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Mercury Levels in Water and Sediment of Elephant Butte Reservoir, New Mexico

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An assessment of mercury levels in rocks, soils and sediments of the Western United States indicates normal levels to be within the range of 50-200 ppb (PIERCE et al. 1970). KLEIN and GOLDBERG (1970) report levels of 20-1,000 ppb as natural for California coastal areas. KONRAD (1972) reports levels of 10-150 ppb as normal for sediments of Wisconsin rivers and lakes. COPELAND (1972) gives normal mercury levels of 300-1,000 for Lake Michigan sediments. KIDD and POTTER (1972) report mercury levels of 4-53 ppb in Lake Powell sediments (Arizona-Utah) which is believed to be free of artifical mercury contamination.

WERSHAW (1972) reports natural levels of mercury in unpolluted surface waters from 33 states. Mercury concentrations from less than 0.1 ppb to 17 ppb are common. HEM (1970) indicates that about 25 ppb represents the likely upper equilibrium limit of mercury in surface waters. The concentration of mercury in water is reduced in the presence of suspended particulate matter which will adsorb many ionic mercury species (WERSHAW 1970).

The question to be considered here is whether or not mercury levels found in Elephant Butte water and sediments represent natural levels compared to levels reported for other parts of the United States.

SITE DESCRIPTION

Elephant Butte Reservoir is located in Sierra County in south-central New Mexico 8 km northeast of Truth or Consequences, New Mexico and is New Mexico's oldest reservoir and second largest impoundment. (Figure 1). Major characteristics relevant to this investigation include its fluctuating water levels, its diminishing storage capacity and its chemical and physical parameters which influence the chemical equilibrium of mercury in this system and associated biological factors.

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Original storage capacity was 3,257 million m^3, but reduced to 2,640 million m^3 due to siltation by 1969 (U. S. Department of the Interior, 1970.) Water storage fluctuates greatly as a result of seasonal inflow and drawdown. It varied between 295 million m^3 and 43 million m^3 during the course of this study (U. S. Bureau of Reclamation, 1972).

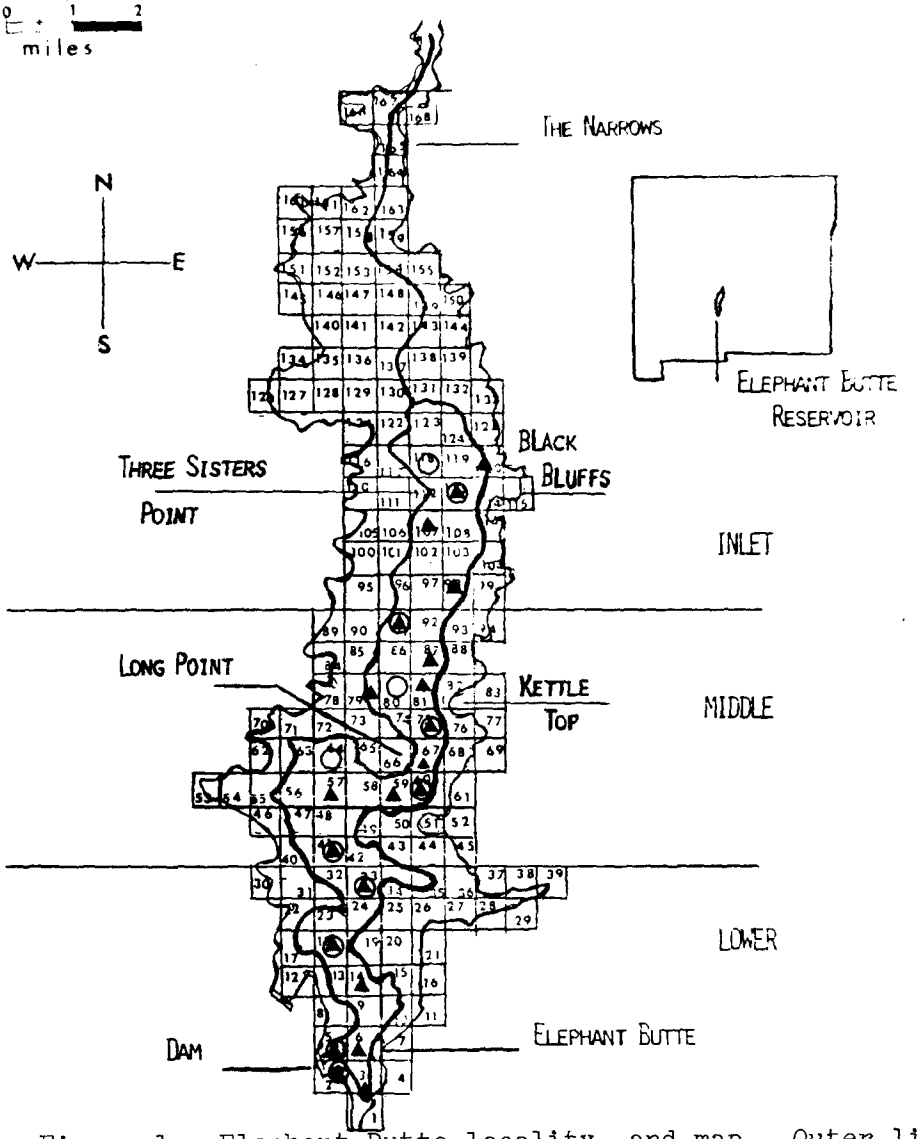

Figure 1. Elephant Butte locality, and map. Outer line indicates shoreline at maximum storage capacity. Inner line indicates the approximate shoreline during this study. Each square of the grid represents an area with one half mile sides. Triangles indicate sites where sediments were collected and circles indicate water sampling stations.

Chemical characteristics include dissolved oxygen levels usually ranging from 5.5-8.5 mg/L, but occasionally may be as low as 2.4 mg/L in certain areas of the lake during mid-summer months. Total hardness varies from 175-225 mg/L; pH usually near 8.3 but may vary from 7.5-9.2; chlorides from 39-91 mg/L; sulfates from 89-180 mg/L (JESTER 1972). Total alkalinity ranges from 124-160 mg/L; phosphates from 0.090-1.08 mg/L; and total nitrogen ranges from 0.21-0.93 mg/L (KIDD and JOHNSON 1971). Surface water temperatures may reach 28 C during July and August, and temperatures of 20 C have been recorded to depths of 23 m (JESTER 1972).

Bottom types vary little along the main river channel from inlet to the dam. Sediments in the lower third contain greater amounts of organic material than do sediments from the inlet or middle thirds. The bottom along the eastern shore, from north to south, is a silt-rock mixture.

MATERIALS AND METHODS

Collection. Sediment samples were collected at 21 sites and sub-surface water samples were collected at 12 sites from late May, 1971 through October, 1972 (Figure 1). Sediments were collected using an Eckman dredge and the water was collected with a 1,200-mL Kemmerer bottle.

Preservation. Sediment samples were placed in polyethylene freezer containers, labeled and kept in an ice chest until they could be frozen (usually 3 to 4 h.). Preservation procedures are described by COPE (1960); sediments were kept frozen until analysis. Water samples were stored in glass jugs and were preserved with 3 mL/liter 50% nitric acid as recommended by CHAU and SAITOH (1970). They were analysed within 1 to 2 weeks after collection.

Analysis and Sample Preparation. Water and sediment samples were analyzed using a Perkin-Elmer Model 306 Atomic Absorption Spectrophotometer and a flameless technique described by HATCH and OTT (1968). Mercury in water samples was prepared for analysis by the dithizone extraction method of CHAU and SAITOH (1970) in which it was concentrated to 100 mL samples. A minimum of five replicate sediment samples each weighting 5 g (wet weight) were analyzed from each site, and other portions were weighed and saved for dry weight comparison. The percentage of mercury recovered from fortified samples was most frequently between 83-95% with no values below 80% but some values about 100%. The mean coefficient of variation was less than 10%. Data were evaluated using the Student-Newman-Keuls Multiple Range test (computer program) from SOKAL and

RHOLF (1969). Significance level selected was P = 0.05.

RESULTS

Sediments. Variation in sediment mercury levels occurred within and between locations. However, these differences were not clearly significant by the Student-Newman-Keuls Multiple Range test. Mercury samples values combined and compared by lake third established a significant gradient of increasing concentration from inlet to dam (Table 1). The mean ppb levels were: inlet 45, middle 55 and dam 69. The mean level for all sites was 57 ppb and the range was 39-89 ppb on a dry weight basis.

TABLE 1

Average mercury levels in sediment samples where values are combined by lake thirds.

Sediment. Combined location values Location No. [1]	N	Mean Hg ppb [2]	
95 to 113	45	45 Inlet	a
40 to 94	130	55 Middle	b
1 to 39	70	69 Lower	c

Water. Average concentrations of mercury in water samples compared between 12 locations did not show a significant or ordered pattern in mercurial concentrations between sites. However, values by lake thirds indicated that the mean ppb mercury levels of the inlet (0.029) were significantly different from the 0.024 ppb levels of the lower third. Neither of these levels was significantly different from the 0.028 ppb levels of the middle-third of the reservoir (Table 2). The mean ppb mercury level for all locations was 0.027 and the range was 0.019-0.047.

TABLE 2

Average mercury levels in water samples where values are combined by lake thirds.

Water. Combined location values Location No. [1]	N	Mean Hg ppb [2]	
95 to 118	24	0.029 Inlet	a
40 to 94	52	0.028 Middle	ab
1 to 39	40	0.024 Lower	b

1/ Location number refers to grid number (Fig. 1).
2/ Means within a column followed by the same letter are not significantly (P = 0.05) different.

DISCUSSION

The low mercury levels in water suggested that the amount entering the inlet from external sources must be small or rapidly removed by some process. It also suggested that biological transformations of mercury in sediments must also be slow or that mercury which is released must be rapidly removed. Several processes are involved which can affect the chemical equilibria of mercury and thus its mobility in this aquatic system.

The extreme fluctuations in the water level at Elephant Butte reservoir along with associated changes are believed to control availability and turnover of mercury in the reservoir. The major processes are believed to be siltation, adsorption, chemical precipitation, evaporation and factors which control abundance and activity of microorganisms. Some mercury will also be removed from water and sediments by aquatic organisms.

The most likely forms of mercury in bodies of water with chemical characteristics similar to Elephant Butte waters are Hg° and HgS. These are in equilibrium with various solute species, but will change as shifts occur in water characteristics. Various changes will either inhibit or enhance the solubility and turnover of mercury.

The inlet-third of the reservoir with its high silt load does not allow the sediment to become stable. It is also low in organic material and the instability inhibits the establishement of large populations of microorganisms and benthic fauna which contribute to mercury turnover. JERNELOW (1970) indicated that the upper few centimeters of sediment are responsible for almost the entire amount of methyl mercury released into the water by microorganisms.

Low organic matter contained by inlet sediments may partially account for its low mercury concentration compared to the higher levels found in the more stable sediments at the lower third of the reservoir. The mercury gradient of increasing concentration from inlet to dam is believed to be due mainly to progressive sediment stability and associated factors. The higher mercury levels in water from the inlet third of the reservoir might be partially accounted for by adsorption. Since water samples were unfiltered when acidified in the field, mercury from these particles would yield higher levels in water analyzed. Various chemical species of mercury are readily adsorbed by suspended particulate matter and dissolved solids (WERSHAW 1970, JENNE 1970), and others.

Organic debris washed into the reservoir is transported toward the lower-third of the reservoir and eventually settles to the bottom. This may partially account for higher mercury levels in these sediments and may also partially account for lower mercury levels in the upper water layers in the lower-third of the reservoir. Lower levels here may also be due to greater water volume which dilutes whatever mercury is released from sediments. STANDIFORD (1973) demonstrated that floating, water transported organic material taken from Lake Powell waters displayed greater mercury concentrations than the same plant material growing near the lake. He further demonstrated that recently submerged plant material contained greater mercury levels than non submerged plants of the same species. GARCIA (1973) also showed higher mercury levels in water transported plant debris taken from Elephant Butte Reservoir. Both investigations indicate that mercurials are adsorbed by organic materials. This phenomenon has also been reported by several other investigators.

During periods of extreme drawdown much of the inlet-third of the reservoir dries up and other areas remain as bog flats isolated from the main river channel. Because of the hot summer days mercurials may evaporate from dry areas. Furthermore the strong anerobic reducing conditions in boggy areas may allow more mercury to exist dissolved in water in its elemental state or other volatile form. These may evaporate directly from the waters surface. Such phenomena are described by HEM (1970) and JENNE (1970).

Elephant Butte reservoir receives water from intermittent sulfur springs common to this region, (Truth or Consequences was formerly called Hot Springs). Mercury in water containing sulfur forms the insoluble precipitate HgS under mildly reducing conditions which exist in lake sediments. This compound remains relatively immobile in the sediments, HEM (1970). When chemical, physical and biological conditions permit it, mercury will be released via biotransformation processes. Some forms will be more readily removed by aquatic organisms at all trophic levels. Significant amounts of various mercurials can be removed via this route.

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