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Atmospheric Environment 39 (2005) 4671–4679
ATMOSPHERIC ENVIRONMENT
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# Atmospheric dry deposition in the vicinity of the Salton Sea, California—I: Air pollution and deposition in a desert environment

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Received 15 October 2004; received in revised form 29 March 2005; accepted 12 April 2005

**Abstract**

Air pollutant concentrations and atmospheric dry deposition were monitored seasonally at the Salton Sea, southern California. Measurements of ozone ($O_3$), nitric acid vapor ($HNO_3$), ammonia ($NH_3$), nitric oxide (NO), nitrogen dioxide ($NO_2$) and sulfur dioxide ($SO_2$) were performed using passive samplers. Deposition rates of $NO_3^-$, $NH_4^+$, $Cl^-$, $SO_4^{2-}$, $Na^+$, $K^+$ and $Ca^{2+}$ to creosote bush branches and nylon filters as surrogate surfaces were determined for one-week long exposure periods. Maximum $O_3$ values were recorded in spring with 24-h average values of 108.8 $\mu g\,m^{-3}$. Concentrations of NO and $NO_2$ were low and within ranges of the non-urban areas in California (0.4–5.6 and 3.3–16.2 $\mu g\,m^{-3}$ ranges, respectively). Concentrations of $HNO_3$ (2.0–6.7 $\mu g\,m^{-3}$) and $NH_3$ (6.4–15.7 $\mu g\,m^{-3}$) were elevated and above the levels typical for remote locations in California. Deposition rates of $Cl^-$, $SO_4^{2-}$, $Na^+$, $K^+$ and $Ca^{2+}$ were related to the influence of sea spray or to suspended soil particles, and no strong enrichments caused by ions originated by human activities were detected. Dry deposition rates of $NO_3^-$ and $NH_4^+$ were similar to values registered in areas where symptoms of nitrogen saturation and changes in species composition have been described. Deposition of nitrogenous compounds might be contributing to eutrophication processes at the Salton Sea.


*Keywords:* Ozone; Nitrogenous pollutants; Major ions; Surrogate surfaces; Arid ecosystems

## 1. Introduction

Terrestrial systems have many allochthonous inputs, not the least of which are nutrients and toxicants from large bodies of water nearby and from the atmosphere. Salt from the ocean is one important input that has major consequences on terrestrial biota. The Salton Sea is a large shallow saline lake located in the desert area of Riverside and Imperial counties in southern California (Fig. 1). The Sea has no natural outlet and fluctuates in size and depth depending on the balance between inflowing water and evaporation. Agricultural drainage flows from surrounding watersheds of Imperial, Coachella and Mexicali valleys are the main inflows for the Salton Sea, representing the primary source of nutrients delivered to the sea. Because the Salton Sea is a closed-basin lake in an arid environment, it accumulates salts

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doi:10.1016/j.atmosenv.2005.04.016

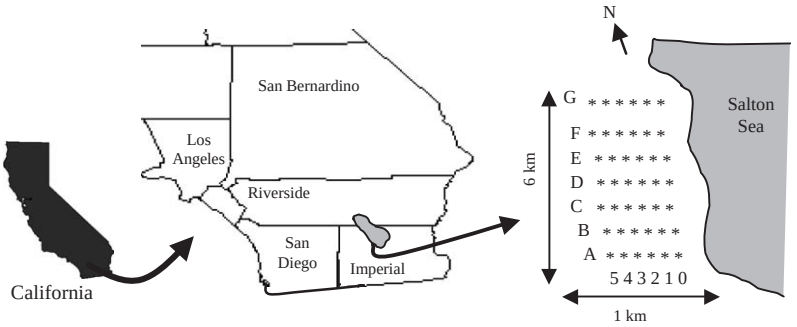


Fig. 1. Location of the study area in the Salton Sea basin and surrounding area.

and high levels of nutrients. The Sea is eutrophic and that richness in nutrients supports a rich and abundant life. The Salton Sea, the largest inland body of water west of the Rocky Mountains, has become a critical wintering and staging area for migratory birds on the Pacific flyway. However, the Salton Sea faces difficult challenges to sustain the health of the ecosystem mainly due to rising salinity and nutrient levels (Kaiser, 1999; Schroeder et al., 2002). Algae bloom and subsequent by-products of decomposition have caused large fish kills and bird die-offs (Kaiser, 1999).

The adjoining South Coast Air Basin (Los Angeles Basin) in southern California has been considered one of the most heavily polluted areas in the world, especially for ozone ($O_3$). Riverside and Imperial counties experienced violations of the 8- and 1-h ozone standards during the period 2000–2002 (US EPA). In recent years, it has become evident that nitrogen (N) deposition in terrestrial ecosystems located downwind of the Los Angeles area is among the highest in North America (Fenn et al., 1998). Atmospheric dry deposition can be an important source of nutrients causing changes in natural ecosystems (Bytnerowicz and Fenn, 1996; Goulding et al., 1998; Fenn et al., 1998). Nitrogen dry deposition alone may account for as much as 95% of the total terrestrial N load in the Mediterranean ecosystems of the western United States (Bytnerowicz and Fenn, 1996). Atmospheric N compounds, when occurring at high concentrations, can induce phytotoxic effects causing reductions in the growth of some plants (Bytnerowicz et al., 1998). Very little is known about the dynamics of arid terrestrial ecosystems and the influence of air pollutants and dry deposition on desert vegetation.

Besides the ecological importance of the Salton Sea, agricultural valleys surrounding the lake are among the most productive agricultural areas in the world. Deterioration of air quality, combined with high rates of dry deposition in the Salton Sea area, besides posing a threat for the increasing population, might have important ecological and economical consequences. Our study was to identify the airborne inputs to the terrestrial ecosystem in the immediate vicinity of the Salton Sea. The study was part of the US Geological Survey (USGS) project "Effects of particulate deposition on plant and animal communities at the Salton Sea, California" designed to evaluate the environmental impact of an Enhanced Evaporation System as a method for controlling salinity, and to gain understanding of the dynamics of the arid terrestrial ecosystems immediately neighboring the Sea. The objectives of our study were to measure air pollutant concentrations and dry deposition rates of airborne ions relative to distance to the Sea, with special attention paid to those compounds that might be contributing nutrients to the terrestrial ecosystems.

## 2. Material and methods

### 2.1. Study site

The study was conducted within the boundaries of the US Navy's former Salton Sea Test Base near the southwestern corner of the Salton Sea, California (Fig. 1). Desert vegetation around the Salton Sea is relatively sparse, with average cover of 18.7% ($\pm$2.83; unpublished data). Creosote bush (*Larrea tridentata* [Sessé & Moc. ex DC.] Coville) is the dominant plant species on the study site. A sampling grid was established with seven transects running perpendicular to the Sea shore and six running parallel to it covering a $1 \times 6$ km area. Transects parallel to the shoreline were placed at approximately 2 m from the water (labeled site No. 0), at about 20 m from the water's edge (site No. 1) and further west at 250 m intervals (sites No. 2–5). Six of the perpendicular transects or lines were placed at 800 m intervals from south to north (named A–F lines). A seventh line (G) was placed approximately 2 km north of the others. The sampling grid surrounded a pilot Enhanced Evaporation System described elsewhere (Alonso et al., this issue). Air pollutant concentrations and dry deposition rates were sampled seasonally during