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# Wet and dry deposition of formaldehyde in Izmir, Turkey

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**Abstract**

Samples were collected between May 2003 and May 2004 in Izmir, Turkey to measure dry and wet deposition of formaldehyde (HCHO).

Particle-phase HCHO fluxes measured with dry deposition plates ranged between 2 and 56 μg $m^{-2}$ $day^{-1}$ (average ± SD, 17 ± 12 μg $m^{-2}$ $day^{-1}$). Particulate phase dry deposition velocities calculated using the particulate fluxes measured and ambient particulate concentrations ranged from 0.1 to 9.6 cm $s^{-1}$ (1.4 ± 1.4 cm $s^{-1}$). The particulate overall dry deposition velocity agreed well with those measured previously for other pollutants using the same method.

Formaldehyde concentration measured in 27 rain samples collected at the sampling site ranged between 10 and 304 μg $l^{-1}$. The annual formaldehyde wet deposition was calculated as 31.4 mg $m^{-2}$ $year^{-1}$. The annual HCHO total deposition (wet + dry) was dominated by wet deposition (83.7%).


*Keywords:* Dry deposition; Wet deposition; Dry deposition velocity; Formaldehyde

## 1. Introduction

Formaldehyde (HCHO) is released into the atmosphere as a result of incomplete combustion of fossil fuels. It is a widely used industrial chemical to manufacture building materials and numerous household products. Vegetation and photochemical reactions are other identified sources of formaldehyde. Therefore, it is present in substantial concentrations in ambient air.

Formaldehyde is a labile compound that is involved in several important processes within the troposphere (Economou and Mihalopoulos, 2002). Following its release or formation, formaldehyde is transported through the atmosphere where it is subject to chemical and physical transformations (Finlayson-Pitts and Pitts, 1986). Removal of formaldehyde from the atmosphere can occur by chemical transformations, rain and snow scavenging of vapors and particles, by dry deposition of particles, and by vapor exchange across the air–water interface.

Atmospheric deposition is a significant source of HCHO to aquatic systems since concentrations in rainwater are expected to be up to three orders of

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magnitude higher than in surface waters (Economou and Mihalopoulos, 2002; Kieber et al., 1999). Despite the potential role of wet deposition of HCHO, only a limited number of studies have addressed its presence and variability in rain. There has been no previous study on HCHO wet deposition in Turkey.

Atmospheric formaldehyde is also found in particle phase (Klippel and Warneck, 1980; Deandrade et al., 1993; Deandrade et al., 1995; Liggio and McLaren, 2003). Therefore, particle-phase dry deposition may also be an important mechanism transferring atmospheric HCHO to the surface waters and terrestrial surfaces. However, there is no generally accepted method to directly measure or estimate dry deposition. The use of various types of surrogate surfaces is one approach that has been used to directly measure dry deposition. Recently, the dry deposition plates have been successfully used to directly measure particle dry deposition of organic and inorganic air pollutants (Odabasi et al., 1999; Shahin et al., 1999; Cakan, 1999; Tasdemir, 1997; Yi et al., 1997).

The objectives of this study were (1) to measure directly particulate dry deposition of HCHO and determine the particulate phase dry deposition velocity and (2) to measure wet deposition of formaldehyde and determine its relative importance in total (dry + wet) deposition.

## 2. Experimental

### 2.1. Sample collection

Eighty-nine concurrent ambient air and dry deposition samples (14 daily, 39 daytime, and 36 nighttime) were collected between May 2003 and April 2004 on a 4-m high sampling platform located on the Kaynaklar campus of the Dokuz Eylul University, Izmir, Turkey. Samples were collected during successive daytime and nighttime (sunrise–sunset) periods. During the sampling program, 4–12 samples were collected each month. Twenty-seven rain samples were also collected manually during the rainy season in Izmir (October 2003–April 2004).

Izmir metropolitan city is the center of a highly industrialized area by the Aegean Sea shoreline of Turkey. Izmir is located in a basin surrounded by mountain series of approximately 1000–1500 m height with only the west end open to the Aegean Sea. The climate is Mediterranean with warm and rainy winters, hot and dry summers. The major air movements over the area are mainly from northerly directions. The city with 2.7 million population has significant economic, industrial, and agricultural activities emitting high quantities of air pollutants. The sampling site is located approximately 10 km southeast of Izmir's center (Fig. 1). The campus is relatively far from any settlement zones or industrial facilities. There are residential areas located approximately 2 km southwest and a highway 0.5 km south of the sampling site. Land cover in the adjacent area is a young coniferous forest.

Meteorological data was obtained from a 10-m high tower located at the sampling site. The tower was equipped with temperature, humidity, pressure and wind direction sensors, a rain gauge, and an anemometer (Davis Instruments, Australia). The monitored parameters were stored in a data logger in 1-min intervals and downloaded to a computer located at the same site.

The following instruments were used during the sampling program:

*Dry deposition plate*. The particle dry deposition flux was measured using a smooth deposition plate ($22 \times 7.5$ cm) with a sharp leading edge, mounted on a wind vane. Glass fiber filter (GFF) sheets mounted with cellulose acetate strips on the plates were used to collect the deposited particles. The dimensions of the GFF sheet's deposition surface were $5.5 \times 12$ cm. Five plates and sheets with a total collection area of 330 $cm^2$ were used for sampling.

*Ambient air sampling train*. Gas-phase atmospheric formaldehyde was collected using a sampling train consisting of a filter holder, two impingers in series, a vacuum pump, a rotameter, and a gas meter. Air was first drawn through a 47 mm glass fiber filter to remove particles and then, through two impingers connected in series. Gaseous HCHO is absorbed in the first and second impingers containing 75 and 50 ml deionized water, respectively. Then, air flowed through a rotameter and a dry gas meter used for flow rate and sampling volume monitoring.

*Particulate formaldehyde*. Particulate formaldehyde was collected on glass fiber filters using a high-volume sampler, Model GPS-11 (Thermo-Andersen Inc.). Particles were collected on 10.5-cm diameter quartz filters.