Literature Review
Chemical and Physical Analyses of the Salton Sea, California

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In light of recent interest in the area, there is a surprising paucity of published historical water quality data on the Salton Sea. I examined available references from the Salton Sea Database Program (University of Redlands, 1998) and web site, as well as some additional reports provided during a literature search performed by the Bureau of Reclamation Library in Denver. Information from the available reports is summarized below.

Major Ions

The earliest water quality data on the Salton Sea was presented in reports by MacDougal (1907) and Ross (1915). MacDougal compared the major ion composition of the Salton Sea in 1907 to normal sea water. Ross presented data on cations and anions, as well as total and dissolved solids information, collected in May or June each year from 1907 to 1914.

Arnal (1961) reported results collected along several transects in the Salton Sea from November 1953 to January 1955. Arnal compared data from 1907 (McDougal, 1907), 1913 (Ross, 1915), 1929 (Coleman, 1929) and 1955 (Arnal, 1961) to examine changes in composition over time and to determine salt budgets for the Sea, but indicated that the data presented by Coleman was not very accurate. Arnal also presented data on turbidity and Secchi depth (0.10-3.05 m during the study), as well as data on currents, sediments and microorganisms.

Carpelan (1958; 1961) summarized some historical data on the major ion (Ca, Mg, Na, K, $CO_3^{=}$, HCO_3^{-}, $SO_4^{=}$, and Cl^{-}) composition of the Salton Sea and provided detailed information on temperature, dissolved oxygen and nutrients (ammonia, nitrate and phosphate) for the period July/August 1954 to June/July 1956. Profiles for temperature, dissolved oxygen and pH were presented, as well as data on chlorinity and sulfide.

Hely et al. (1966) also summarized historical chemical analyses of Salton Sea water. Data from a variety of sources provided major ion analyses (Ca, Mg, Na, K, HCO_3^{-}, $SO_4^{=}$, and Cl^{-}) for the years 1907-1916, 1923, 1929 and 1945-1964. In addition, Hely et al. calculated salinity for each year in which data was available, as well as water volume (millions of acre-ft) and mineral content (millions of tons) in the Sea.

Setmire et al. (1990) presented major ion concentrations from the Salton Sea area as part of a larger, comprehensive study. The results reported included specific conductance, pH, temperature, Ca, Mg, Na, K, alkalinity, sulfate, chloride, fluoride, silica, dissolved solids and from 9 tile drains, the Alamo and New River outlets and a composite from the Salton Sea. Single samples were collected at each location from August 12-14, 1986.

Nutrients

Carpelan (1958; 1961) also measured nitrate-N, ammonia-N and phosphate-P concentrations in surface and bottom samples at four locations in the Salton Sea in 1954-1955, although he indicated the nitrate concentrations were of questionable value. Average reported concentrations for the four stations ranged from 5.35-12.3 ☞g-at./L for ammonia-N, 0.78-7.63 ☞g-at./L for nitrate-N and 0.47-1.1 ☞g-at./L for phosphate-P. In all cases, lower concentrations were from mid-Sea stations and the highest concentrations were from a site off Mullet Island affected by the inflow from the Alamo River. Bottom water ammonia-N concentrations were significantly higher than surface concentrations, which is indicative of a high amount of internal loadings. Phosphate concentrations were also higher in the bottom waters.

The Federal Water Quality Administration (FWQA, 1970) presented information on nutrients in Sea inflows, water and sediment from both the FWQA and the California Department of Water Resources. The report covered the period 1963-1969 and also calculated nutrient loading. While no information was provided on the analytical methods used, the data were considered good because of the agencies participating in the study. Additional information on fish, invertebrates and phytoplankton as also presented. The report characterized the Sea as "objectionably eutrophic". High algal growth led to dissolved oxygen supersaturation in surface waters and oxygen depletion at the bottom of the water column. Algal growth studies conducted as part of the study indicated nutrients were generally not limiting algal growth, with only one sample showing evidence of phosphorus limitation.

Irwin (1971) reported nutrient concentrations at several stations in the New and Alamo Rivers and the All American and East Highline Canals, including stations at Westmorland, CA for the New River and Niland, CA for the Alamo River near the Salton Sea for 1969-1970. Nitrogen and phosphorus concentrations were high in both rivers and lower in the canals. Specific conductance and dissolved solids concentrations were also reported for these stations.

Metals

There is detailed information on selenium, and to a lesser extent boron, in the Salton Sea area from the USGS (Setmire et al., 1990; Setmire et al., 1993; Setmire and Schroeder, 1998), but there is a lack of routine monitoring data. Setmire et al. (1990) analyzed trace elements (As, Ba, B, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Ag, V, Zn) from 9 drains, the Alamo and New River outlets and a composite from the Salton Sea on August 12-14, 1986. Detailed analyses of Se and B in water, sediment and biota samples were presented by Setmire et al (1990) and Setmire et al., 1993). The 1993 report contained data collected from 1988-1990. A more detailed analysis of Se results, including data from 1994-1995, was presented by Setmire and Schroeder (1998).

Pesticides

Irwin (1971) also reported results of pesticide analyses for selected tributaries to the Salton Sea collected from August 1969 to June 1970. All analyses were performed by the USGS laboratory in Sacramento. DDT and its metabolites and dieldrin were found in all samples at the stations from the New (Westmorland, CA) and Alamo (Niland, CA) Rivers closest to the Salton Sea at concentrations up to 11 ☞g/L for the individual metabolites, while dieldrin was found concentrations of 0.01-0.03 ☞g/L at both stations. Methyl parathion, 2,4-D and Silvex

were also found in nearly all samples from the two stations. Maximum observed concentrations were 0.03, 0.65, 19 and 1.7 ☞g/L in the Alamo River and 0.19, 1.6, and 0.84 ☞g/L in the New River for methyl parathion, 2,4-D and Silvex, respectively. Endrin, lindane, parathion and 2,4,5-T were detected in some samples at both locations, while aldrin, heptachlor and heptachlor epoxide were not found in any of the samples.

Hogg (1973) examined chlorinated hydrocarbon pesticides in water sediment and tissue samples from the Salton Sea in 1970-1971. Data was produced with accepted methods. Hogg found DDT and its metabolites in 146 of the 159 samples examined, and dieldrin and its metabolites in 66 of the 159 samples. Total DDT in the water samples was found at a level of 0.006 mg/L while dieldrin was not detected. In general, pesticide residue concentrations were higher in samples collected from the southern part of the Sea.

Results of organochlorine pesticide analyses were presented by Setmire et al. (1990; 1993). Those studies included results from sediment and biota samples, but did not measure pesticides in Salton Sea water. Although the use of DDT was banned in the U.S. in 1972 and in Mexico in 1983, its metabolites were still detected in most samples analyzed by Setmire et al. (1993).

Other Results

Most other reports examined (e.g., Kim, 1973; USDI/RAC, 1974; Colorado River Board of California, 1992) contained general information, but no original data. Recent work at the University of California-Davis (Cook and Orlob, 1997; Cook et al., 1998) collected detailed temperature and conductivity data for their hydrodynamic modeling efforts on the Salton Sea, but little information on additional water quality variables.

In addition to the published reports listed above, Richard Thiery (personal communication, February 24, 1999) indicated that there is a wide variety of unpublished water quality data on the Salton Sea. These data were collected by different agencies at differing levels of quality. Some of the sources of this unpublished information are listed in Table 1.

Table 1 - Sources of Unpublished Water Quality Data on the Salton Sea

Source	Typical Analyses Performed	Collection Information
Coachella Valley Water District	Major ions, some heavy metals	1960's to present
Imperial Irrigation District	Major ions	Collected May and December at five shoreline stations
Regional Water Quality Control Board	Nutrients and BOD	Center of Sea from about 1980-1990
California Department of Fish and Game	Primarily TDS	Center of Sea
San Diego State University	Nutrients, temperature and D.O. profiles, plankton	Several stations throughout the Sea

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