Dissolved oxygen in the Dead Sea—
seasonal changes during the holomictic stage

Michal Shatkay¹,², David A. Anati¹,³ and Joel R. Gat¹

¹Department of Environmental Sciences and Energy Research, Weizmann Institute of Science, 76100 Rehovot, Israel.
²Now at Center for Research in Particle Physics, Carleton University, Ottawa, Ontario K1S 5B6, Canada.
³Now at the Institute of Earth Sciences, the Hebrew University of Jerusalem, Givat Ram, Jerusalem, Israel.

Key Words: Dead Sea, dissolved oxygen, gas exchange

Abstract

Measurements of dissolved oxygen, density and temperature were conducted in the Dead Sea between August 1987 and December 1989. Oxygen concentrations were found to vary around an average value of 0.8 mlSTP (standard temperature and pressure) per kg. Dissolved oxygen variations were found to reflect both physical processes (a deepening of the epilimnion, a turnover etc.) and chemical processes (oxidation–reduction). Transport coefficients for the oxygen exchange across the air/sea interface were found to be generally low compared to expected values based on laboratory experiments; the presence of surface films which inhibit the gas exchange rates under calm weather conditions is suspected. During stormy weather, the exchange rates were considerably higher, suggesting that the entrainment of bubbles was involved in the gas exchange process.

Introduction

The Dead Sea, the terminal lake of the Jordan river system, is situated in the Jordan Rift valley. It covers the deepest continental depression in the world, its water-level being more than 400 m below sea-level, and the deepest bottom point in its basin being at −728 m below sea-level.
The salt content is very high, reaching values above 270 g kg\(^{-1}\), with a typical density of about 1.235 g cm\(^{-3}\). Beginning in the early sixties, increasing amounts of fresh water which used to flow into the Dead Sea have been diverted from the Jordan river. Since the Jordan river constitutes the main water source of the Dead Sea, these diversions resulted in a sharp lowering of the Dead Sea surface level (continuing a trend already established since about 1930) making the water in the upper layer of the lake saltier, and therefore denser, than before. In 1979, following a few hundred years of stable stratification, a historic overturn of its water masses took place (Steinhorn et al., 1979). This overturn was followed by a second, short meromictic phase of a four year duration, terminating in 1982 (Anati et al., 1987), and then by a holomictic phase (Anati and Stiller, 1991) which ended in late 1991, when a very rainy season re-established a meromictic state.

The Dead Sea water column during the holomictic phase consisted of an upper layer (epilimnion) of 20–40 m depth and a lower layer (hylolimnion) extending down to the bottom of the lake. Since 1982, these two layers have been observed to mix once a year in the winter season, when winter cooling and the increase in salinity due to the cumulative effect of the previous summer evaporation upset the stratification. Stratification is re-established during the late winter and spring season due to freshwater inflows and is intensified by the spring/summer warming (Anati et al., 1987).

Dissolved oxygen (DO) in the Dead Sea has been measured on several occasions prior to the period covered in the present work. Neev and Emery (1967) conducted measurements in 1959, and reported a concentration of 1.6 ml L\(^{-1}\) at the surface, 1.0 ml L\(^{-1}\) at a depth of 30 m and an absence of oxygen at depths greater than 40 m. Levy (1980) reported DO profiles in the Dead Sea, measured on five occasions between September 1979 and August 1980, at which time the Dead Sea was in a short meromictic phase. His results show that DO values in the upper water layer were in the range of 0.9–1.9 ml L\(^{-1}\), while values of 0.65–0.75 ml L\(^{-1}\) were measured in the bottom waters.

The unit of ml L\(^{-1}\) can be converted into the conservative unit of mlSTPkg\(^{-1}\), provided the temperature and the salt concentration are known. Among the five oxygen profiles reported by Levy (1980), only two, the March 1980 and May 1980 profiles, are accompanied by independent hydrographic data. The DO values for these two profiles could thus be converted into conservative units (mlSTP kg\(^{-1}\)) and the corresponding saturation curves could be constructed based on the formulas of Weiss and Price (1989). The results are given in Fig. 1. It is apparent that these profiles indicate a pronounced oxygen stratification. Surface values are