = 6.4 to 6.6), and had temperatures ranging from 10.8 to 23.0 degrees Celsius (table 1).

Nutrient concentrations were adequate for good growth in all of the springs (table 3), especially since new water continuously replaced the old. The large variation in nutrient concentrations between springs is interesting since water for each spring is thought to pass through similar minerals (Schoff and Moore, 1964). Green Spring had exceptionally high concentrations of total phosphorus (2,030 μg/l), dissolved orthophosphorus (898 μg/l), and total kjeldahl nitrogen (4,800 μg/l). The elevated values may be due to a high rate of evaporation with no flushing action. This spring has a low flow rate and the bowl shape of the basin traps water not allowing any to pass through. These same conditions also allow for accumulation of allochthonous material which upon decomposition would increase nutrient values.

Results of the gamma-emitting radionuclide and tritium analyses are presented in table 4. No gamma-emitting radionuclides were found in any of the spring waters and tritium levels were either undetectable or at ambient levels. Three of four algae samples contained detectable levels of cesium-137 and the sample from Captain Jack Spring (2,500 pCi/kg) was about 10 times higher than the value for algae sampled at the other springs. However, this might be partially due to differences in the moisture content of the respective samples.

TABLE 2. RESULTS OF STANDARD CHEMICAL WATER ANALYSIS PERFORMED FOR SELECTED NEVADA TEST SITE SPRINGS SAMPLED ON MAY 4, 1976*

	Concentrations (mg/l)		
Parameter	Green Spring	White Rock Spring	Cane Spring
Calcium (Ca^{2+})	0.7	1.4	15.2
Magnesium (Mg^{2+})	3.2	0.7	6.8
Sodium (Na^{+})	139	35.5	34.3
Potassium (K^{+})	36.0	9.4	16.2
Alkalinity			
as Carbonate (CO_3^{2-})	0.0	0.0	0.0
as Bicarbonate (HCO_3^{-})	315	63.5	130
Sulfate (SO_4^{2-})	34.5	45.5	21.0
Chloride (Cl^{-})	16.9	12.4	21.8
Iron (Fe^{3+})	32.2	3.6	<0.03
Boron (B)	0.0	0.8	1.8
Silica (SiO_2)	-	116	55.0
Arsenic (As)	<0.005	<0.005	<0.005
Lead (Pb)	<0.003	<0.003	<0.003
Selenium (Se)	<0.005	<0.005	<0.005
Barium (Ba^{2+})	<0.1	<0.1	<0.1
Chromium (Cr)	<0.03	<0.03	<0.03
Cadium (Cd)	<0.01	<0.01	<0.01
Manganese (Mn)	0.14	<0.02	<0.02
Fluoride (F^{-})	1.65	0.38	0.81
Zinc (Zn)	0.43	0.07	0.01

*These analyses were performed by an independent laboratory.

TABLE 3. NUTRIENT CONCENTRATIONS OF SPRING WATER COLLECTED AT THE NEVADA TEST SITE ON JUNE 16, 1976

SPRING	Total phosphorus (μg/l)	Dissolved Ortho-phosphorus (μg/l)	Ammonia nitrogen (μg/l)	Nitrate nitrogen (μg/l)	Total kjeldahl nitrogen (μg/l)	Total alkalinity (mg/l)
Cane	52	26	30	3,230	800	167
Captain Jack	414	358	20	400	400	101
Green	2,030	898	<20	1,180	4,800	203
Oak	92	38	40	300	210	109
Tippipah	185	158	20	1,220	340	92
Topopah	470	159	120	500	3,100	60
Tub	31	9	<20	500	300	118
White Rock	238	159	50	1,430	600	81

TABLE 4. TRITIUM AND GAMMA ANALYSIS OF SPRING WATER AND ALGAE, NEVADA TEST SITE, 1976*

	WATER ANALYSIS			ALGAE ANALYSIS		
SPRING	Date	Gamma Analysis	^{3}H (pCi/1)	Date	K (g/kg)	^{137}Cs (pCi/kg)
Cane	05/04/76	GSN**	<230	06/16/76	4.4 ± 0.36	350 ± 8.3
Captain Jack	05/04/76	GSN	<230	06/16/76	14 ± 4.8	2,500 ± 72
Green	05/04/76	GSN	<230			
Oak	05/04/76	GSN	<230	06/16/76	1.9 ± 0.27	170 ± 19
Tippipah	05/04/76	GSN	270 ± 260			
Topopah	05/04/76	GSN	910 ± 240			
Tub	05/04/76	GSN	<230			
White Rock	05/04/76	GSN	<230	06/16/76	GSN	GSN

*A similar table was presented in Smith et al., 1978.
**GSN = Gamma spectrum negligible.

ALGAL FINDINGS

Fifty-two algal species were identified in the NTS springs (table 5). Chrysophyta, Chlorophyta, and Cyanophyta were the three major groups of algae represented in the springs with 33, 14, and 5 species, respectively. Diatoms were the outstanding contributors to diversity in the algal communities, while in many cases filamentous green algae (Chlorophyta) provided the bulk of the biomass. Two diatoms, Achnanthes lanceolata and Gomphonema parvulum, were the most common species; both of these diatoms occurred in most of the springs.

At the tunnel entrance to Cane Spring, a well-developed mat of Vaucheria sp. was providing an attachment substrate for Oedogonium sp., Microthamion kuetzingianum, and several species of diatoms. In and near the tank, where maximum sun exposure prevailed, Oedogonium sp. grew abundantly, providing the growing surface for diatoms and other epiphytes. Three of the more common diatoms collected from Cane Spring (Nitzschia palea, N. linearis, and Navicula minima) have been considered associates of eutrophic conditions (Lowe, 1974).

In order to present a complete list of algae associated with the NTS springs, the following species identified in the vicinity of Cane Spring by Shields and Drouet (1962) are included: Amphithrix janthina (Mont.) Born. and Flah., Nodularia sphaerocarpa Born. and Flah., Nostoc enthophytum Born.

TABLE 5. ALGAE COLLECTED FROM NATURAL SPRINGS OF THE NEVADA TEST SITE

SPECIES	SPRING							
	CANE	CAPTAIN JACK	GREEN	OAK	TIPPIPAH	TOPOPAH	TUB	WHITE ROCK
CHRYSOPHYTA								
Pennales								
Achnanthes exigua Grun.				X		X		X
A. lanceolata (Bréb.) Grun.	X	X		X	X	X	X	X
A. minutissima Kütz.	X							
A. saxonica Krasske		X		X				X
Amphora submontana Hust.								X
Asterionella formosa Hass.			X					
Denticula elegans Kütz.								X
Epithemia adnata v. *proboscidea* (Kütz.) Patr.					X			
E. sorex Kütz.							X	
Fragilaria sp.				X		X		X
F. construens (Ehr.) Grun.								X
Gomphonema parvulum Kütz.	X	X		X	X	X		X
Hantzschia sp.								X
Meridian circulare (Grev.) Ag.		X						
Navicula cryptocephala Kütz.		X						
N. cuspidata v. *ambigua* (Ehr.) Cleve	X							
N. laevissima Kütz.				X				
N. minima Grun.	X			X		X		
N. rhynchocephala v. *amphiceras* (Kütz.) Grun.?							X	
Nitzschia sp.	X	X	X	X		X		X
N. amphibia Grun.?								X
N. gracilis Hantzsch				X				
N. linearis W. Smith	X			X				X
N. palea (Kütz.) W. Smith	X			X				
N. tryblionella Hantzsch forma								X
Pinnularia sp.								X
P. abaujensis v. *subundulata* (A. Mayer ex Hust.) Patr.						X		
P. viridis v. *minor* Cl.	X							
Stauroneis anceps Ehr.		X						
Surirella ovalis Bréb.	X					X		X
Centrales								
Melosira granulata (Ehr.) Ralfs			X					
Stephanodiscus niagarae Ehr.			X					
Vaucheriales								
Vaucheria sp.	X							

TABLE 5. ALGAE COLLECTED FROM NATURAL SPRINGS OF THE NEVADA TEST SITE (continued)

SPECIES	SPRING							
	CANE	CAPTAIN JACK	GREEN	OAK	TIPPIPAH	TOPOPAH	TUB	WHITE ROCK
CHLOROPHYTA								
Volvocales								
Chlamydomonas sp.								X
Haematococcus lacustris (Girod.) Rostafinski				X				
Ulotricales								
Microthamnion kuetzingianum Naeseli	X			X				
Protoderma viride Kütz.				X				
Stigeoclonium sp.	X	X		X			X	
Oedogoniales								
Oedogonium sp.	X	X						X
Chlorococcales								
Ankistrodesmus falcatus (Corda) Ralfs			X					
Chlorella vulgaris Beyernick		X	X					
Oocystis borgei Snow				X				
Scenedesmus acutus Meyen				X				
Zygnematales								
Closterium turgidum						X		
Cosmarium sp.		X					X	
Spirogyra juergensii Kütz.		X						
Ulothrix sp.				X				
CYANOPHYTA								
Oscillatoriales								
Lyngbya sp.								X
Oscillatoria sp.		X	X			X		
Phormidium sp.								X
P. tenue (Menegh.) Gomont							X	
Nostocales								
Calothix sp.		X		X				
TOTAL NUMBER OF SPECIES	14	14	7	19	3	10	6	19

and Flah., Oscillatoria brevis Kütz. ex Gom., Plectonema boryanum Gom., Phormidium autumnale (Ag.) Gom., P. tenue (Menegh.) Gom., Bulbochaete sp., Chara sp. Franceia droescheri (Lemm.) G. M. Smith, Oocystis crassa Wittr., Pandorina morum Bory, and Scenedesmus bijuga (Turp.) Lagerh.

All of the algae collected from Captain Jack Spring (table 5) were in a floating mat which completely covered the surface of the water in the tank. The mat was composed primarily of Oedogonium sp. with lesser amounts of Spirogyra juergensis and Stigeoclonium sp. The other species were epiphytic and tychoplanktonic within the mat.

Green Spring, relative to the others, had few diatoms. However, three species which did occur (Asterionella formosa, Melosira granulata, and Stephanodiscus niagarae) were not found in any of the other springs (table 5). M. granulata and S. niagarae were the only centric diatoms identified in the study. M. granulata and A. formosa are often considered associates of eutrophic water (Lowe, 1974), as are the green algae (Chlorophyta) Ankistrodesmus falcatus and Chlorella vulgaris (Palmer, 1969) which were also identified in the spring. As indicated earlier, Green Spring had some unusually high nutrient values (table 3).

Nineteen species of algae were identified in Oak Spring (table 5), all of which were collected from the tank. Encysted Haematococcus lacustris formed loose layers about one centimeter thick on the steps of the ladder which was immersed in the water tank. Mixed in with the dense red cysts were patches of green, comprised primarily of Scenedesmus acutus and H. lacustris cysts which had not changed to the red color so characteristic of the encysted stage. The bottom of the tank was covered with an equally thick green carpet of S. acutus and Oocystis borgei. Nitzschia palea, N. linearis, Navicula minima (diatoms indicative of eutrophic waters), Achnanthes exigua, A. lanceolata, and Gomphonem parvulum were present in large numbers. The remaining forms were scattered throughout the dense growths.

The only water associated with Tippipah Spring was pooled in the back of the tunnel with very limited light. As might be expected under these circumstances, algae were extremely scarce. Three algal species, all diatoms, were identified (table 5). Achnanthes lanceolata and Gomphonema parvulum were found in most of the other springs as well, but Epithemia adnata var. proboscidea occurred only in the Tippipah Spring samples.

Topopah Spring had a flow volume just adequate to maintain a small pool under a rock overhang near all that remained of the tunnel entrance. Eight species of diatoms were identified from sample material collected there (table 5). The only other forms were Closterium turgidum (desmid) and Oscillatoria sp. (blue-green).

The algae found at Tub Spring were growing within a layer of Phormidium tenue just inside the mouth of the pipe filling the tank. P. tenue was the only nondiatom encountered at the spring (table 5). No living material, plant or animal, was located in the tank itself.

Nineteen algal species were identified from White Rock Spring (table 5). Fifteen species were diatoms. *Oedogonium* sp. was the most abundant organism, forming a floating mat on the surface of the tank. Soft gelatinous masses of *Chlamydomonas* sp. were floating in association with *Oedogonium* sp. Within the two caves from which the spring water emerged, diatoms dominated the flora.

GENERAL DISCUSSION

The small number of algal species encountered in each of the NTS springs is probably indicative of a limited water supply and the harsh desert environment. The variety and quantity of substrates available for algal colonization is dependent upon the availability of water to cover them. Several of the springs barely produced enough water to maintain small pools even though sampling visits took place during the springtime in May and June. Water in springs with higher flow rates was conserved primarily due to human efforts directed towards improving water storage facilities. Most of the algae were collected directly from the tanks where the water was located. Another condition encountered, especially at Tippipah Spring and to lesser extent at Topopah Spring, was light limitation. Tippipah Spring was constantly in semidarkness during the daytime hours while Topopah Spring was tucked under a rock overhang seldom receiving much direct sunlight. If not for pipelines and water tanks, other springs would have had similar limited light conditions.

Major nutrients were sufficient to support good algal growth at each spring as indicated by the dense algal mats and attached growths in the tanks which were exposed to full sunlight. Tub Spring was the exception where no algae were found in the tank. Visitors to Tub Spring at other times, however, have reported dense algal mats in the tank.

Although several species of algae were commonly encountered at most of the springs, 29 species were site specific. They were not necessarily rare when found. *Haematococcus lacustris*, *Oocystis borgei*, and *Scenedesmus acutus* were identified only in samples collected at Oak Spring, but were in concentrations large enough that one could scoop them by the handfuls. *Ankistrodesmus falcatus* on the other hand was rare and difficult to locate in Green Spring, and was not found at all in any of the other springs.

Diatoms provided the greatest variety of algal species at each of the springs. Three-fifths of all algal species identified in the springs were diatoms. Many of them were quite small but developed large populations. Maximum diatom development, both quantitative and qualitative, was usually associated with the presence of dense growths of green algae.

Undoubtedly the number of algal species listed for NTS springs would increase with a more comprehensive sampling program designed to consider seasonal variations in weather conditions and possible changes in flow rates. Future work on NTS algae should include culturing of sample material specifically to induce production of reproductive structures necessary to make species determinations, particularly for some of the important filamentous green algae. Monitoring implications associated with our findings of measurable cesium-137 concentrations in algal samples, when it was undetectable in the water, may be worthy of further investigation.

REFERENCES

APHA. Standard Methods for the Examination of Water and Wastewater. 13th ed. American Public Health Association. Washington, D.C. 874 pp. 1971

Drouet, F. "Algal flora of the Nevada Test Site." The Colorado-Wyoming Acad. Sci. 4:31. 1960

Giles, K. R. Springs of the Nevada Test Site and Their Use by Wildlife. NERC-LV-539-26. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada. 14 pp. 1976

Hayward, C. L., M. L. Killpack, and G. L. Richards. "Birds of the Nevada Test Site." Brigham Young University. Sci. Bull. Biol. Ser. 3(1):1-27. 1963

Johns, F. B. National Environmental Research Center-Las Vegas Handbook of Analytical Methods. EPA-680/4-75-001. U.S. Environmental Protection Agency, National Environmental Research Center, Las Vegas, Nevada. 140 pp. 1975

Jorgensen, C. D. and C. L. Hayward. "Mammals of the Nevada Test Site." Brigham Young University. Sci. Bull. Biol. Ser. 6(3):1-81. 1965

Lowe, R. L. Environmental Requirements and Pollution Tolerance of Freshwater Diatoms. EPA-670/5-74-005. U.S. Environmental Protection Agency, Washington, D.C. 334 pp. 1974

Moore, J. E. Wells, Test Holes, and Springs of the Nevada Test Site and Surrounding Area: U.S. Geologic Survey. TEI-781. 1961

Mullins, J. W., R. N. Snelling, D. D. Moden, and R. G. Seals. National Eutrophication Survey: Data Acquisition and Laboratory Analysis System for Lake Samples. EPA-600/4-75-015. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada. 21 pp. 1975

Palmer, C. M. "A composite rating of algae tolerating organic pollution." J. Phycol. 5:78-82.

Quiring, R. F. Climatological Data Nevada Test Site and Nuclear Rocket Development Station. ERLTM-ARL-7. U.S. Department of Commerce, Environmental Science Services Administration Research Laboratories. August 1968

Schoff, S. L. and J. E. Moore. Chemistry and Movement of Ground Water, Nevada Test Site. U.S. Geologic Survey. TEI-838. 1964

Shields, L. M. and F. Drouet. "Distribution of terrestrial algae within the Nevada Test Site." Amer. J. Bot. 49(6):547-554. 1962

Smith, D. D., K. R. Giles, D. E. Bernhardt, and K. W. Brown. Animal Investigation Program 1975 Annual Report: Nevada Test Site and Vicinity. EMSL-LV-0539-14. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada. 47 pp. Apps. A-H. 1978a

Smith, D. D., K. R. Giles, D. E. Bernhardt, and K. W. Brown. Animal Investigation Program 1976 Annual Report: Nevada Test Site and Vicinity. EMSL-LV-0539-20. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada. 111 pp. 1978b

U.S. Geological Survey. Wells and Springs in California and Nevada Within 100 Miles of the Point 37°15' N., 116°25' W., on the Nevada Test Site. USGS-474-85. U.S. Department of the Interior, Denver, Colorado. 1971

Worman, F. C. V. Archeological Investigations at the U.S. Atomic Energy Commission's Nevada Test Site and Nuclear Rocket Development Station. LA-4125. Los Alamos Scientific Laboratory of the University of California, Los Alamos, New Mexico. August 1969

DISTRIBUTION

1 - 40	Environmental Monitoring and Support Laboratory-Las Vegas
41	Mahlon E. Gates, Manager, DOE/NV, Las Vegas, NV
42	Troy E. Wade, DOE/NV, Las Vegas, NV
43	David G. Jackson, DOE/NV, Las Vegas, NV
44	Paul J. Mudra, DOE/NV, Las Vegas, NV
45	Elwood M. Douthett, DOE/NV, Las Vegas, NV
46 - 47	Ernest D. Campbell, DOE/NV, Las Vegas, NV
48 - 49	Paul B. Dunaway, DOE/NV, Las Vegas, NV
50	Roger Ray, DOE/NV, Las Vegas, NV
51	Robert W. Taft, DOE/NV, Las Vegas, NV
52	Leon Silverstrom, DOE/NV, Las Vegas, NV
53	Robert W. Newman, DOE/NV, Las Vegas, NV
54	Bruce W. Church, DOE/NV, Las Vegas, NV
55 - 56	Technical Library, DOE/NV, Las Vegas, NV
57	Chief, NOB/DNA, DOE/NV, Las Vegas, NV
58	Hal Hollister, GTN, DOE/HQ, Washington, DC
59	Tommy F. McCraw, DOS, DOE/HQ, Washington, DC
60	L. Joe Deal, DOS, DOE/HQ, Washington, DC
61 - 65	Major General Joseph K. Bratton, Director, MA, DOE/HQ, Washington, DC
66	Gordon C. Facer, MA, DOE/HQ, Washington, DC
67	Robert L. Watters, OHER, DOE/HQ, Washington, DC
68	Jeff Swinebroad, OHER, DOE/HQ, Washington, DC
69	Robert W. Wood, OHER, DOE/HQ, Washington, DC
70	William S. Osburn, Jr., OHER, DOE/HQ, Washington, DC
71	Ray Brechbill, DOE/SAN, Oakland, CA
72	March Williamson, RESL/INEL, DOE/ID, Idaho Falls, ID
73	Steven V. Kaye, Oak Ridge National Lab., Oak Ridge, TN
74	Helen Pfuderer, ESIC, Oak Ridge National Lab., Oak Ridge, TN

75 H. E. Walburg, CARL, Oak Ridge National Lab., Oak Ridge, TN

76 Assistant Administrator for Research and Development, EPA, Washington, DC

77 Deputy Assistant Administrator for Monitoring and Technical Support, ORD, EPA, Washington, DC

78 Acting Deputy Assistant Administrator for Radiation Programs, EPA, Washington, DC

79 Director, Monitoring Technology Division, Office of Monitoring and Technical Support, ORD, EPA, Washington, DC

80 Director, Technical Support Division, Office of Monitoring and Technical Support, ORD, EPA, Washington, DC

81 Director, Criteria Development and Special Studies Division, Office of Health and Ecological Effects, ORD, EPA, Washington, DC

82 Library, EPA, Washington, DC

83 Regional Administrator, Region IX, EPA, San Francisco, CA

84 Regional Radiation Representative, Region IX, EPA, San Francisco. CA

85 Director, Radiochemistry and Nuclear Engineering Branch, EPA, Cincinnati, OH

86 Director, Eastern Environmental Radiation Facility, EPA, Montgomery, AL

87 Harold F. Mueller, NOAA/WSNSO, Las Vegas, NV

88 Gilbert J. Ferber, NOAA/WSNSO, Silver Spring, MD

89 K. M. Oswald, Manager, Health and Safety, LLL, Mercury, NV

90 Richard L. Wagner, LLL, Livermore, CA

91 Howard W. Tewes, LLL, Livermore, CA

92 Paul L. Phelphs, LLL, Livermore, CA

93 Mortimer L. Mendelsohn, LLL, Livermore, CA

94 J. C. Hopkins, LASL, Los Alamos, NM

95 Harry S. Jordan, LASL, Los Alamos, NM

96 Lamar J. Johnson, LASL, Los Alamos, NM

97 George E. Tucker, Sandia Lab., Albuquerque, NM

98 Carter D. Broyles, Sandia Lab., Albuquerque, NM

99 Melvin L. Merritt, Sandia Lab., Albuquerque, NM

100 R. Glen Fuller, Oracle, AZ

101 Richard S. Davidson, Battelle Memorial Institute, Columbus, OH

102 Arden E. Bicker, REECo, Mercury, NV

103 Savin W. Cavender, REECo, Mercury, NV

104 Auda F. Morrow, CETO, Mercury, NV

105 Joseph H. Dryden, NTSSO, DOE/NV, Mercury, NV

106 Billy Moore, NVHQ, DOE/NV, Las Vegas, NV

107 Leo Bustad, Director, Veterinary Medicine, Washington State University, Pullman, WA

108 Vincent Schultz, Washington State University, Pullman, WA

109 Arthur Wallace, University of California, Los Angeles, CA

110 Wesley E. Niles, University of Nevada, Las Vegas, NV

111 Library, University of Nevada, Las Vegas, NV

112 Verle R. Bohman, University of Nevada, Reno, NV

113 Lloyd P. Smith, President, Desert Research Institute, University of Nevada, Reno, NV

114 Paul R. Fenske, Desert Research Institute, University of Nevada, Reno, NV

115 William S. Twenhofel, U.S. Geological Survey, Denver, CO

116 Manager, Desert National Wildlife Range, U.S. Fish and Wildlife Service, Las Vegas, NV

117 Supervisor, Region III, Nevada Fish and Game Department, Las Vegas, NV

118 Paul Lyons, Nevada Wildlife Research Division of Archives, Capitol Building Annex, Carson City, NV

119 Deward W. Efurd, McClellan Central Lab., McClellan Air Force Base, CA

120 L. L. Skolil, San Diego State University, San Diego, CA

121 C. S. Fore, ESIC, Oak Ridge National Lab., Oak Ridge, TN

122 - 148 Technical Information Center, DOE, Oak Ridge, TN (for public availability)