

# Problems of Measurement in the Environmental Field

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## ENVIRONMENTAL INSTRUMENTATION 1972

The desire for improved environmental quality is continuing to be a nation wide goal. This year it was a key issue in many elections. The U.S. Congress has passed far reaching legislation in the Clean Air Act of 1970 and the 1972 Amendments to the Federal Water Pollution Control Act. California has been actively implementing the Mulford-Carroll Act of 1967 (air) and the Porter-Cologne Act of 1969 (water quality).

Environmental measurements are fundamental in achieving the goals of the legislation. They are used to relate observed effects on health or welfare to exposure, determine level of control needed to protect the public health, determine efficiency of controls installed and determine background levels.

Of interest will be some of the newer aspects of environmental measurements. Instrumentation needs with respect to existing standards will also be considered. Air quality measurement will be of chief concern.

## MONITORING NETWORKS

Monitoring networks in air quality control activities have been used for problem diagnosis, problem definition and problem solution. Table 1 outlines these applications.

The effective network must be tailored to the agencies need for data. If monitoring equipment is justified, one asks: what pollutants must be monitored?, where is the best location for monitoring?, how often and over what averaging time are measurements made?, what is the acceptable delay in reporting data and the treatment of raw data?

## TABLE 1 ROLE OF AIR MONITORING IN AIR QUALITY CONTROL ACTIVITIES (1)

### PROBLEM DIAGNOSIS

1. Identification of Contaminants
2. Discovery of Contaminant Effects
3. Declaration of the Air Quality Crisis

### PROBLEM DEFINITION

1. Assembly and Documentation of Data
2. Definition of Critical Levels and Ranges
3. Setting of Air Quality Standards
4. Formulation of Requirements for Warnings and Alerts

### PROBLEM SOLUTION

1. Development of Instrumentation
2. Development of Modeling Techniques
3. Formulation of Implementation Plans
  - (a) For control of existing sources
  - (b) For the issuance of timely alerts
  - (c) For regulating future land use
4. Affirmative Action
5. Quality Control

## AMBIENT MEASUREMENTS

Methods of sampling in the 20's-30's were static and wet chemical. Automation of these wet chemical techniques followed as the need arose for continuous monitoring. There was much dissatisfaction with the performance of much of this equipment. (Performance is measured in terms of range, drift, noise, sensitivity, interferences, precision and response time.) As new

instrumental concepts in air pollution monitoring showed potential of providing reliable results, field testing was required. This type of work has been done by EPA and the Air and Industrial Hygiene Lab — California State Department of Public Health. Some representative results appear in Table 2.

On the basis of data now available National Air Quality Standards (APPENDIX A) have been set and are scheduled to be met by mid-1976. In addition, Significant Harm Levels have been defined which are 'never to be reached' (APPENDIX B). In addition to the gases mentioned previously, Table 3 lists other pollutants being monitored by EPA.

TABLE 2  
AMBIENT MONITORING METHODS (2)

POLLUTANT	METHOD	COST RANGE (3)
NO <sub>2</sub>	Coulometric	2500-7000
	Chemiluminescent	3500-7500
	Colorimetric (Saltzman)	2000-5000
NO	Chemiluminescent	
SO <sub>2</sub>	Flame photometric	2500-7000
	GC-flame photometric	
	Coulometric	
O <sub>3</sub>	Chemiluminescent	3000-4500
	Coulometric	2500-7000
	Colorimetric	1000-7000
CO	GC-FID	2500-5000
	NDIR	
Total Hydrocarbons	GC-FID FID	2000-5000
Nonmethane Hydrocarbons	GC-FID	

TABLE 3  
Ambient Pollutants Monitored by EPA  
TOTAL SUSPENDED PARTICULATE MATTER (3)

INORGANICS — as total element or radical				
Antimony	Boron*	Iron	Selenium*	Ammonium
Arsenic	Cadmium	Lead	Tin	Fluoride
Barium*	Chromium	Manganese	Titanium	Nitrate
Beryllium	Cobalt	Molybdenum	Vanadium	Sulfate
Bismuth	Copper	Nickel	Zinc	
ORGANICS				
	Benzene — soluble		Benanthrone	
	Benzo (a) pyrene			
MISCELLANEOUS				
Asbestos*		Pesticides* (solids and vapors)		
β radioactivity		Mercury* (solid, vapor, organic)		
Aeroallergens*		suspended particulate size distribution*		

\* Method development, evaluation, and pilot program

A National Aerometric Data Information Service has been established to accelerate, expand and coordinate collection and dissemination of data throughout the nation.

The measurement of exposure in epidemiological studies has left something to be desired. Many studies involve single sampling stations in a city over relatively short periods of time. Including population density and biological response in sampling is important. EPA and local health agencies are currently conducting a study using indicators shown in Table 4.

An overview of new techniques of measurement of air pollution discussed in the literature between 1969 and 1970 has been published by Mueller.<sup>6</sup>

#### STATIONARY SOURCES

The Clean Air Act authorized establishing new source performance standards (APPENDIX C). These are emission standards for certain types of stationary sources based on the best system of reduction presently available.

Instrumentation used in monitoring is subject to a much wider range of environmental conditions than is met in the ambient. Different measurement approaches for stationary sources are represented in Figure 1.

Instrument development can be visualized as progressing through four steps:<sup>7</sup>

1. Conception of a technique and a feasibility study
2. Development of a research prototype and evaluation
3. Development of a field prototype and evaluation
4. Development of a production model and evaluation

It is useful to use this classification and review the status of development of instrumentation for gases and particulates from stationary sources. (Tables 5 and 6)

For methods, sensitivity, interferences, accuracy and procedures see Reference 5.

TABLE 5  
STATUS OF INSTRUMENT DEVELOPMENT FOR GASES<sup>7</sup>

MANUAL METHODS

TECHNIQUES	STATUS	REMARKS
Probe and Impinger Sampling	C	Multi-gas excluding HC, CO
Solid Sorbant	R	EPA sponsored — SO <sub>2</sub> , NO <sub>x</sub>

EXTRACTIVE METHODS

Probe sampling—mech. dilution	P	EPA development
—diffusion	C,R	EPA development
NDIR (Gas filters)	C,R	CO, HC, SO <sub>2</sub> , NO
(Optical filters)	C	requires interface; CO, HC, SO <sub>2</sub> , NO
UV spectroscopy	C	NO <sub>2</sub> , SO <sub>2</sub>
Coulometric Titration	C	unsat. HC sulfur compounds
Conductimetric	C	SO <sub>2</sub> , SO <sub>3</sub>
Electromechanical	C	NO <sub>x</sub> , SO <sub>2</sub>
Thermal Conductivity	C	nonspecific
Colorimetric	C	SO <sub>2</sub> , NO <sub>2</sub>
Flame Photometric	C	requires interface sulfur compounds
Flame Ionization	C	HC only
2nd Derivative Spectroscopy	P	requires interface; NO <sub>2</sub> , SO <sub>2</sub>
Chemi-Luminescence	P	requires interface; NO, NO <sub>2</sub> , SO <sub>2</sub>
Faraday Rotation Spectroscopy	R	requires interface; NO, SO <sub>2</sub> , Hg
Mass Spectroscopy	R	requires interface; multi-gas

IN-SITU MONITORS

UV Correlation Spectroscopy	C	NO <sub>2</sub> , SO <sub>2</sub>
IR & UV Dispersive Spectroscopy	C	NO, CO, SO <sub>2</sub>
IR Laser Coincidence Spectros.	R	SO <sub>2</sub> , NO

REMOTE SENSORS

UV Correlation Spectroscopy	C	NO <sub>2</sub> , SO <sub>2</sub>
Raman Scattering (Vibrational)	R	NO, SO <sub>2</sub>
Raman Scattering (Rotation)	R	NO, SO <sub>2</sub>
IR Emission Spectroscopy	R	multi-gas
Fluorescence & Resonance Raman Scattering	F	NO
IR Laser Heterodyne	F	SO <sub>2</sub>

LONG-PATH SENSORS

UV Correlation Spectroscopy	C	NO <sub>2</sub> , SO <sub>2</sub>
NDIR (Gas chopper)	P	CO
IR Absorption Spectroscopy	R	multi-gas
Laser Coincidence	R	multi-gas
Raman Scattering	R	multi-gas

TABLE 6  
STATUS OF INSTRUMENT DEVELOPMENT FOR PARTICULATES<sup>7</sup>

MANUAL METHODS

TECHNIQUES	STATUS	REMARKS
Probe, Filter & Impinger Sampling	C	mass conc., chem. composition
Impactor Sampling	C	size dist.; chem. composition
Cyclone Sampling	P	size dist.; chem. composition

EXTRACTIVE MONITORS

Beta gauge	C,R	requires interface; mass conc.
Piezo-Electric	C,R	requires interface; mass conc.
Optical	C	visible emissions
Inertial Sampling & Beta gauge	R	requires interface; size dist.
Stimulated Emission spectros.	R	requires interface; chem. comp.

IN-SITU MONITORS

Impact momentum	R	mass conc.
Optical	C,R	visible emissions
Laser Doppler	F	size distr.
Raman Scatter	F	chem. composition

REMOTE SENSORS

Comparative opacity guide	C	visible emissions
Lidar (pulsed)	C,R	visible emissions; size distr.
Lidar (CW)	F	visible emissions

LONG-PATH SENSORS

Optical	C	visible emissions
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C denotes commercial product  
P denotes prototype development  
R denotes research development  
F denotes feasibility study

**TABLE 4**  
**COMMUNITY HEALTH AND ENVIRONMENTAL**  
**SURVEILLANCE STUDIES (CHESS)**

HEALTH INDICATORS	ENVIRONMENTAL MONITORING
<i>Acute Responses</i> —Asthma Chronic respiratory disease Cardiac Episode Daily mortality	<i>Particulates</i> — Total Respirable Sulfates & Nitrates Trace substances  <i>Gases</i> — 24 hour SO <sub>2</sub> , continuous SO <sub>2</sub> , NO, NO <sub>2</sub> , HC, O <sub>3</sub>
<i>Chronic Responses</i> —Pollutant burdens Acute respiratory disease incidence Lower respiratory disease frequency Chronic respiratory disease prevalence	UNDER DEVELOPMENT  <i>Climate</i> — Temperature, humidity, wind  <i>Trace Sub</i> — Food, water, house dust, rodents

**MOBILE SOURCES<sup>8</sup>**

Both EPA and California's Air Resources Board have set emission standards for new automobiles (APPENDIX D). A basic tool used at present in the process of measuring exhaust emissions is the chassis dynamometer. The sample is collected by a constant volume sampling (CVS) technique as published in the Federal Register, November 10, 1970. The entire sample is diluted and collected in a small plastic bag while the vehicle is operating on a prescribed cycle. Analysis is made using a flame ionization detector for hydrocarbon analysis, non-dispersive infrared analysis for CO and chemiluminescent analysis for oxides of nitrogen. Previously non-dispersive infrared analysis were made for all these gases.

Short cycles are being explored for vehicle testing, such as the New Jersey ACID test and IDLE test.<sup>9</sup>

**N.J. ACID Test:** 7 min cycle, exhaust collected in constant volume, sampler-flow 100 cfm, subsample is collected in bag or analyzed continuously using: NDIR for CO and flame ionization for hydrocarbons (HC)<sub>1</sub>

**IDLE Test-Standard:**  
 400 ppm (as hexane) HC  
 4% CO  
 300 ppm NO<sub>x</sub>

**FURTHER APPLICATIONS**

The average person spends about 80% of his time indoors, and those who are most susceptible to the health effects of pollution, the elderly and chronically ill, spend an even higher percentage indoors. Measurement of pollution indoors presents problems such as noisy air samplers and high flow rates.<sup>10</sup>

An air monitoring system may also be applied to the land use planning process. Table 7 suggests potential interrelationships.

**TABLE 7**  
**AIR QUALITY INPUT TO THE LAND USE**  
**PLANNING PROCESS<sup>1</sup>**

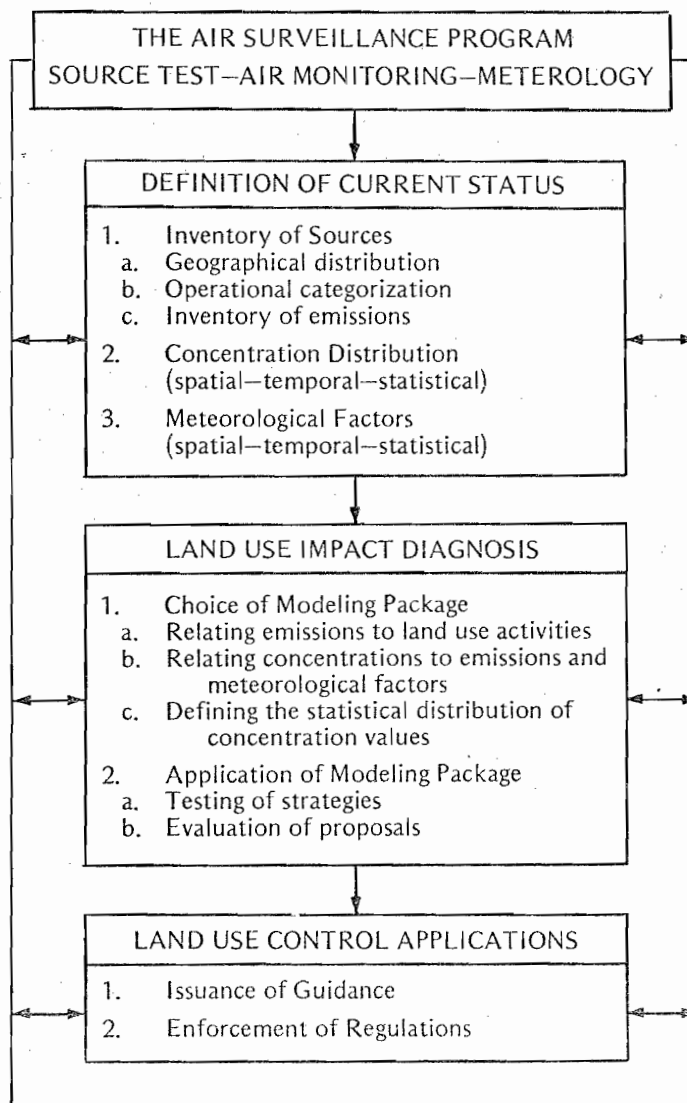
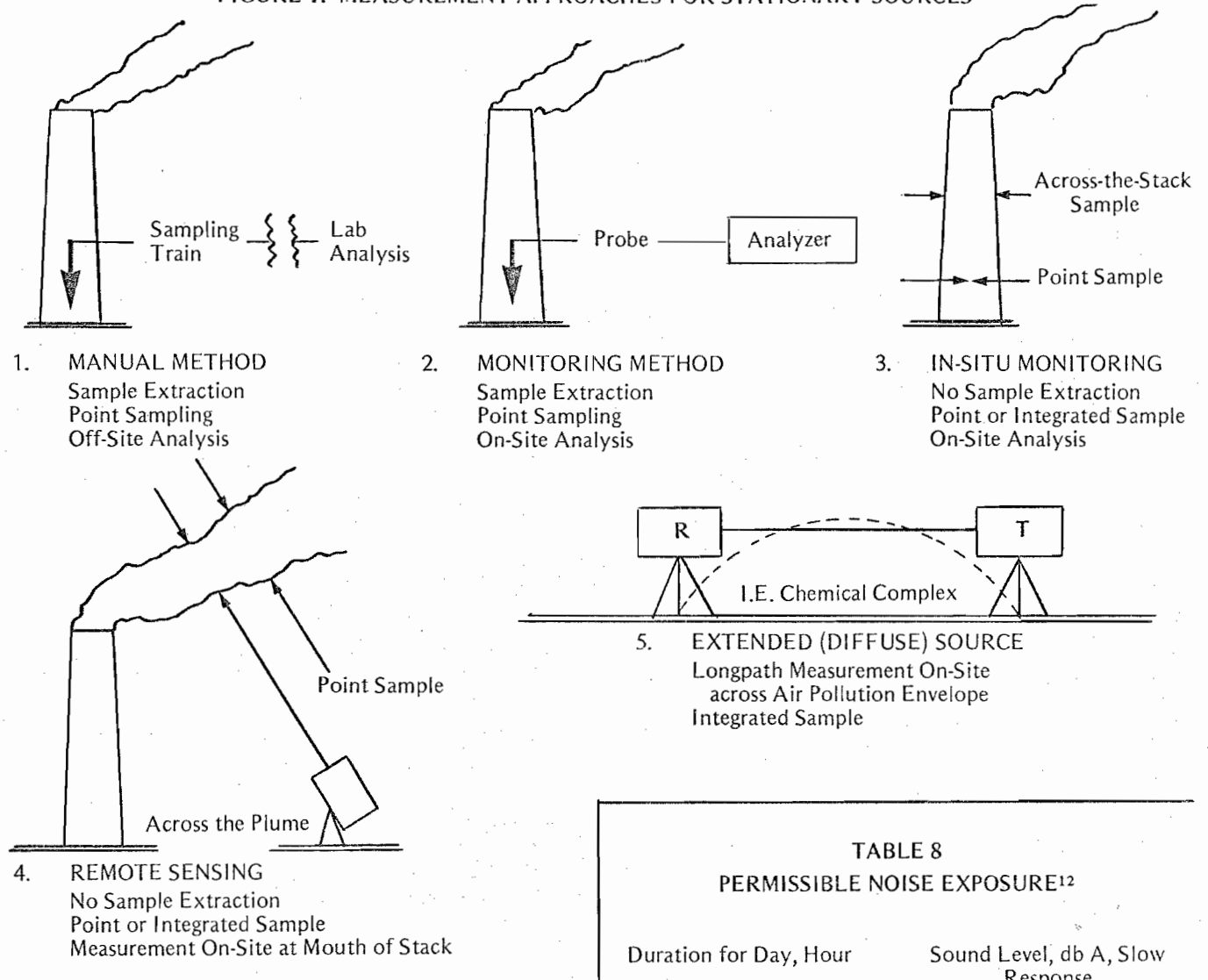


FIGURE 1. MEASUREMENT APPROACHES FOR STATIONARY SOURCES<sup>7</sup>



### WATER QUALITY

At its July 6, 1972 meeting the State Water Resources Control Board adopted the Water Quality Control Plan for Ocean Waters of California. Effluent requirements for waste discharge to the ocean for heavy metals and certain other compounds are specified in APPENDIX E. Complying with these requirements along with others adopted by EPA and California will require extensive instrumentation. Chemical and physical analysis should be performed by the procedures outlined in *Standard Methods for the Examination of Water and Waste Water*, most recent edition. Details for sampling and reporting data are contained in *Guidelines for Technical Reports and Monitoring Programs* published by the California Water Resources Control Board, October 6, 1972. A recent review of the literature applied to water analysis was given by Fishman.<sup>11</sup>

### NOISE

One example of the growing need for noise measurements is the Federal regulations for noise exposure established by the Occupational Health and Safety Act of 1970. Permissible limits obtained with an acceptable sound level meter appear in Table 8.

TABLE 8  
PERMISSIBLE NOISE EXPOSURE<sup>12</sup>

Duration for Day, Hour	Sound Level, db A, Slow Response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

When the daily noise exposure is composed of two or more periods of exposure to different levels of noise, their combined effect should be considered rather than the individual effect of each. If the sum of the fractions,

$$C_1/T_1 + C_2/T_2 + \dots + C_n/T_n$$

exceeds unity, then the mixed exposure should be considered to exceed the limit value. C indicates the total time exposure at a specified noise level and T indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 db peak sound pressure level.

Description of equipment and measurement procedures appear in numerous references.<sup>13,14</sup>

## CONCLUSIONS

Instrumentation is a key to evaluating and managing the environment. It is often extremely difficult with existing equipment to adequately characterize or represent the state of the environment. Problems exist in obtaining reproducible results, being consistent with reference methods, cost of instrumentation, portability of equipment, etc. Competition among instrument manufacturers, continued support of research and development programs initiated, and increased communications among users will help resolve some of these problems.

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## APPENDIX A NATIONAL AMBIENT AIR QUALITY STANDARDS

Pollutant	Standard concn. <sup>1</sup> time	Reference method <sup>2</sup>	Sensitivity <sup>3,4</sup>
SO <sub>2</sub>	.03 ppm (a) .14 ppm (b)	colorimetric	.01 to .4 ppm
particulate	75 µg/m <sup>3</sup> (c) 260 µg/m <sup>3</sup> (b)	gravimetric	1 µg/m <sup>3</sup>
CO	9 ppm (d) 35 ppm (e)	infrared	0-50 ppm ± .5%
photochemical oxidant	.08 ppm (e)	chemiluminescent	.005 - 1 ppm ± 7%
Hydrocarbons (as CH <sub>4</sub> )	.24 ppm (f)	flameionization GC	4 to 3000 ppm
NO <sub>x</sub>	.05 ppm (a)	colorimetric	

- a annual average (arithmetic)  
 b max. 24 hr.  
 c annual geometric mean  
 d max. 8 hr. concn. not to be exceeded once a year

- e Max. 1 hr. concn. not to be exceeded once a year  
 d max. 3 hr. concn. not to be exceeded once a year

### APPENDIX B SIGNIFICANT HARM LEVELS<sup>5</sup>

SO <sub>2</sub>	1 ppm	24 hr
particulate	1000 µg/m <sup>3</sup>	24 hr
SO <sub>2</sub> -particulate	490X10 <sup>3</sup> (µg/m <sup>3</sup> ) <sup>2</sup>	24 hr
CO	50 ppm	8 hr
photochemical oxidant	.4 ppm	2 hr
NO <sub>2</sub>	2 ppm	1 hr

### APPENDIX C NEW PERFORMANCE STANDARDS<sup>6</sup>

New Power Plants	.2 lb particulate/10 <sup>6</sup> Btu 20% opacity limit
Gas	.3 lb NO <sub>x</sub> , .8 lb SO <sub>2</sub> /10 <sup>6</sup> Btu
Oil	.3 lb NO <sub>x</sub> , 1.2 lb SO <sub>2</sub> /10 <sup>6</sup> Btu
Coal	.7 lb NO <sub>x</sub> , 1.2 lb SO <sub>2</sub> /10 <sup>6</sup> Btu
New Incinerators	.1 grain/std. ft <sup>3</sup> , corrected to 12% CO <sub>2</sub>

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**APPENDIX D**  
**NEW VEHICLE STANDARDS - UNDER 6000 Lbs**

YEAR	STANDARD	COLD START TEST	HYDRO-CARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN
Prior to controls			850 ppm (11 gm/mi)	3.4% (80 gm/mi)	1000 ppm (4 gm/mi)
1966-67	State	7-mode	275 ppm	1.5%	no std.
1970	State & Federal	7-mode	2.2 gm/mi	23 gm/mi	no std.
1971	State	7-mode	2.2 gm/mi	23 gm/mi	4 gm/mi
	Federal	7-mode	2.2 gm/mi	23 gm/mi	—
1972	State	7-mode	1.5 gm/mi	23 gm/mi	3 gm/mi
	or Federal	CVS-1	3.2 gm/mi	39 gm/mi	*3.2 gm/mi
1973	Federal	CVS-1	3.4 gm/mi	39 gm/mi	—
	State	CVS-1	3.2 gm/mi	39 gm/mi	3 gm/mi
1974	Federal	CVS-1	3.4 gm/mi	39 gm/mi	3 gm/mi
	State	CVS-1	3.2 gm/mi	39 gm/mi	2 gm/mi
1975	Federal	CVS-1	3.4 gm/mi	39 gm/mi	3 gm/mi
	State	CVS-1	1 gm/mi	24 gm/mi	1.5 gm/mi
1976	Federal	CVS-2	0.41 gm/mi	3.4 gm/mi	3 gm/mi
	State	CVS-1	1 gm/mi	24 gm/mi	1.5 gm/mi
	Federal	CVS-2	0.41 gm/mi	3.4 gm/mi	0.4 gm/mi

**APPENDIX E**  
**CALIFORNIA EFFLUENT REQUIREMENTS**  
for Waste Discharge to the Ocean

Pollutant	Concentration not to be exceeded more than 50% of the time mg/l	recommended method	useful range <sup>8, 9</sup> mg/l
Arsenic	.01	silver diethyldihiocarbamate	
Cadmium	.02	atomic absorption spectrophotometric	
Total Chromium	.005	atomic absorption spectrophotometric	.005
Copper	.2	atomic absorption spectrophotometric	.005
Lead	.1	atomic absorption spectrophotometric	.03
Mercury	.001	atomic absorption spectrophotometric	.0002
Nickel	.1	atomic absorption spectrophotometric	.005
Silver	.02	atomic absorption spectrophotometric	.005
Zinc	.3	atomic absorption spectrophotometric	.002
Cyanide	.1	titration	
Phenolic Compounds	.5	colorimetric	.05
Total Chlorine Residual	1.0	idometric	
Ammonia (as N <sub>2</sub> )	40.	distillation-Nesslerization	.05
Chlorinated Hydrocarbons	.002	gas chromatography	

7. *Ocean Waters of California—Water Quality Control Plan*, State Water Resources Control Board, July 6, 1972.

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