Draft

An Overview of Aerial Deposition As A Priority Source Impacting Surface Water Quality

Prepared by Project Clean Water Science and Technology Technical Advisory Committee

Background

Atmospheric deposition has long been recognized as a potentially significant non-point source of contaminants and nutrients to water bodies (Baker 1997). Numerous studies of the effects of aerial deposition of acidic substances (mainly oxides of nitrogen and sulfur) on the health of sensitive aquatic ecosystems have been conducted worldwide since the 1970's (Havas, M. and T. C. Hutchinson, 1980). These early studies often focused on the effects of acidic deposition on poorly buffered alpine lake and forest ecosystems in Scandinavia and the eastern United States.

The scope of aerial deposition investigation has expanded in recent years as researchers have identified several pollutants of concern in addition to the traditionally monitored inorganic constituents of concern. The most important of these pollutants are summarized in **Table 1**. Toxic pollutants such as mercury, PAHs, and dioxins are common byproducts of the combustion of organic compounds and fuels. Other pollutants such as pesticides are easily volatilized from contaminated sediments and landfills, while metallic pollutants like lead and cadmium are produced in industrial operations. Each of these substances can be transported substantial distances from their points of origin.

Monitoring Networks and California Initiatives

In 1978 the National Atmospheric Deposition Program/ National Trends Network (NADP/ NTN) monitoring network, a cooperative effort between several government, non-government, academic, and industry entities was established to study wet deposition in the United States. In 1983 there were 9 NADP/ NTN monitoring stations in California. Today there are 11 such stations in the state. Most of these sites are located in rural areas to allow the characterization of background levels of chemical constituents in precipitation.

By the mid-1980's research studies on the extent and effects of aerial deposition were commonplace in California. The California Legislature initiated two comprehensive state-funded monitoring and research programs in 1983 to address concerns over the potential for environmental degradation due to excessive sulfur and nitrogen deposition. The Kapiloff Acid Deposition Program (KADP) and the Atmospheric Acidity Protection Program (AAPP) were created to examine the atmospheric processes associated with acid deposition and its effects on human health, aquatic ecosystems, forest ecosystems, agricultural crops, and man-made materials (California Air Resource Board, 2000).

With the support of the KADP and AAPP, the California Air Resources Board (ARB) created the California Acid Deposition Monitoring Program (CADMP) to measure acidic air pollutants in precipitation, fog, and dry-deposited particles and gases. Several research programs were funded with grants of approximately $25 million over the 11-year period from 1983 – 1993. The major findings of the Kapiloff Acid Deposition Program and Atmospheric Acidity Protection Program are presented in the draft report "Final Assessment of the Atmospheric Acidity Protection Program" (see http://www.arb.ca.gov/research/acid-dep/acid-dep.htm.).

Aerial Deposition Monitoring in San Diego County

To be written…..

Major Research Findings

Research has demonstrated that sulfur-derived acids are the predominant acidic pollutants of concern in the eastern U.S., while nitric acid is the primary concern in the West (California ARB, 2000). Potentially serious environmental problems associated with excessive aerial deposition of nitrogen have been identified in sensitive aquatic and terrestrial ecosystems in California. For

example, the Air Resources Board (2000) reported that due to the aerial deposition of nitrogen, only phosphorus and not a combination of nitrogen and phosphorus limit phytoplankton growth in Lake Tahoe. In addition, *nitrogen saturation*, a condition where excessive nitrogen inputs saturate the retention capacity of a forest ecosystem has been documented in the San Bernardino Mountains of southern California (California ARB, 2000). The potential effects of nitrogen saturation include increased nitrate leaching to ground and surface waters, soil chemistry alteration, and possible forest decline (Aber, 2000).

The relative importance of the wet and dry components of aerial deposition varies substantially with geographic location, prevailing weather patterns, and location relative to pollutant sources. Several studies in California have indicated that on an annual basis, dry deposition of certain pollutants far exceeds wet deposition. For example, the California Air Resources Board (1996) reported that dry deposition rates for oxidized nitrogen species at seven urban sites ranged from approximately 10 to about 35 times wet deposition rates for nitrate. In highly populated and industrialized regions like Southern California, aerial inputs to terrestrial ecosystems may represent a substantial fraction of the total pollutant loading to watersheds. For example, Stolzenbach et. al, 2001, concluded that for some trace metals, atmospheric deposition is the major contributor to the metal loading in runoff in Southern California.

Aerial Deposition and the TMDL Process

The importance of quantifying the aerial deposition of pollutants to watersheds and the eventual loading of these substances to water bodies has become increasingly important as water quality managers struggle to develop and implement Total Maximum Daily Load programs in watersheds that are heavily influenced by atmospheric inputs. Despite technical and regulatory difficulties, atmospheric loadings have been incorporated into a limited number of TMDLs (EPA, 2001). This trend is likely to continue as more TMDLs are developed and implemented.

Several existing or proposed Clean Water Act 303(d)-listed waterbodies in San Diego County may be influenced by aerial inputs. These include 11 waterbodies listed for excessive nutrients or eutrophication, two waterbodies listed for sulfate, four lead listings, and one listing for cadmium (see Section 303(d) Impaired Water Bodies List).

Measuring Atmospheric Deposition

The measurement of atmospheric deposition involves the measurement of wet and dry precipitation. Standard procedures for collecting wet precipitation samples are described in National Atmospheric Deposition Program/ National Trends Network documents (see NADP Sampling Procedures Webpage). They normally involve collecting the sample using a plastic bucket or a funnel connected to a bottle.

Numerous studies have attempted to measure dry deposition to land and water surfaces. Two methods are commonly used; 1) direct measurement using depositional plates or collectors and 2) indirect measurement obtained by multiplying a measured atmospheric concentration by a theoretical deposition velocity (Stolzenbach et. al, 2001).

To be continued…….

References

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Table 1: Common Water Pollutants of Aerial Origin

Pollutant of Concern	Major Pathway(s)	Anthropogenic Sources	Human/ Environ. Effects	Notes
Nitrogen	• Wet and dry precipitation • Gas phase	Combustion, agriculture, feedlots, fertilizer production	Above 10 ppm in drinking water may cause methemoglobinemia, 'blue baby syndrome'. Excess in aquatic systems causes algal blooms, eutrophication	Extreme levels in aquatic systems may cause toxicity.
Mercury	• Dry precipitation • Gas phase	Utility plants (mainly coal-fired), commercial industrial boilers, chlor-alkali industrial plants, waste incineration, gold mining, batteries	Highly toxic, bioaccumulates in fish and biomagnifies in the food chain	Fish consumption is dominant exposure route for humans and fish. Most frequent (68%) cause of fish consumption advisories. One-third of emissions total is from utility plants. Elemental Hg travels great distances, perhaps globally. Methylmercury is most toxic.
Lead	• Dry precipitation	Commercial industrial boilers, smelting, plating, mining, combustion, batteries, solder, ammunition, old paint	Has been linked to the impairment of child mental and physical development	Children in older neighborhoods may be exposed through peeling lead-based paint and contaminated soils.
Cadmium	• Dry precipitation	Commercial industrial boilers, smelting, plating, mining, combustion, pigments, batteries	Liver, kidney, blood, and bone damage. Bioaccumulates in some aquatic species.	Highest amounts of cadmium release from Arizona, Utah, and Montana. Most important industries are copper and zinc smelting.
POMs and PAHs - Polycyclic organic matter - Polynuclear aromatic hydrocarbons	• Dry precipitation • Gas phase	Incomplete combustion of fossil fuels and plant biomass, waste incineration, refractory manufacturing	Human mutagen, probable carcinogen, endocrine disrupter, immune system and possible reproductive effects. Resists breakdown, bioaccumulates and animal carcinogen.	Theoretically, millions of POMs can be formed. However, only a fraction of them have been identified. The PAHs are a subclass of the POMs.
Dioxins and furans	• Dry precipitation • Gas phase	Combustion of chlorine-containing organic material, chlorine bleaching in pulp and paper manufacturing, residential wood burning, waste incineration	Persistent in environment, bioaccumulates, human and animal carcinogen, and other severe non-carcinogenic health effects	Levels appear to be declining however, still a frequent cause of fish consumption advisories nationally. Bioaccumulates in animal fat tissue.
PCBs - Polychlorinated biphenyls	• Wet and dry precipitation • Gas phase	Electrical, heat transfer, and hydraulic equipment, paints, plastics and rubber products	Human carcinogen, and endocrine and immune system disruptor. Bioaccumulate in organisms and biomagnify in the food chain. Persistent in the environment.	U.S. manufacture stopped in 1977. Levels appear to be declining however, still a frequent cause of fish consumption advisories nationally.
Pesticides (Banned or restricted)	• Dry precipitation • Gas phase	Volatilization from contaminated sediments and landfills, long-range transport from other countries	Toxicity to aquatic species, human carcinogen, extremely persistent in the environment	Due to mainly historical contamination by now banned substances. Many of these compounds are still used in the rest of the world but only special uses in U.S. Atmospheric transport of DDT is global.

Table 2: Air Monitoring Networks

Network	Type	Parameters	Agency/ Entity	Date	Nationwide Sites	SD Co. Sites	Notes
National Atmospheric Deposition Program/ National Trends Network (NADP/NTN)	• Wet Deposition	pH, SO_4, NO_3, NH_4, Cl, Ca, Mg, Na, K	Cooperative of numerous federal, state, local, industry, and academic entities	1978 - present	> 200	None currently	11 sites currently monitored in CA. Four sites inactive. Palomar Mt. site monitored from 1983-88. The closest currently monitored site is in Joshua Tree N.M.
National Atmospheric Deposition Program/ Mercury Deposition Network	• Wet Deposition	Total and methyl Hg	Cooperative of numerous federal, state, local, and academic entities	1995 - present	~ 50	None	Sub-network of NADP/NTN. Two sites in CA (San Jose and Mendocino County)
National Atmospheric Deposition Program/ AirMon	• Wet Deposition • Dry Deposition	**Wet** - pH, SO_4, NO_3, NH_4, Cl, Ca, Mg, Na, K **Dry** - SO_2, SO_4, HNO_3, NO_3	NOAA's Air Resources Laboratory	1992 - present	9 (wet) 13 (dry)	None	Sub-network of NADP/NTN. High quality data for data users and modelers. Dry deposition is measured in Sequoia NP. Designed to quantify the extent to which changes in emissions affect air quality and deposition at selected locations
Clean Air Status and Trends Network (CASTNet)	• Dry Deposition	SO_2, SO_4, HNO_3, NO_3, NH_4, O_3	National Park Service	1987 - present	Approximately 80	None	Primary national network for measuring dry acidic deposition. Six sites in CA including Death Valley and Joshua Tree NPs
National Dioxin Air Monitoring Network	• Dry Deposition	Dioxins, furans, and PCB	United States EPA	1998 - present	30	None	Measure levels in rural areas of U.S.
California Air Resources Board - sponsored monitoring and research projects	• Wet Deposition • Dry Deposition • Air Quality Monitoring	Various parameters depending on research	California Air Resources Board	1967 - present	-	Various	Numerous research projects completed and ongoing
San Diego Air Pollution Control District (APCD)	• Air Quality Monitoring	O_3, NO, NO_2, Total HCs, CH_4, CO, SO_2, PM10. PM2.5	San Diego County	1974 - present	-	11	Monitor ambient air pollutant concentrations at eleven sites in SD County.
National-Scale Air Toxics Monitoring Assessment	• Toxic Pollutant Emissions Inventory	34 toxic compounds	United States EPA Office of Air Quality and Planning Standards	1998 - present	Many	Unknown	Comprehensive modeling project. Designed as a periodic assessment. First to be completed 2001 on 1996 data. Second assessment will use 1999 emissions inventory.