

UCLA INSTITUTE OF THE ENVIRONMENT

Southern California Environmental Report Card 2000

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Cover: Southern California, as seen
from the Space Shuttle Discovery,
April 29, 1996.

Contents

RC 2000



Air Toxics



Drinking Water Quality

2

From the Editors

3

Letter From the Director

4

Households That Pollute



12

20

Coastal Water Quality



30

40

About the UCLA Institute of the Environment

42

RC 1999 Revisited

From the Editors

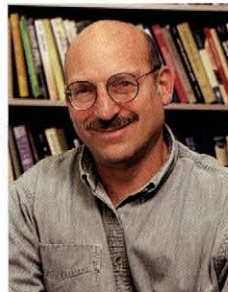
The Southern California Environmental Report Card is produced once a year by UCLA faculty under the sponsorship of the UCLA Institute of the Environment. Each issue contains articles addressing critical environmental concerns facing the fifteen million people in the Southern California region. The goal of every article is to provide an introduction and background to the related science and policy, describe the current situation, and then evaluate in a balanced manner relevant performance of the public and private sectors, and the general public, in meeting the challenges of that particular environmental concern.

The environmental issues addressed in each Report Card rotate over time. While the dominant environmental problems of the region dictate that various aspects of air and water quality will be ongoing themes, other important environmental topics will also be addressed. For example, the first Report Card, published two years ago (RC 1998), discussed the state of wetlands in Southern California, progress in improving air quality, water conservation, and wastewater treatment. Last year's Report Card (RC 1999), considered the impact and control of wildfires, assessed the state of environmental education in primary and secondary schools,

and addressed stormwater impacts and groundwater quality.

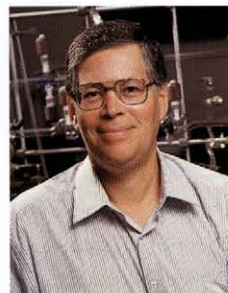
While faculty who write for the Report Card are all experts in their fields, they represent a wide range of academic disciplines, including social science, natural science, law, public health, engineering, urban planning, public policy, and others. Since environmental issues do not come neatly packaged in the usual academic disciplines, it is appropriate that the Report Card present a multidisciplinary perspective. But all of the authors share a common desire to draw on the best scholarship possible in order to help inform local and regional policy discussions.

The environmental problems facing Southern California are complex, and rarely are there simple solutions on which all stakeholders can agree. Therefore, each Report Card includes reactions from knowledgeable commentators on the content of the articles from past years. Our aim is to foster informed dialog from different points of view. We welcome constructive responses from any readers who wish to share their views. All of us in Southern California have a stake in working together to find cost-effective and socially acceptable solutions to our major environmental problems. We hope you find RC 2000 to be interesting and informative.



Richard Berk, Ph.D.

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Editors

UCLA Institute of the Environment

Letter from the Director

THE MILLENNIUM OF THE ENVIRONMENT

It is probably not an understatement to say that in the coming millennium—especially in the present century—we face extraordinary decisions with regard to preserving the environment. Worldwide, and within regional boundaries, we must collectively agree to rational and wise courses of action to control greenhouse gas emissions, set aside preserves for endangered species, and develop sustainable water use policy, in addition to many other pressing issues. If we fail in any one of these areas, our descendants could face unprecedented hardship.

Over the next 1,000 years, we might imagine a sustained civilization based on current levels of technology, medicine, and social organization—of course, with some badly needed equity adjustments. While this would not be an ideal situation, its practicality is proven. On the other hand, we could not imagine the sustained exploitation of the environment at present rates for even a hundred years without widespread deprivation. It follows that our behavior and way of life, in the long run, must be significantly altered.

Any changes, first and foremost, must be directed toward establishing a permanently sustainable and viable environment.

Some may argue that new technologies, yet unrealized, will soon enable growth and preservation to be achieved simultaneously. We must recognize, however, that knowledge already exists to begin the process of building long term sustainability. What is lacking is the will to move toward implementation. With respect to conserving the environment, we already know what works: reducing toxic emissions, increasing energy efficiency, recycling, preservation of habitat and biodiversity, population control, and environmental education. All of these actions are currently being undertaken at a low, although not insignificant, level.

The experts who are contributing to this and previous Report Cards are deeply involved in research that contributes to the goal of sustainability. In the current issue, for example, the authors are leaders in the fields of coastal water quality, residential runoff, drinking water quality, and air toxics. Each of these experts, acting alone, has a positive impact. Working together, however, they become a much greater force for ratio-


nal change. So it is with every individual, whether a specialist or a concerned citizen. Anyone who has a stake in a cleaner environment should act to have their interests represented more effectively. The first step is to gain reliable information. That is where we hope this Report Card will help. We propose to continue publishing it as long as there is a need—hopefully not too far into the millennium.



Richard P. Turco, Ph.D.

Director

UCLA Institute of the Environment

An aerial photograph of a suburban neighborhood, showing a grid of streets, numerous houses with dark roofs, and green lawns. The perspective is from a high angle, looking down on the community. The houses are mostly two-story structures with varying rooflines. Some yards have swimming pools. The streets are paved and have some parked cars. The overall scene is a typical suburban residential area.

GRADE D

Households That Pollute

by Richard Berk, Ph.D.

Professor, Departments of Statistics and Sociology

INTRODUCTION

Early this year, the Los Angeles Regional Water Quality Control Board made the historic decision to confront head-on the issue of polluted urban runoff. As described in detail elsewhere in this issue of the Southern California Environmental Report Card, and in the 1999 Report Card as well, water that flows into storm drains ultimately finds its way to Santa Monica Bay. And with the water are carried a variety of debris and contaminants that can be harmful to the near-shore ecosystem and to people who frequent local beaches. The main concern of the Water Quality Control Board was new industrial, commercial, and residential developments and how storm runoff was going to be handled. Proposals included the use of porous paving materials so that rainfall would percolate into the ground rather than being channeled into storm drains.

While it is certainly useful to target new developments, the existing "hardscape" characterizing the Los Angeles region largely is here to stay. It makes sense, therefore, to also examine the sources of the debris and contaminants that storm water carries to the sea. An appropriate place to start is with the everyday

The data used in this article were collected through a telephone survey of just over 500 individuals contacted during the late fall of 1999. Households served directly by the Los Angeles Department of Water and Power were selected at random, and the resident responsible for paying the local water bill was interviewed. Because many of the questions would deal with water use, the person responsible for paying the water bill was the household resident anticipated to be the most knowledgeable. The interview was completed by 63% of the more than 800 eligible respondents contacted. This response rate was well above the response rates of most household surveys and within an acceptable range for the intended purposes of the study. With a sample size of just over 500, the margin of error due to chance is about plus or minus 5% for questions answered by the entire sample. Of course, some respondents may have occasionally misunderstood questions or even give incorrect information. The data collection was part of a larger study funded by the National Science Foundation, Program in Methods and Models for Integrated Assessment. The Los Angeles Department of Water and Power generously provided technical assistance.

activities of the people who live in the region, and especially those activities over which local residents have direct control.

In this article, we will consider how the day-to-day actions of Los Angeles residents in and around their home can affect the "urban cocktail" that empties into Santa Monica Bay. In the late fall of 1999, a random sample of over 500 respondents was interviewed by telephone and asked about a

range of household activities that can influence storm water composition, such as the use of fertilizers, weed killers, and pesticides, and the hosing of driveways, patios, and sidewalks. Questions were also asked to determine whether respondents appreciated the consequences of their actions for urban runoff. The key issue, to paraphrase the comic strip character Pogo, is whether we have met the enemy and they are us.

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CHEMICALS THAT PEOPLE USE IN THEIR YARDS

Water soluble chemicals used in a person's yard can become part of the urban runoff. The obvious question, therefore, is whether such chemicals are widely used.

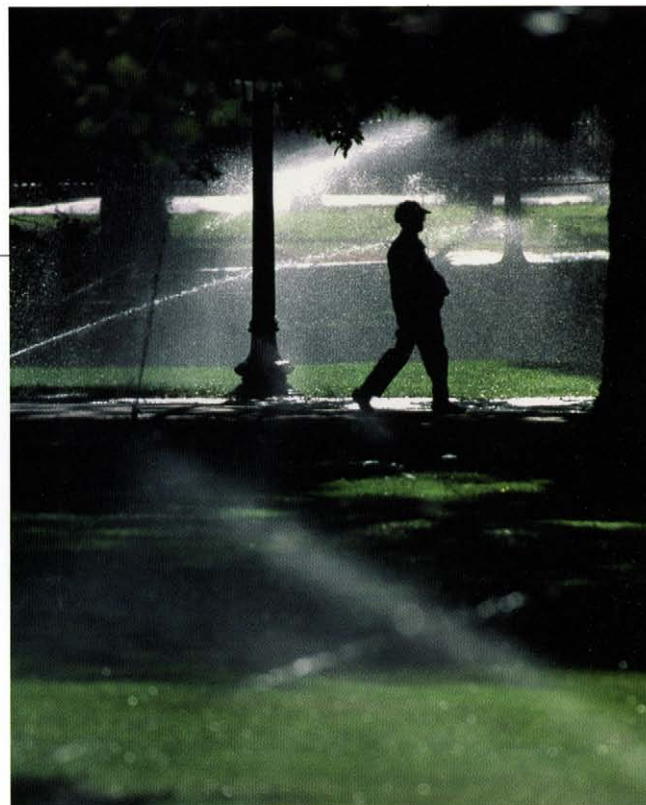
Virtually all homeowners in the study had yards or gardens to take care of. We asked about the use of fertilizers, and found that about 80% of the respondents used some form of fertilizer. Breaking this down, about 20% used chemical fertilizers exclusively, about a third used natural fertilizers exclusively, and about a third used both. For our purposes, the key point is that a little more than half used at least some chemical fertilizer, either exclusively or in combination with natural fertilizers.

About two-thirds of the respondents applied some form of weed control. Of those, about a quarter used a chemical herbicide at least part of the time, rather than barriers such as plastic sheeting or simply pulling weeds by hand. Herbicide use was not nearly as common as the application of chemical fertilizers.

About half of the respondents tried to control plant diseases and pests such as

aphids and slugs. Of these respondents, nearly three-quarters used some form of chemical pesticide. A quarter stated they tried to control backyard insect pests with "friendly" insects such as ladybugs, while about a third said they used environmentally benign procedures such as traps for slugs and soaps to wash off aphids and other insects. Informal talks with staff at local nurseries suggest that these last two figures are a bit high.

In short, of the means by which respondents took care of lawns, trees, shrubs, and flowers, chemical pesticides appear to be the most popular, followed by chemical fertilizers. Herbicides were the least popular. The main point is a substantial majority of our Los Angeles sample used chemicals in caring for their yards, and these chemicals can add to the harmful content of urban runoff.



OUTDOOR WATER USE

Chemical fertilizers, herbicides, and pesticides vary in their potential harm. But if they do not get into the storm drains, they at least do not end up in Santa Monica Bay. One of the key ways in which chemicals are transported to the Bay is in runoff; not from rainfall, but from the outdoor use of water.

One main use of water in households is to irrigate lawns, trees, shrubs and plants, and using too much water leads to runoff. An approach that reduces the need for water to

A majority of our Los Angeles sample used chemicals in caring for their yards, and these chemicals can add to the harmful content of urban runoff.

begin with is to landscape with drought tolerant plants (i.e., xeriscaping). About 5% of the respondents had landscaped fully in a drought tolerant fashion, while another 16% had yards that were mostly drought tolerant. Clearly, conventional landscaping still dominates in Los Angeles. Indeed, nearly 90% of the respondents landscaped at least in part with grass.

Of those respondents, nearly 20% watered their lawn once a day during the summer months. Another 15% watered their

lawns every other day. At the other extreme, about 20% watered their lawns once a week or less. One inference is that the majority of the respondents may be “over-watering,” which can be an important source of runoff.

But over-watering is also a function of how much water is applied. We could not obtain in a survey format accurate and direct estimates of the amount of water used, but we were able to learn that a third of the respondents watered for 15 minutes or more each time they irrigated. Whether watering

for lengthy periods is a problem depends in part on the relationship between how often watering is done and how much water is applied each time. Ideally, households that watered their lawns most often would also be the households that used less water per applications. While there is this tendency in

the data, it is not very strong. In other words, for a large fraction of the respondents, our measures of the frequency of watering and the amount used in each application are effectively unrelated. This suggests that over watering may indeed be common.

Without some formal means of monitoring and controlling water use, it is not surprising that inefficient water use can be common. For example, only about 40% of the respondents water their lawns with a sprinkler system operated by a timer. But another problem is determining how much water is required for a healthy lawn. It is often apparent when a lawn begins to dry out and watering is needed. But a lawn will look healthy even if substantially over watered. So, it is often difficult to judge by appearance alone when too much water is being applied.

Water used for washing driveways, patios, and sidewalk can also contribute to the amount of runoff, and car washing done at home sends detergent-filled water into the storm drains. About 60% of the respondents regularly wash down their sidewalks, driveway or patio in the summer, and about third do so in the winter. (According to the data, “regularly” most commonly translates into once a week.) There is apparently a substantial con-



Example of drought-tolerant landscaping.



tribution to runoff in Los Angeles resulting from water used to clean outside surfaces.

About half of the respondents wash one or more of their cars at home. In the summer months, about 20% wash their cars at home once a week, a figure that drops to approximately 10% in the winter months. Clearly, car washing at home is another substantial source of urban runoff.

DO PEOPLE UNDERSTAND WHAT THEY ARE DOING AND DOES THAT MATTER?

We read respondents several questions about the sources of polluted water near public

beaches and about where storm water ultimately ends up. The two key questions asked were as follows.

As you may know, beaches in Los Angeles are sometimes closed because the ocean where people like to swim is polluted. Can you tell me how the pollutants wind up in the ocean near the beaches, or do you not know?

Now I want to turn your attention to water that flows into storm drains. Rainwater and water from watering lawns, washing vehicles, and other outdoor, domestic water uses flows into grates on the streets near your home, into storm drains. Do you happen to know where the

One inference is that the majority of the respondents may be “over-watering,” which can be an important source of runoff.

drains eventually empty out once the water is in the storm drain, or do you not know?

After both questions, there were follow-up items for those who said “yes,” asking for their understandings. Three-quarters of the respondents said they knew what the sources of beach pollution were and of these, the vast majority of respondents correctly identified storm drains. Most of those who did not mention storm drains, mentioned the “sewer system as a source of beach pollution,” which is true during unusually heavy rains when treatment plants “overflow.” Similarly, about three-quarters of the respondents claimed to know the ultimate destination of the urban runoff, and again, the vast majority effectively identified what that was (e.g., Santa Monica Bay, “The Ocean,” the Los Angeles River, Ballona Creek). In short, about three-quarters of the respondents were aware of the issues.

But, was that knowledge related in any way to behavior? One might think that people who knew about the harmful effects of storm water would be more prudent in their use of chemical fertilizers, pesticides, and herbicides, and that they would use water more sensibly and efficiently. However, such is not the case. *In our survey, there was virtually no*

Clearly, car washing at home is another substantial source of urban runoff.

association between correct knowledge about runoff and a range of behavior affecting the amount and content of chemical use. For example, 56% of the respondents who correctly identified runoff as a problem used chemical fertilizers, while 49% of those who did not have this knowledge used chemical fertilizers. Although the difference in percentages is within the chance margin of error, correct knowledge is, if anything associated with greater use of chemical fertilizers. Likewise, 26% of the respondents who correctly identified runoff as a problem used chemical herbicides, while 23% of those who did not have this knowledge used chemical herbicides. Similarly, 33% of the respondents who correctly identified storm runoff as a problem regularly washed down their sidewalks, patios and driveways. In comparison, 37% of those who did not have this knowledge did the same. This comparison slightly favors the more informed respondents, but the difference in percentages could well be a chance result. All of the other comparisons led to the same overall conclusion: *knowledge about storm water and runoff are unrelated to behavior affecting runoff volume and composition.*

What is one to make of this? Perhaps most simply, it is possible respondents did



not make the explicit and direct links between their actions and the environmental consequences. While runoff affects the Bay, runoff may in respondents' minds be unrelated to outdoor water use and yard care. This explanation seems unlikely given the manner in which the questions were worded, but it is possible that the wording was not fully digested by many respondents.

Alternatively, it is widely understood both in academic disciplines such as psychology and professional disciplines such as public health that links between what people know and how people behave are often weak or even absent. One reason is that sometimes

it is difficult for people to translate their knowledge into action. For example, even if a household is committed to conserving the water they use for irrigation, it can be difficult to know how much water is needed and equally difficult to measure if the right amounts are being delivered.

Another reason why knowledge and behavior may be unrelated is that people often do not think through the consequences of their actions when those actions are about to be undertaken. A homeowner sees the leaves of young plants being destroyed by foraging snails and slugs and not surprisingly, focuses on the immediate



...knowledge about storm water and runoff are unrelated to behavior affecting runoff volume and composition.

problem of saving the plants. A nearby nursery will have one or more brands of inexpensive “pellets” that if spread on the ground will shortly put an end to the problem. The larger consequences will typically go unexamined.

Yet another reason for the knowledge-behavior disconnect is that sometimes an individual’s decision is well informed and carefully examined, but the perceived tradeoffs favor environmentally harmful actions. It may well be, for example, easier and more effective to wash down a driveway than to sweep it. Moreover, since any single individual’s decision to wash an outdoor surface has virtually imperceptible environmental consequences by itself, it is rational solely from the individual’s point of view to proceed as if there were virtually no negative consequences. Finally, it does not pay for any individual to behave differently

unless a large number of other individuals facing the same decision behave differently as well. Indeed, one could imagine an outcome in which the actions of some to behave more responsibly actually provide more leeway for other to behave less responsibly. Thus, a reduction in runoff because some individuals decide to sweep their driveways rather than hose them down, means that others could wash their driveways more often and runoff problems would become no worse.

WHAT NEEDS TO BE DONE?

It is quite clear that by their actions households in Los Angeles contribute significantly to the amount and composition of urban runoff. It is also clear that changing behavior in a beneficial fashion will be difficult. Nevertheless, what might be done?

To begin, if water is the vehicle by which harmful chemicals are transported to the Bay, it stands to reason that using less water to begin with is a good idea. And one way to reduce outdoor water use is to landscape with drought tolerant plants. Over the past several years, wholesale growers and nurseries have begun to provide a remarkable variety of attractive, drought tolerant plants, shrubs and trees that do well in Southern California. It is now relatively easy to have beautiful and water-efficient landscaping.

For some problems, technology can be helpful. For example, moisture sensing devices can put in the ground so that sprinklers are turned on only as needed. Water efficient distribution systems, such as those based on drip irrigation, can be effective in reducing water use. There is also a growing range of cost-effective alternatives to harmful fertilizers, herbicides and pesticides. And there are more environmentally benign “cleansers” that can be used for washing cars.

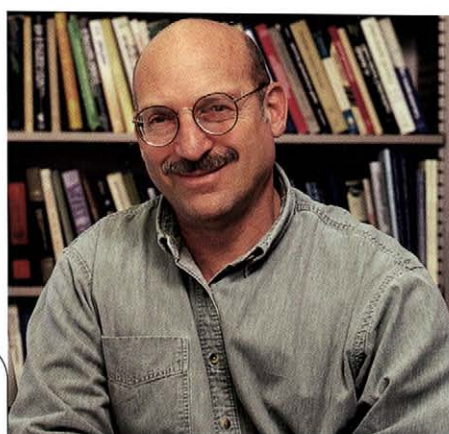
With respect to changing behavior, it is important to appreciate that knowledge about the problem is but a first step. Individuals must also know (a) what they can do about the problem; (b) believe they are capable of acting on that knowledge; and (c) be con-

The data make clear that despite a general understanding about the role of urban runoff in the pollution of the Southern California near-shore ocean, a large fraction of households behave as if their actions do not matter.

vinced their actions will make a difference. There have been a number of examples in the past where educational campaigns built around these and related principles were quite successful. Perhaps the most widely known are educational efforts to conserve water during the two most recent California droughts. But other successful campaigns include those directed against littering, and those encouraging recycling. It should be possible to build on these experiences, and to design affective educational efforts to reduce urban runoff.

GRADE

The data make clear that despite a general understanding about the role of urban runoff in the pollution of the Southern California near-shore ocean, a large fraction of households behave as if their actions do not matter. While this may be understandable as a scientific conclusion, it is unfortunate for the local environment. And clearly, we are capable of doing better. Overall grade: D. Were it not for a small minority trying to make a difference, the overall grade would be an F.



Richard A. Berk is a Professor of Statistics and Sociology at UCLA. He is also the Director of the UCLA Statistical Consulting Center, which provides technical assistance to individuals and organizations in need of statistical expertise. He is fellow of the American Association for the Advancement of Science, and currently sits on the National Research Council's Committee on Applied and Theoretical Statistics and on the Scientific Advisory Committee for Climate Modeling Program of the National Center for Atmospheric Research.

Professor Berk has published a dozen books and over 150 journal articles and book chapters, many on environmental issues. His current work addresses the links between climate, water resources, and water quality in large urban areas. In addition to his research on Southern California, he is beginning related work in several large Asian Pacific cities. He also collaborates with statisticians and scientists at UCLA and the Los Alamos National laboratories on statistical tools for evaluating large-scale computer simulation models, such as those used in climate research, and on new statistical tools to permit sound generalizations from environmental case studies. His recent work is funded by the National Science Foundation and the Environmental Protection Agency.

The background of the entire page is a photograph of several industrial smokestacks or chimneys. They are silhouetted against a bright, hazy sky at sunset or sunrise, with a warm orange and yellow glow. Thick plumes of white smoke or steam are rising from the stacks, particularly from the central one. The stacks have various platforms, ladders, and pipes attached to them.

GRADE B

Air Toxics

By Yoram Cohen, Ph.D.

Professor, Department of Chemical Engineering

THE AIR TOXICS PROBLEM

A toxic air contaminant, or "air toxic," is an air pollutant which may contribute to mortality or serious illness, or pose other potential hazards to human health. Most air toxics are volatile and are found primarily in the atmosphere in the gaseous form but some occur in atmospheric particles or liquid droplets.

The Magnitude of the Problem

- 189 Air Toxics on the Federal List
- 245 listed by the California EPA
- The U.S. EPA lists about 3,000 chemicals targeted for evaluation for pollution prevention action
- There may be more than 10,000 chemicals that require evaluation from a pollution prevention viewpoint

Toxic air contaminants originate from various chemical and manufacturing processes and can be released to the environment from a variety of controlled and uncontrolled sources ranging from automo-

biles to chemical manufacturing plants to consumer products. As a result, there is an enormous variation in the sources and ambient concentrations of air toxics on both local and regional scales.

Air toxics are of particular concern since they can be distributed over large regions, thus leading to population-wide exposure. With rapidly increasing population density, and robust growth in many industrial sectors, in Southern California the use of synthetic chemicals has escalated. For example, chemical solvents are used in paints, as degreasing agents in the automotive and aerospace industries, and by dry-cleaning establishments and auto repair shops. Synthetic chemicals are the building blocks of advanced materials such as plastic composites, and household pesticides and insecticides are used extensively. Despite their benefits many of these chemicals may also be harmful to human health and thus must be used cautiously.

Although a wide range of chemicals are an indispensable part of modern living, when they escape to the environment due to inadvertent releases, faulty equipment or poor handling, human exposure can result. To protect the public, a number of environmental regulations have been enacted to identify air

toxics, determine their sources, assess the amounts released to the environment, evaluate potential risk to the public and implement appropriate control strategies.

California is a pioneer in the area of air quality management. Aggressive programs to reduce emissions of carbon monoxide, oxides of nitrogen and sulfur, hydrocarbons and particulate matter have resulted in significant improvements in air quality in Southern California (1998 Report Card). However, these programs focus on the so-called "criteria pollutants" and were not designed to protect the public from chronic exposure to pollutants that could cause cancer or neurotoxic effects. The accident in Bhopal, India, which claimed 4000 lives and injured tens of thousands more in December 1984, was a watershed event in calling attention to the potentially devastating effects of massive releases of toxic chemicals. This event heightened concerns that protection measures were needed to reduce potential risk to the public from exposure to airborne toxic chemicals.

The passage of the 1990 Federal Clean Air Act was a milestone in environmental protection since, for the first time, specific chemicals and groups of chemicals were listed as hazardous air pollutants. Air



toxics were also regulated on the basis of integrated exposure assessment in which (Figure 1) all possible exposure pathways are considered.

Parallel legislation in California in the mid-1980's also established a statewide framework for evaluating and regulating potential toxic air contaminants. This legislation recognized that to protect the public from air toxics, it is necessary to understand their specific toxicity, source locations and emission rates, how they travel in the environment, how people are exposed, and the level of existing and potential health risks. The purpose of this article is to promote an understanding of the complexity of the air toxics problem in Southern California. Because of the enormous variation in the chemical, physical and health impact characteristics, as well as the origins of air toxics, devising properly encompassing health protection strategies is an enormous task we are only now beginning to address.

SOURCES OF TOXIC AIR CONTAMINANTS

Air toxics are released to the environment from a variety of outdoor and indoor sources. Indoor releases result from activities such as cooking, use of home and garden supplies, releases from building materials and consumer products, as well as from tobacco smoke. In some cases, vehicular emissions can also lead to indoor contamination, as in houses that have attached garages. Although exposure to air toxics generated indoors can be significant in some cases, such emissions are currently not directly regulated.

Outdoor releases of air toxics are due to emissions from "mobile" sources such as automobiles, and from "stationary sources" such as manufacturing facilities, refineries, chemical production facilities, gasoline service stations, dry-cleaners, and other facilities that produce or utilize chemicals. It is important to note that, in Southern California vehicular emissions are a significant or even dominant contributor to emissions of certain air toxics including benzene and polycyclic aromatic hydrocarbons (PAHs). Mobile and stationary sources are considered intrinsically different from a reg-

ulatory viewpoint. In this article we focus only on stationary sources of air toxic emissions since such sources produce the largest number of different airborne toxic chemicals. We will treat air toxics from mobile sources, including diesel exhaust, in a future Report Card article.

In California, the identification, tracking, monitoring and assessment of public health risks due to air toxics are guided by two major Assembly Bills, AB 1807 and AB 2588, enacted in 1983 and 1987, respectively. The resulting California Air Toxics (CAT)



Figure 1: Multi-Pathway Exposures – inhalation, ingestion (food, water, soil), dermal

Successful control of air toxic emissions requires a thorough understanding of emission sources and their distribution throughout the region.

Program, includes provisions to make the public aware of significant toxic exposures and to reduce risk. With the development of the CAT monitoring program, and the Federally mandated toxic release inventory (TRI), information on air toxic emissions from stationary sources has been mounting. Although these databases do not provide a complete reporting of all sources, they provide insights as to the relative distribution of various emitted air toxics and trends in their ambient levels.

The large number of listed air toxics makes it difficult to implement a uniform strategy to control their releases to the environment. For example, in Southern California, the emission profile for benzene (a known human carcinogen) by source category indicates that mobile sources contribute about 90% of the total benzene emissions (Figure 2). Therefore, even if all stationary sources were eliminated, exposure to benzene would only be reduced by about 10%. On the other hand, reduction in benzene levels in gasoline have resulted in reductions in ambient levels of benzene by more than a factor of two since 1990. This does not suggest that reducing benzene emissions from stationary sources is a less worthy goal. On the contrary, exposure to

benzene from stationary sources in the immediate vicinity of residential dwellings is of concern. For example, there are nearly 3000 gasoline dispensing stations distributed throughout the South Coast Air Basin (SoCAB). While their contribution to total emissions may be small, their impact on personal exposure can be significant.

An example of a strikingly different behavior is found for perchloroethylene (PERC), a solvent emitted from primarily dry-cleaning and degreasing operations in 1,300 facilities distributed throughout the SoCAB. These uses of PERC account for about 60% and 30% of its total emissions, respectively (Figure 3).

The above examples point out that successful control of air toxics emissions requires a thorough understanding of emission sources and their relative strength. Many individual sources of air toxics, such as dry cleaners, auto repair shops and metal plating facilities are small establishments scattered throughout Southern California, which do not have the resources needed to reduce fugitive emissions of air toxics. Clearly, controlling the multitude of these widely distributed facilities is a complex task requiring careful regulatory strategies.

Another example of distributed sources,

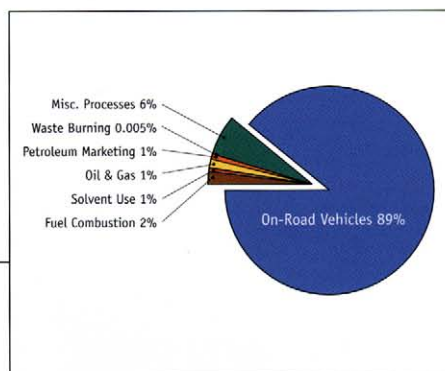


Figure 2: Benzene Emission Profile in Southern California (SCAQMD 1998).

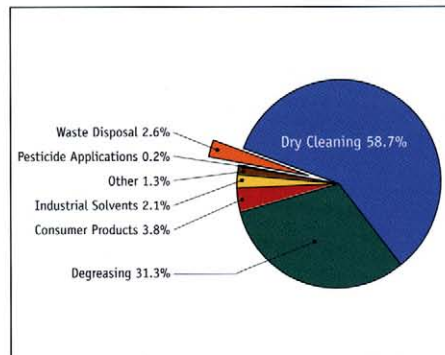


Figure 3: Perchloroethylene Emission Profile in Southern California (SCAQMD 1998).

albeit over a smaller area, is that of chemical or petrochemical production facilities, where fugitive emissions of volatile chemicals can occur as slow leaks from literally thousands of plant components. Detecting and controlling fugitive emissions from refineries and other large chemical manufacturing facilities represents a major technical challenge.

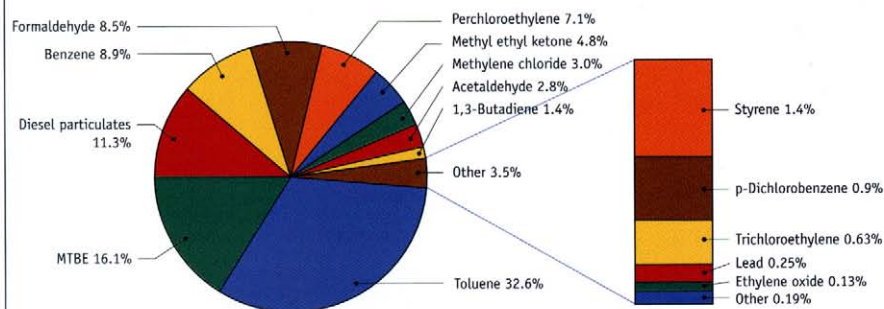


Figure 4: Distribution of emissions for 30 air toxics monitored in SoCAB (MATES-II).

Present programs of emission reporting do not account for all potential sources, necessitating ambient monitoring, along with air quality modeling, to improve emission estimates. In many cases, emissions reported under AB2588 account for only a small fraction of the total emissions. One of the striking findings of studies in the SoCAB is that of the 30 major air toxics evaluated by the South Coast Air Quality Management District (SCAQMD), diesel particulate (now regulated as an air toxic in California) contributes only about 11 % of the total emissions (Figure 4) but are claimed by the SCAQMD to be the major contributor (approximately 70%) of cancer health risks associated with air toxics. It is also important to realize that mobile sources constitute the major portion of the total releases of toluene, MTBE, diesel particulate, benzene, formaldehyde, acetaldehyde and 1,3-butadiene.

In reality, the small generators distributed throughout the basin (many of which

may be exempt from reporting) could contribute to local problems in their immediate neighborhoods. For example, a residential dwelling at the fence line of a small polluting facility may be affected to a degree not detected by intermittent monitoring or sampling removed from that specific source. Exemption of small generators does not make the problem of toxic "hot spots" go away; it simply hides potential local problems. It has been suggested that a monitoring system which is based on cumulative assessment of all potential sources would be most beneficial. Clearly such a system would also be more complex and costly to implement.

WHAT HAPPENS TO AIR TOXICS ONCE RELEASED TO THE ENVIRONMENT?

Once released to the atmosphere, air toxics can rapidly disperse in the atmosphere and

can also transfer from the atmosphere to other media such as water, soil and vegetation. Air toxics which are volatile and sparingly water soluble (e.g., trichloroethylene, benzene and chloroform) are likely to be present mostly in the atmosphere. Chemicals with low vapor pressure are typically present in atmospheric particles which deposit to the terrestrial environment by dry deposition processes as well as by rain and snow scavenging. As a result, exposure to particle-bound chemicals (e.g., lead, PAHs and hexavalent chromium) can occur through multiple exposure pathways. Certain air toxics (e.g., PAHs, polychlorinated biphenyls, dioxins) can also accumulate, to a significant degree, in soil and vegetation. Thus, the intake of these contaminants via the food chain can be significant.

The migration of air toxics across the boundaries of environmental "media" (Figure 5) creates a "multimedia" problem. The major characteristics dictating the multimedia distribution of toxic air contaminants include their solubility in water, how volatile they are, and whether they tend to adsorb onto organic matter and bioaccumulate in living organisms. The persistence of air toxics in the environment is also affected by their chemical and biochemical transformations.

Air toxics behave in a complex way in the environment. More than just air monitoring is required to assess their impact.

In general, the most significant degradation processes for organic air toxics occur in the atmosphere. Reactions with a variety of photooxidants can transform air toxics to other chemicals which can themselves be air toxics. Examples include the formation of formaldehyde and acetaldehyde from organic compounds, and nitro-PAHs from PAHs. Overall, the degradation of air toxics in the aquatic and terrestrial environments are typically less significant than in the atmosphere.

The atmosphere is the main "holding" reservoir for volatile toxic air contaminants with typically 80% or more of the total air toxic mass in the atmosphere. In contrast, the soil environment is the major "holding" reservoir for non-volatile air toxics. For example, more than 90% of the mass of benzo(a)pyrene present in the environment in the SoCAB, resides in the terrestrial environment.

Air toxics that have significant water solubility present another challenge. For example, MTBE, a gasoline additive which is now slated to be phased out, can pose a difficult groundwater remediation problem if it leaks from storage tanks. Groundwater contamination has also been caused by spills and leaks of other air toxics including aromatics and various chlorinated solvents.

The above examples illustrate the fact that air toxics behave in complex ways in the environment. More than just air monitoring is required to assess their impact. Monitoring of soil, vegetation and aquatic biota can also provide important indicators of the impacts of air toxics and improve risk exposure assessments.

AMBIENT LEVELS OF AIR TOXICS

Monitoring of ambient levels of air toxics in Southern California began in 1986 with more intense monitoring of 31 specific air toxics undertaken since 1997 (Table 1). Data from both the California Air Resources Board (six monitoring stations in Southern California) and the SCAQMD (two intensive monitoring studies) demonstrate that during the 1990's there was an overall reduction in the ambient concentrations of the monitored air toxics. For example, there has been a steady decline in atmospheric concentrations of benzene and toluene (Figure 6). This improvement is attributed primarily to a reduction in mobile source emissions due to the introduction of reformulated gasoline. A decline in the ambient concentrations of chlorinated solvents and metals (chromium and lead) is also

Table 1: Monitored Air Toxics in SoCAB (MATES-II)

Benzene	Chloromethane
1,3 Butadiene	Formaldehyde
Dichlorobenzene (ortho- & para)	Acetaldehyde
Vinyl Chloride	Arsenic
Ethyl Benzene	Chromium
Toluene	Nickel
Xylene (m-, p-, o-)	Lead
Styrene	Cobalt
Carbon Tetrachloride	Copper
Chloroform	Manganese
Dichloroethane [1,1]	Phosphorous
Dichloroethylene [1,1]	Selenium
Methylene Chloride	Silver
Perchloroethylene	Zinc
Trichloroethylene	PAHs
	Elemental Carbon (Diesel Particulate)

apparent, although the improvement has been less dramatic.

The number of air toxics that have been monitored to date (Table 1) is only a small fraction of the total number currently listed. New air toxics are also being continuously identified. MTBE is an example of a chemical whose use was promoted rapidly by both government and the refinery industry, despite clear scientific evidence of its propensity to distribute in the environment and its potential toxicity. Recently, there has also been a growing concern with respect to potential cancer health risks associated with emissions from diesel engines. As noted earlier, it is now understood that diesel particulate represent "a toxic air pollutant" which may be the dominant carcinogen among all air toxics in the region.

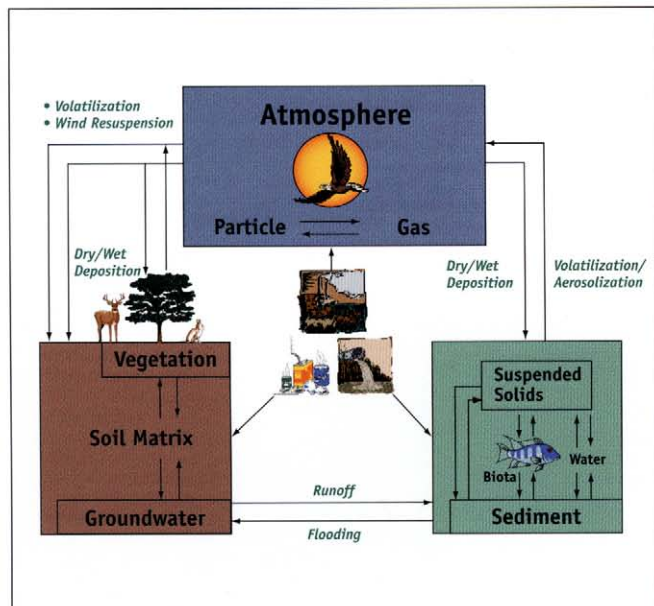


Figure 5: Chemicals do not stay where they originate. They tend to move across environmental phase boundaries.

Despite increased air monitoring efforts, there are numerous sources whose contribution remains unclear. For example, the concentrations of certain air toxics (e.g., benzene and PAHs) may be elevated near airports, but the contribution of airports to local exposure is not fully understood. There are also concerns with the health impact of air toxics which can form in the atmosphere. For example, PAHs can react in the atmosphere to form nitro-PAHs some of which can be more mutagenic or carcinogenic than the parent PAH. Future improvements in air quality should be sought by identifying air toxics that form in the atmosphere and developing appropriate public protection strategies.

contaminated crop, beef and dairy products (Figure 1). Air toxics which are suspected or known carcinogens are of most concern. Cancer health risks for specific air toxics can be estimated based on available monitoring data, toxicological information and model simulations. The cancer health risk is typically expressed as the number of excess cancer cases expected (number of people that will contract cancer) in a given population over a seventy year period, assuming that the entire population stayed in the region during this time period. Although there can be substantial uncertainties in health risk analysis, quantifying the risk helps to place the potential impacts of different air toxics in perspective.

HEALTH RISKS

It is important to recognize that inhalation exposure to air toxics is directly proportional to ambient levels of these chemicals. However, total exposures from secondary routes can also be important as in the case of exposure to PAHs via ingestion of

Recent estimates of health risks by the SCAQMD suggest the 31 air toxics chemicals monitored in the basin contribute to a total cancer risk of about 1,400 per million people. Diesel particulate contribute about 70% of the total cancer health risks followed by other air toxics from mobile and stationary sources that combined contribute 20% and 10%, respectively. However, these estimates must be viewed with caution since only a fraction of the total number of air toxics has been monitored. Moreover, cancer potencies are not available for all of the listed air toxics. Consequently, uncertainties remains regarding the potential risk associated with the long list of air toxics that are still to be monitored.

CONCLUSION AND GRADE

Data from air toxics monitoring, emissions reporting and modeling studies have yielded important information regarding the distribution of toxic air contaminants in Southern California, as well as the relative importance of their emission, and their contribution to cancer health risks. As a result, air quality management with respect to air toxics has improved over the past decade. For example, programs to reduce toxic air emissions from solvent use have resulted in measurable

Air quality management with respect to air toxics has improved over the past decade.



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reduction in ambient concentrations. Reformulation of gasoline has also resulted in significant reduction in the ambient levels of certain air toxics. At present, it appears that on a regional scale air toxics from stationary sources are a relatively minor contributor to health risks in the SoCAB. But despite the progress made, emission inventories for air toxics are incomplete. Moreover,

information on the impact of local sources on personal exposure and identification of the most exposed population in the SoCAB is only beginning to emerge. In conclusion, we give a grade of B to regional efforts by the SCAQMD and CARB to monitor environmental concentrations, quantify potential health risks, and identify new air toxics.

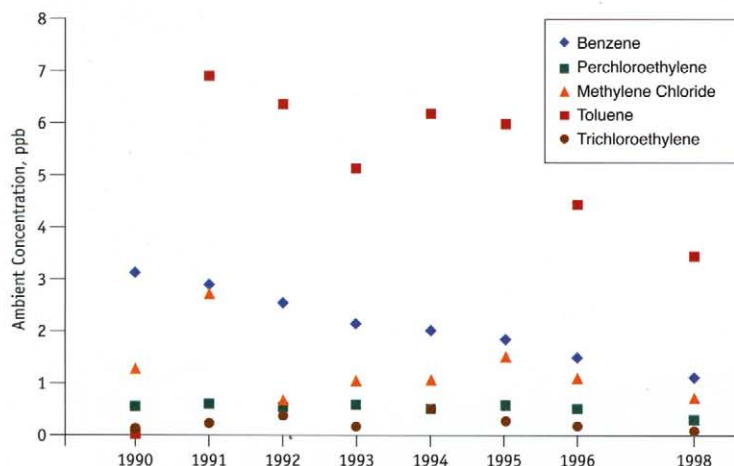



Figure 6: Average atmospheric concentrations of selected air toxics in the Los Angeles Basin. Source: ARB Air Quality Data and SCAQMD MATESII Draft Report



GRADE Source Reduction: A Regional Management: C

Coastal Water Quality

by Keith D. Stolzenbach, Ph.D., P.E., Professor, Department of Civil and Environmental Engineering and
James C. McWilliams, Ph.D., Professor, Department of Atmospheric Sciences

BEYOND THE BEACH

To most people in Southern California good coastal water quality means water that is safe to swim in at the beach. This is a legitimate viewpoint because most of us only experience the coastal water within meters of the shoreline and this region can be polluted by storm water runoff (see Stormwater Impact, RC 1999).

But coastal water quality means much more than that; it means the health of an entire aquatic world beyond the beach, mostly hidden beneath the waves. This article introduces that world and the changes human activities have brought to it, discusses why we should care about it, and gives grades to efforts to conserve and improve coastal water quality.

THE SOUTHERN CALIFORNIA COASTAL OCEAN (SCCO)

The Southern California Coastal Ocean (also called the Southern California Bight) extends along the coast from Santa Barbara to San Diego (see Figure 1). Its offshore boundary

roughly follows a chain of familiar coastal islands: Santa Cruz, San Nicolas, Santa Catalina, and San Clemente. Between these islands and the shoreline are several natural underwater basins with water depths up to 900 meters. Along the shoreline there is a coastal "shelf" with water no deeper than about 100 meters.

Water in the SCCO is constantly moving in response to the push of the wind and the tidal pull of the sun and moon. The long-term average water motion in the SCCO forms a giant counter-clockwise eddy with water near the coastline moving north and water farther offshore moving south (see Figure 1). This eddy is created largely by the California Current, which brings water down the U.S. West Coast from as far north as Alaska and flows south along the outer border of the SCCO.

Superposed on this average motion are short-term local currents that sometimes have very different patterns from the average, particularly near the water surface and the shoreline. For example, depending upon wind conditions, the circulation of water in Santa Monica Bay may be either to the south-

east or to the northwest. The real importance of these water motions is that they move dissolved and suspended substances within the SCCO, creating an interconnected environment in which events at one place can affect another location within hours or days.

The SCCO, partially bounded by topography and stirred by ocean currents, constantly receives inputs of natural elemental material. Rivers and landslides carry dissolved substances and sediments to the shoreline; atmospheric particles and gases pass through the water surface; and oil and other hydrocarbons seep through the ocean floor (see Figure 2). After recirculating within the SCCO, some of this material is carried away by water motions, but much of it is left behind, ultimately to be deposited in the bottom sediments. Material initially deposited on the shallower shelves may eventually become more deeply buried or may be moved by waves and currents to deeper water, often at the bottom of a basin. These natural mechanisms of material retention are a key feature of water quality in the SCCO.

The SCCO teems with life. The smallest forms are microscopic plants called phyto-

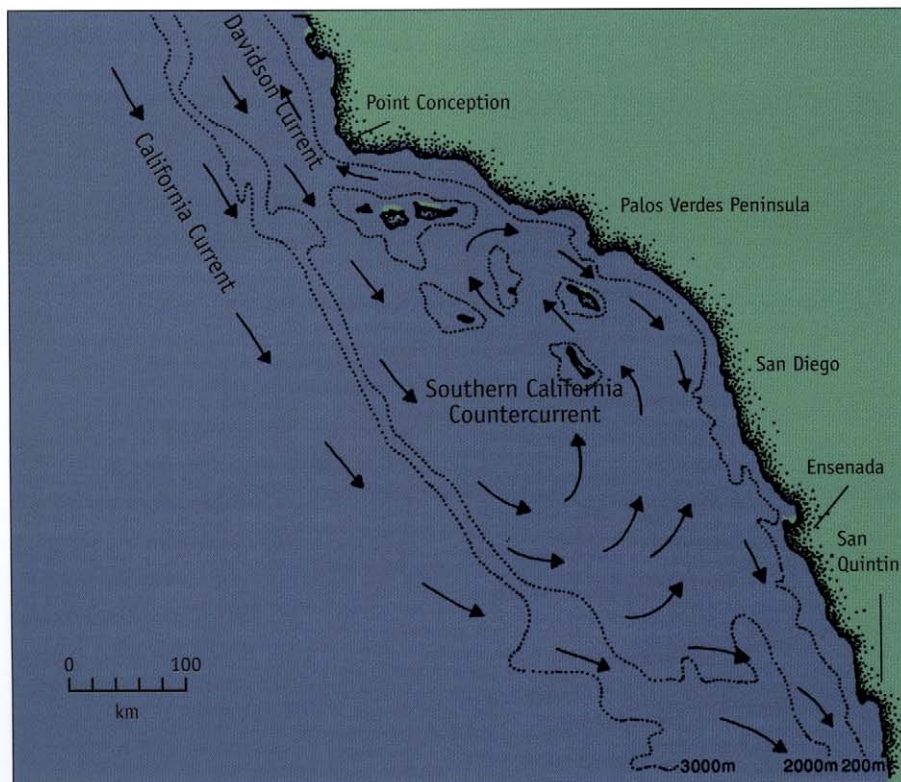


Figure 1: The arrows in this figure indicate the direction of movement of surface water in the Southern California Coastal Ocean.

plankton, or algae, which grow near the water surface where there is light and feed on nutrients brought from deeper water by upwelling ocean currents and in the sometimes nutrient rich California Current surface water. The algae are the base of a food chain that supports many larger forms of life. In addition, sinking algal cells form a “conveyor belt” that carries dissolved and suspended material down to the sediments. This “rain” of parti-

cles feeds a community of more than 5000 species of bottom-dwelling animals.

Larger organisms living in the SCCO include forests of giant kelp, 500 species of fish, 195 species of marine birds, and 39 species of marine mammals such as whales, dolphins, porpoises, sea lions, seals, and otters. The convergence of currents from the north and south in the SCCO provides habitats for both cold water and warm water species.

IS DILUTION THE SOLUTION TO POLLUTION?

How have humans related to the SCCO? We swim at the shore, catch and eat fish and shellfish, and watch the birds and mammals. We also use the coastal ocean as a receptacle for much of the waste we produce. Even before the population of Southern California had grown significantly, the need to protect drinking water sources led the region's urban planners to construct a pipeline system carrying raw sewage from where people lived and worked to the ocean where it was discharged, usually quite near the beach. As the region developed, industries and power plants also located near the shoreline and discharged waste directly into the SCCO. These discharges, called “point sources” of pollution, are found in abundance along the coast from Santa Barbara to San Diego (see Figure 3).

For many of these facilities the volume of waste increased proportionally with the increase in population in Southern California. As it became clear that discharging wastes near the shoreline was incompati-

To most people in Southern California good coastal water quality means water that is safe to swim in at the beach.

ble with people using the beach for recreation, waste pipelines were simply extended to reach deeper water offshore. Engineers also learned how to produce rapid mixing between the waste and the coastal water. They built pipelines with many holes at the end through which the waste was pumped out at high velocity. This dilution of the waste resulted in lower pollutant concentration and toxicity near the point of discharge.

The continued use of the SCCO for waste disposal was scientifically justified by the concept of “assimilative capacity.” It was thought that, as long as pollutant concentrations could be kept below lethal levels by dilution, a coastal water body was capable of receiving waste without experiencing significant harm. The first significant federal water quality regulations, the Water Quality Act of 1965, were based on this concept and specified limits on pollutant concentrations after dilution but did not limit the total volume or concentration of waste discharged. Many environmental scientists and regulators in Southern California believed that the assimilative capacity of the SCCO was large and that limiting localized effects would protect the

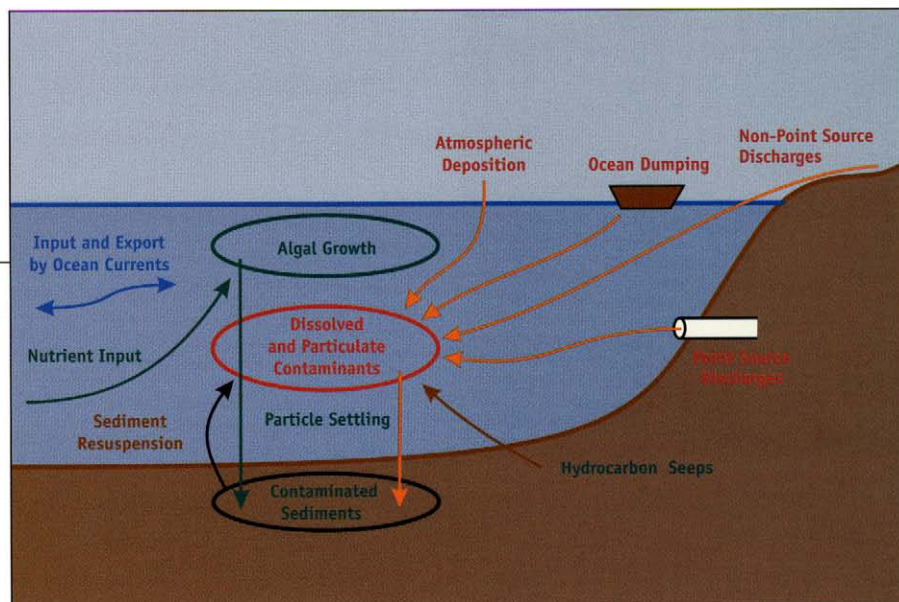


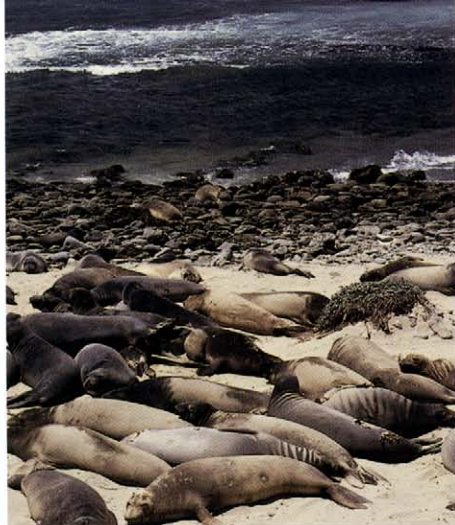
Figure 2: Contaminant inputs to the Southern California Coastal Ocean are either deposited in the sediments or carried away by ocean currents.

coastal environment while allowing managed use of the coastal region for waste disposal.

THE END OF ASSIMILATIVE CAPACITY

The 1970s brought an end to assimilative capacity as the primary way to regulate coastal and inland water quality. Scientific studies showed that the discharge of some pollutants could have long-term and widespread effects even if pollutant concentrations in the water were below immediately “harmful” levels. Kelp forests near the Palos Verdes peninsula

diminished because pollutants clouded the water and blocked the light; fish living near pollutant discharges or in areas with weak natural flushing such as harbors developed conditions such as fin rot and tumors. Some fish species accumulated enough DDT and PCB in their tissues to be unsafe to eat. Waste material settling from the water column (on the algal conveyor belt) near the end of discharge pipes formed deposits of contaminated sediments that extended for kilometers. Prominent examples of sediment contamination in the SCCO included the region of depressed species diversity around the sewage sludge discharge



Source reduction has been highly effective in Southern California.

from Los Angeles City's Hyperion Treatment Plant and a massive (hundreds of metric tons!) DDT deposit in the vicinity of the sewage discharge from the Sanitation Districts of Los Angeles County (see Figure 3).

Regulators also found that setting limits based on pollutant concentrations in the water body was difficult because each discharge needed its own special study and there was disagreement among scientists and engineers over the interpretation and significance of these studies. This led to long delays in implementing water quality regulations, often because of legal actions. Spurred by the ineffectiveness of the 1965 law and, more importantly, the loss of faith in assimilative capacity, Congress passed the 1972 Federal Water Pollution Control Act. This legislation, which in amended form still governs water quality regulation in the United States, placed limits on the concentration of waste discharged from a point source regard-

less of the local effect in the water body after mixing. Although the earlier limits on pollutant concentrations after mixing remained in force, the motto of the 1972 law is "dilution is not the solution to pollution." In related legislation, Congress also banned completely the discharge of sewage sludge and the manufacture of particularly harmful compounds such as DDT and PCB.

POINT SOURCE REDUCTION

The nearly three decades since the 1972 law brought two important changes in the management of wastes discharged into the SCCO. First, as required by the law, some waste treatment facilities in Southern California were upgraded to remove a larger fraction of waste materials before the flow reached the ocean. The most dramatic (and costly) of these facility upgrades were the conversion of the Los Angeles City and Los Angeles County Sanitation Districts main sewage treatment plants to achieve complete secondary treatment (see Wastewater Treatment, RC 1998 and Stormwater Impact, RC 1999). Industrial facilities such as oil refineries also

made significant improvements in treatment for discharges going directly to the SCCO. Second, as sewage treatment plants struggled to meet their required limits on the concentration of waste material discharged, they found that for many kinds of wastes the most cost effective way is not to increase the level of sewage treatment but rather to reduce the amount of wastes industries discharge to the sewer system. This "source reduction" strategy has been highly effective in Southern California.

The result of these actions has been a dramatic reduction in the amount of waste discharged into the SCCO and measurable improvement in the quality of coastal water and sediment quality. While total volume of flow from sewage treatment plants has increased with population growth (sewage is mostly water), the flows of solids, potentially toxic metals, and harmful synthetic hydrocarbon compounds such as PCB and DDT into the SCCO have been reduced far below 1970 levels (see Figure 4). Although high concentrations of waste materials remain sequestered in the bottom sediments of the SCCO, the quality of the surface sediments

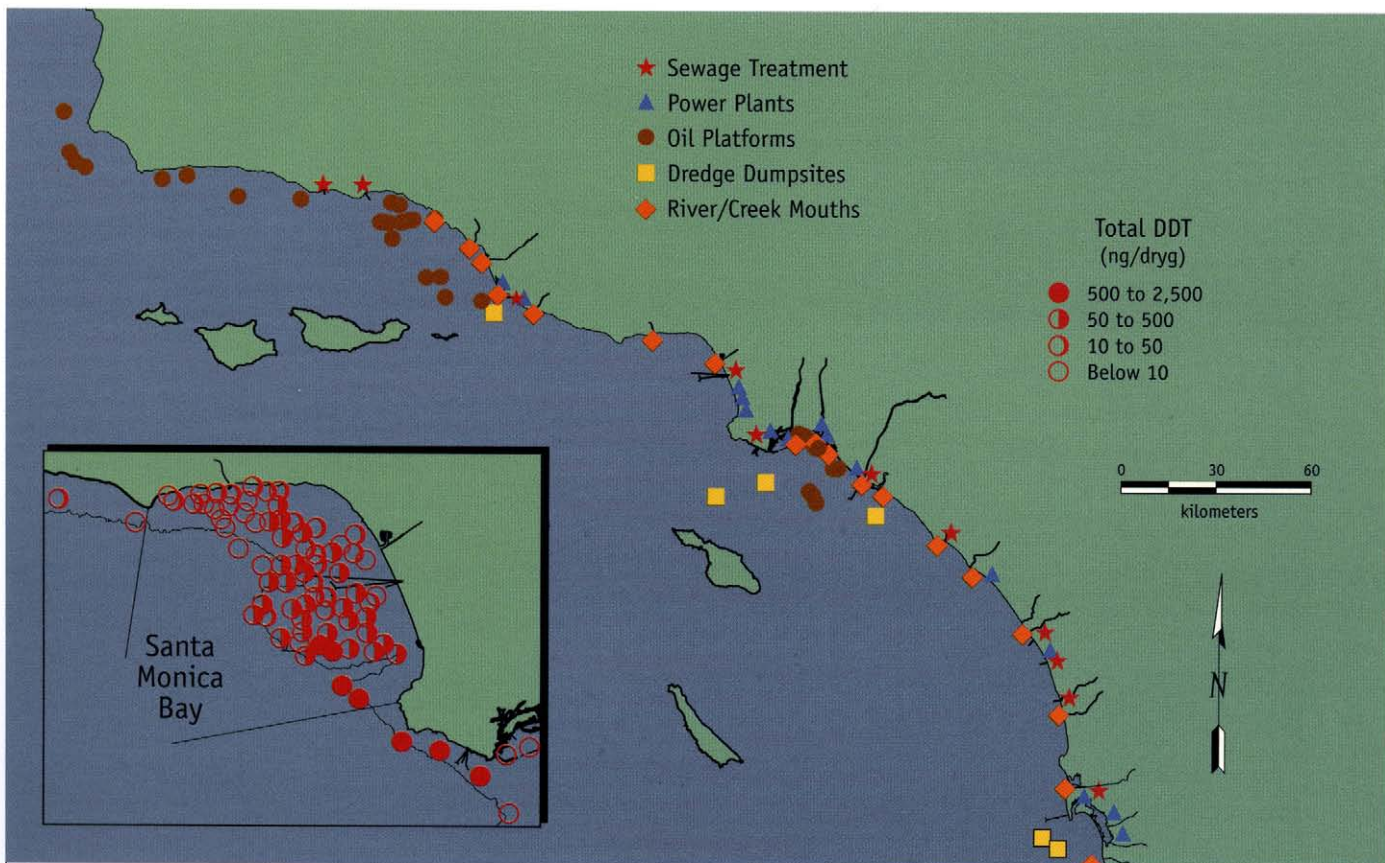


Figure 3: The Southern California Coastal Ocean is characterized by many shoreline or near-shore sources of contaminants and by accumulation of contaminants in the sediments, such as the DDT shown in this figure.

near waste discharges has increased, and in several cases more diverse and healthy biological communities have been reestablished. Other specific beneficial changes include the recovery of kelp beds off the Palos Verdes peninsula and the resumption of reproductive success by pelicans, which had been diminished by the presence of DDT

in the food chain. While contaminated bottom sediments in the SCCO still contain significant remnants of historical waste disposal and need to be addressed by future remediation, the public can enjoy the waters of the SCCO with increased confidence that pollution from point sources is now not a human health concern.

THIS DRAIN CONNECTS TO THE OCEAN

Not all of the human wastes reaching the SCCO come from managed point sources. Previous Report Card articles (see Wastewater Treatment, RC 1998 and Stormwater Impact, RC 1999) and a com-

Management of non-point sources is the most pressing coastal water quality issue in Southern California today.

(EPA) and local environmental groups has initiated new regulations aimed at reducing non-point source pollutants. It is to be hoped that these efforts, over time, will be as successful as the point source management programs.

REGIONAL COASTAL WATER QUALITY MANAGEMENT

A coastal watershed is defined by the fact that all the water raining or sprinkled on the ground flows downhill to the same location at the shoreline. This common flow path connects different parts and different functions of the watershed to each other. For this reason, watersheds have become the logical geographical context for modern water quality management, which is itself just one component of watershed management in the larger sense. Watershed management requires an understanding of the interrelationships among watershed components and human activities. The regulatory tool used by the U.S. EPA to limit Total Maximum Daily Loads (TMDL) of point and non-point pollutants discharged in the watershed is rooted in the total watershed management approach.

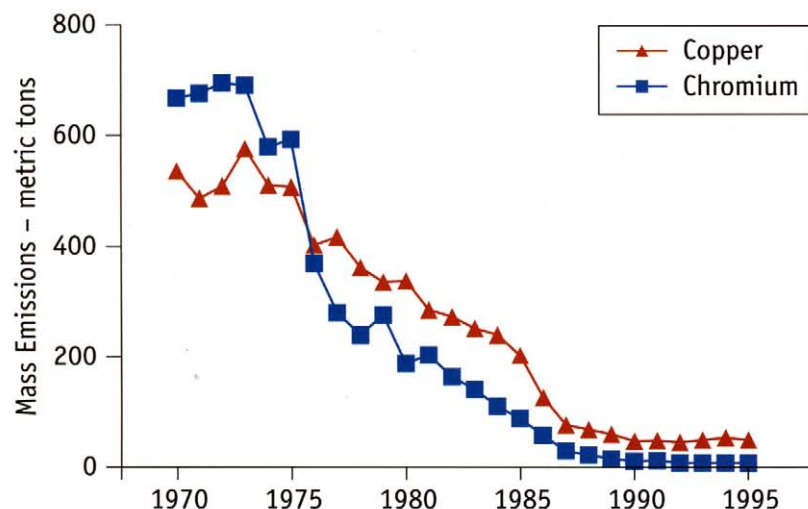


Figure 4: During the last three decades, improved treatment and source reduction have dramatically decreased the input of contaminants such as chromium and copper to the Southern California Coastal Ocean.

panion piece in this issue (see Households That Pollute, RC 2000) address the important issue of non-point waste flows from urban and agricultural areas. Non-point flows can be large volumes of water rushing to the ocean after storms or smaller dry-weather flows resulting from washing urban surfaces (parking lots, sidewalks, etc.) or irrigation of lawns and crops. Also, atmospheric pollutants can deposit directly on the water surface of the SCCO (see Figure 5).

Pollutants contained in non-point source flows include metals, hydrocarbons, and synthetic organic compounds, all of which can be toxic to humans and aquatic organisms. Also

important are nutrients such as nitrogen and phosphorus which may alter the natural system of algal growth, resulting in an overabundance of undesirable species. This "eutrophication" used to be restricted to lakes and reservoirs but is now increasingly commonplace in coastal regions, particularly enclosed bays and harbors. Other potential effects of non-point pollutants are species and habitat loss.

As discussed in the other Report Card articles, management of non-point sources to the SCCO from urban and agricultural areas is the most pressing coastal water quality issue facing Southern California today. Pressure from the U.S. Environmental Protection Agency

Regional management of coastal water quality would have many benefits.

The establishment of TMDLs, considering the benefits to the watershed as a whole, represents a renewed and more rational focus on the assimilative capacity of an ecosystem, but with more sensitive criteria and lower institutional thresholds for change.

The SCCO is interconnected in much the same way as a watershed. The ecosystem is comparably interconnected. Ecosystem functions, such as nutrient cycling and the food web, can only be understood by considering processes throughout the entire SCCO. Waste materials from both point and non-point sources are transported throughout the SCCO, making the health of the ecosystem at any one point potentially dependent on the regional total of waste inputs. So, it is surprising that the management of coastal water quality is still done locally rather than regionally. Point sources of waste continue to be regulated and managed individually; there is no process analogous to regional TMDLs being applied to the coastal ocean.

Regional management of coastal water quality would have many benefits:

- Decisions affecting water quality could be made on the basis of potential changes

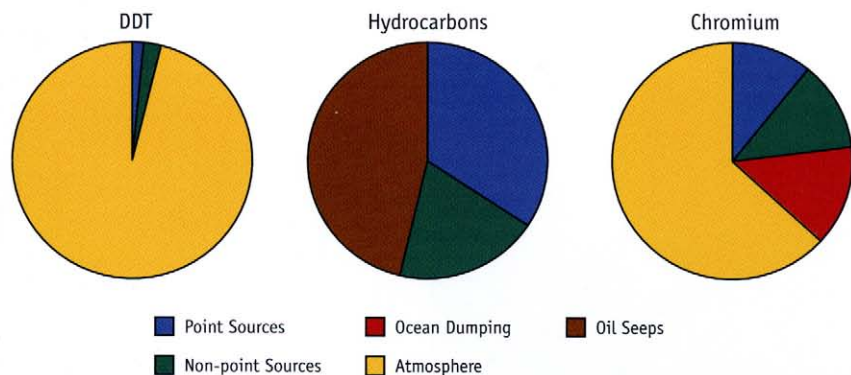


Figure 5: The sources of contaminants entering the Southern California Coastal ocean is different for each contaminant and may include significant contributions from the atmosphere, ocean dumping, and oil seeps in addition to point and non-point sources.

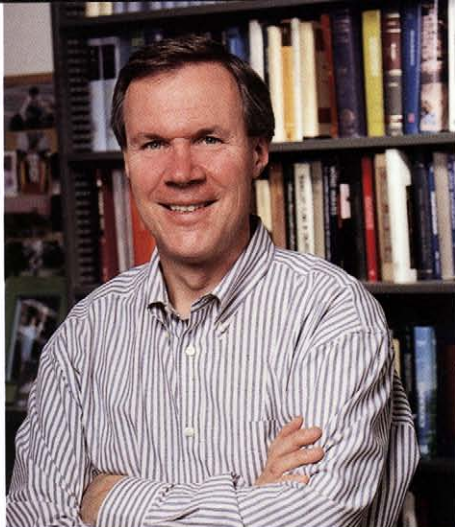
in the regional ecosystem.

- Waste inputs, point or non-point, could be better understood and managed with respect to local, regional, and cumulative effects.
- The relative effects of shoreline waste inputs and material carried into the SCCO by ocean currents from the north (the California Current) and the south could be delineated.
- The tradeoffs between land and ocean disposal of wastes such as sewage sludge could be quantified for policy makers.
- Regional monitoring programs would detect longer-term and larger-scale ecosys-

tem changes that remain undetected by local measurement programs.

- Effects from human activities could be distinguished from natural variability such as El Niño and La Niña.
- Regional management would focus attention on the protection of the vast “commons” of the SCCO.

To do good regional management requires good science and engineering based on good measurements and models. Regional measurements programs would include the use of satellite imagery, boat measurements, and fixed moorings (see Figure 6). Regional ocean models would



Keith D. Stolzenbach is a Professor in the Department of Civil and Environmental Engineering. His research deals with environmental fluid mechanics and transport, particularly the fate and transformation of natural and anthropogenic substances in natural water bodies and the interactions between physical, chemical and biological processes. He has been involved with the scientific and policy issues of coastal water and sediment quality issues in Boston and Southern California. He and Professor McWilliams are collaborating in the development of an ecosystem and water quality model applied to the Southern California Coastal Ocean. Although sewage can be interesting, his most memorable professional moment was diving 2500 meters deep in the Alvin submarine to make measurements of deep-sea hydrothermal vents. Professor Stolzenbach received his Ph.D. from MIT in 1971 after which he worked for the Tennessee Valley Authority. Before moving to Los Angeles in 1992, he was a faculty member at MIT for eighteen years.

provide integrated predictions of physical quantities such as water movement and temperature as well as ecosystem functions. These models would be predictive in a useful sense, but would rely heavily on the measurements for verification, calibration, and initialization. An example of our current ability to predict variability in nutrient concentrations and plankton growth and death is shown in Figure 7. These model results are strikingly similar to the satellite images shown in Figure 6. Both images highlight the interplay between physical and biological functions that must be understood.

GRADES

Point Sources: A. On the basis of observed improvements in the water and sediment quality over the last three decades, we give a high grade to the environmental regulators and facility operators for reducing waste discharges from managed point sources into the SCCO.

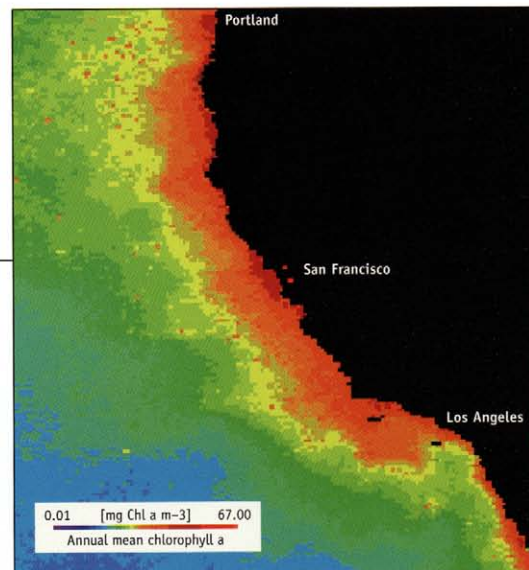


Figure 6: Ocean color measured by the SeaWiFS satellite can be used to determine the distribution of phytoplankton in surface water, shown in this figure in terms of the annual mean chlorophyll concentration along the U.S. West Coast. The higher values along the coast result from the upwelling of nutrient rich water.

Non-Point Sources: No Grade. It is to be hoped that efforts to regulate non-point sources discharging into the SCCO, over time, will be as successful as the point source management programs, but it would be premature to give a grade now.

Regional Management: C. We give only an average grade because of the current inco-

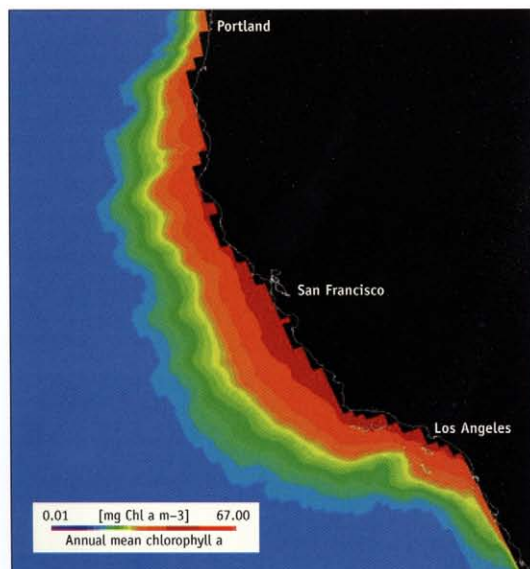
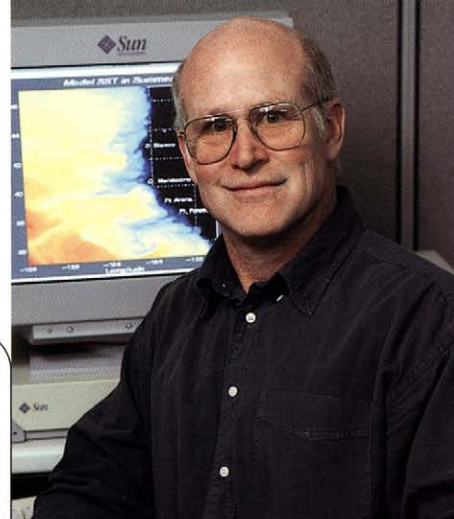


Figure 7: The Regional Ocean Modeling System applied to the U.S. West Coast by the authors simulates the response of coastal phytoplankton populations to nutrient inputs. The predicted annual mean chlorophyll concentrations in this figure are very similar to the SeaWiFS satellite measurements shown in Figure 6 except in the offshore regions that have open-ocean plankton populations not represented in the model.


herence of regional coastal water quality management in the SCCO. We give this grade expecting that future report card evaluations will see improvements in this important aspect of environmental protection.

ACKNOWLEDGMENTS AND SUGGESTIONS FOR ADDITIONAL READING

The authors thank Dr. Stephen Weisberg of the Southern California Coastal Water Research Project (SCCWRP) and Dr. Alan Mearns of the National Oceanic and Atmospheric Administration for their input to this article. Readers interested in additional material should consult the book *Ecology of the Southern California Bight*, published by the University of California Press, and the publications of SCCWRP (see www.sccwrp.org).



James C. McWilliams is the Louis B. Slichter Professor of Earth Sciences in the Department of Atmospheric Sciences and the Institute for Geophysics and Planetary Physics and a senior scientist at the National Center for Atmospheric Research. His primary area of scientific research has been the fluid dynamics of the earth's oceans and atmosphere, both their theory and computational modeling. In the past several years he has helped develop a three-dimensional coastal ocean model of the U.S. West Coast that incorporates the physical oceanographic and biogeochemical aspects of the coastal circulation. This model is being used to interpret coastal phenomena, diagnose historical variability in relation to observational data, and assess future possibilities. Professor McWilliams received his Ph.D. from Harvard in 1971 and worked at the National Center for Atmospheric Research for twenty years as a senior scientist in the Climate and Global Dynamics Division before coming to UCLA.



GRADE A+ to C

Drinking Water Quality

by I.H. (Mel) Suffet, Ph.D.

Professor, Environmental Science and Engineering Program and
Department of Environmental Health Sciences

INTRODUCTION

The majority of tap water the people in Southern California drink is imported. Sources include the Colorado River, the San Francisco Bay Delta, and runoff from the Sierra Nevada Mountains. Local sources, primarily water pumped from underground aquifers, account for only a small fraction. Most drinking water is transported to Southern California via a system of aqueducts, reservoirs, water treatment plants and a water distribution system operated by the Metropolitan Water District (MWD) of Southern California and the Department of Water and Power (DWP) of the City of Los Angeles. The Los Angeles Aqueduct, from the Owen's Valley and Mono Basin, carries water to the city of Los Angeles only.

The water utilities that provide drinking water to local customers work hard to deliver water of high quality; but how good is the water? The widespread use of bottled water in Southern California suggests that at least some people have concerns. This article addresses the question of drinking water quality for Southern California. After presenting background material, the current situation is described along with what the future might hold. Both the reality and perceptions of that reality are considered;

since the perception is often as important as the reality.

HISTORICAL PERSPECTIVE

Drinking water quality from the early 1900's to the late 1960's was primarily concerned with microbiological quality. Waterborne infectious diseases were controlled by disinfecting water supplies. Disinfection is the process of destroying or inactivating disease producing organisms (i.e., bacteria, viruses, protozoans, etc.). Water supplies are routinely disinfected but never sterilized (the process of destroying every living thing). Many people think potable water supplies are sterile, but they are not, and many contain non-harmful bacteria. Bottled and vended water may also contain non-harmful bacteria.

In the United States, and in many other places in the world, disinfection is usually performed by chlorination. Chlorination is the process of adding small amounts of chlorine (a few parts per million or mg/L), either from chlorine gas cylinders or solid hypochlorite, similar to adding chlorine to swimming pools. In the early twentieth century, drinking water disinfection dramatically reduced the occurrence of waterborne diseases such as cholera and dysentery, and disinfection ranks with the discovery of antibiotics as one of the

major public health accomplishments of the 20th century. In terms of risk, chlorination has allowed people to live long enough to worry about cancer.

Disinfection of public water supplies continues to this day, although we are much more sophisticated in our understanding of the process. Microbial water quality is extensively monitored by measuring residual chlorine as well as indicators of microbiological quality. Water purveyors measure residual chlorine at various points in the distribution system and maintain a small concentration of the chlorine disinfectant all the way to the consumer. The small residual prevents regrowth of microorganisms and also ensures the water supply has not been contaminated in the distribution system. In rare instances, non-potable water can flow backwards into the potable water system, a process called cross connection. Plumbing codes are designed to prevent cross connection; the vacuum breaker on sprinkler systems is only one of many devices to prevent cross connections.

Indicator organisms are also measured as a way of monitoring water quality, by indicating the presence or absence of pathogens. Indicator organisms are used because they are more numerous and more reliably measured than pathogens, which are usually too few in number to be reliably measured. For

Disinfection ranks with the discovery of antibiotics as one of the major public health accomplishments of the 20th century.

Primary Drinking Water Standards are “legally enforceable standards” developed by the U.S. EPA. The standards are developed as a Maximum Contaminant Level (MCL) for a chemical or a microbe. The MCL is the concentration that is not anticipated to produce adverse health effects after a lifetime of exposure, based upon toxicity data and risk assessment principles. The goal is to assure that even small violations for a period of time do not pose significant risk to the public's health over the long run. U.S. EPA drinking water standards as of January 2000 are summarized in Tables 1 and 2.

The states can set MCLs for other chemicals at or below the U.S. EPA level. The 1996 California Safe Drinking Water Act included the development of the office of “Environmental Health and Hazard Assessment” list of 46 chemicals as Public Health Goals, which could lead to new Drinking Water Quality MCLs specifically for the State of California.

Secondary Standards are not legally enforceable. Each U.S. EPA standard listed, as a cosmetic or aesthetic parameter is a recommendation. No health effects are involved, but a state may choose to adopt these as enforceable standards, as well as developing standards for other parameters. California has done this for the fuel additive MTBE.

Water purveyors usually employ the best water quality source available and then treat the water to minimize contamination risks. A key problem at each water treatment plant is to balance the disinfection process that kills pathogens while avoiding hazardous disinfection by-products. Also, California is one of the few states to develop two secondary standards based on taste and odor considerations. These are for MTBE and a rice herbicide breakdown product in the Sacramento Valley.

In many cases, it is the “non-enforceable” secondary standard, such as the musty odor of drinking water that is crucial to the general public's inaccurate perception of drinking water safety.

nitrate and arsenic. The 1962, U.S. Public Health Service drinking water standards included the key concept of using the purest water source available to protect against any unknown contaminants.

In 1970, researchers found byproducts from disinfection that are hazardous. When disinfectants are applied during drinking water treatment, chemical reactions occur in the water to produce these byproducts. However, the risk of these byproducts is far less than the risk of microbial contamination, and disinfection is still warranted. Since this discovery, researchers have improved disinfection practice to use minimum disinfection concentrations that provide protection from pathogens while reducing unwanted byproducts. A large investment in research and improved water treatment practices have shown there is an optimum dose of disinfectants. A series of regulations have been developed since 1974 to insure the development and use of better disinfection practices. Improved chlorine disinfection techniques as well as alternate disinfection methods (e.g., disinfection with ozone, chlorine dioxide and ultraviolet light) have been developed.

The first disinfection byproducts (DBP) observed are called trihalomethanes or haloforms, and the four most common are chloroform, bromoform, chlorodibromomethane

every pathogen, there may be thousands of indicator organisms. Newer microbial techniques are being developed to better measure pathogens, but it will be many years before these techniques are sufficiently reliable and economical enough to be used for routine monitoring. Coliforms are the most common indicator organism, and can be measured by several laboratory techniques. Coliforms, especially a subset called fecal coliforms, are always associated with human fecal pollution. Water purveyors analyze for coliforms at many places in treatment and distribution systems. If coliforms are detect-

ed, additional tests are performed to confirm their presence (false positives are common; one can easily culture coliforms from fingers, hands and poorly washed dishes). Confirmed presence of coliforms in a potable water supply is a cause for alarm, and corrective action is immediately warranted.

Federal regulations for drinking water to protect the traveling public began in 1914. The U.S. Public Health Service published mandatory drinking water quality standards to minimize exposure to chemical pollution, especially inorganic metals such as cadmium and lead and inorganic non-metals such as

The Treatment Process

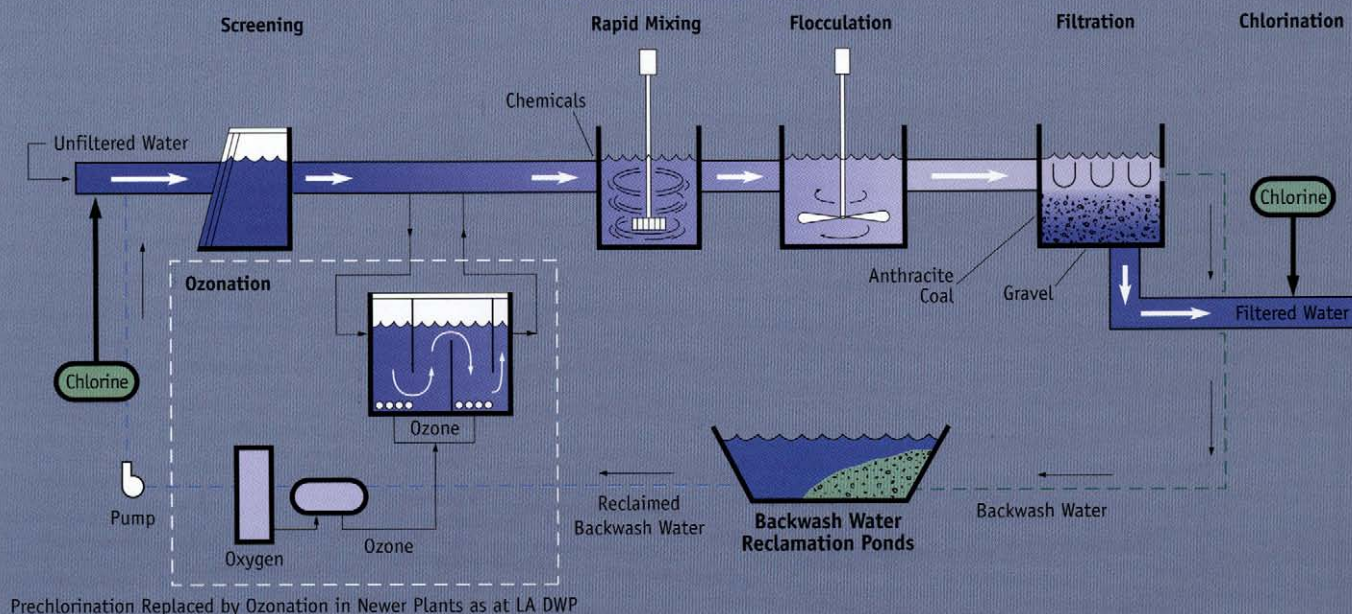


Figure 1: Schematic diagram of the traditional U.S. drinking water treatment plant using chlorination.

and dichlorobromomethane. They result from the reaction of chlorine and natural organic matter (NOM). Natural organic matter is present in varying concentration in all drinking water supplies. It results from the decay of vegetation in surface waters and its yellow-brown humus color is observed in many rivers and lakes. Much of the NOM is removed by water treatment processes. The residual concentrations of NOM in drinking waters have no apparent harmful effect to humans. However, the haloform DBP's can be a health risk above certain concentrations. Subsequently, it was learned that every disinfectant (e.g. ozone, chlorine dioxide and

chloramines) produces its own series of disinfection by-products that can have adverse health effects above certain concentrations. However, as with chlorine disinfection, there is an optimum dose range for the application of each disinfectant to protect the public.

There are other drinking water contaminants that can cause health risks. A popular movie, *Erin Brockovich*, described risks from hexavalent chromium, a metal formerly used to control corrosion in cooling systems. Cleaning solvents such as trichloroethylene (TCE) have also contaminated groundwater supplies. Methyl tertiary butyl ether (MTBE), a gasoline additive, is another example of

many instances of drinking water contamination from industry or agriculture. There are also naturally occurring contaminants, such as arsenic, which can present significant drinking water risk. Current water regulations are designed to protect us from these contaminants.

Building on these discoveries, the 1974 U.S. Safe Drinking Water Act (SDWA) authorized the U.S. Environmental Protection Agency (EPA) to establish national drinking water standards for "maximum contaminant levels" (MCLs). MCLs are enforceable standards for potentially toxic or carcinogenic chemicals. They are defined in part by risk



Figure 2: The LA aqueduct filtration plant which produces 600 million gallons of drinking water per day.

- A. The liquid oxygen (LOX) production facility is on the top right. (See Figure 3.)
- B. The ozone system is found in the building at the top center. The ozone generator is shown in Figure 4.
- C. The coagulation and sedimentation basins are the four open basins. (See Figure 3.)

associated with duration of exposure and concentration level.

In this context, the term “safe” drinking water does not mean absolutely risk free. “Safe” means the risk is very small and cannot be quantified, or that water quality limits cannot be lowered further by economical water treatment processes. For potential carcinogens, risk is typically quantified as an upper maximum limit, such as a lifetime risk of cancer of no greater than one in a million. This means there will be, on average, one additional cancer in a population of one million people drinking several liters of water each day, over a 70-year lifetime. Smoking less than a dozen cigarettes or taking one short trip on a freeway creates a similar risk.

For non-carcinogens, the goal is to limit exposure so there are no adverse health effects. Thus, the State Drinking Water Act of 1974 set MCL goals and enforceable “primary” drinking water standards for contaminants that may have adverse health effects. The SDWA also included (besides the use of the purest possible source water), the new concepts of using the most efficient available technology for removal of contaminants, monitoring MCLs, and evaluating acceptable risk based on the cost of treatment. In 1977, the U.S. EPA gave the California’s Department of Health Services (DHS) the responsibility to administer drinking water regulations in

California, (i.e. to develop, promulgate and enforce EPA drinking water standards). The California DHS proactively began a testing program of defining hazardous chemical “action levels” for any new and potentially hazardous chemicals. The DHS in October 1987 created 61 action levels, based upon criteria of toxicity, carcinogenicity and aesthetics (aesthetics in drinking water means taste, odor, color and clarity).

The action level concept is an excellent proactive approach to inform water utilities, consumers and other interested parties about local and state water quality problems. It can be viewed as an early warning system. However, the shortcoming of action levels is they are not enforceable. Water purveyors must voluntarily accept them; otherwise action levels will be ignored unless or until their customers demand compliance.

In 1989 the California Safe Drinking Water Act (AB 21) was adopted. This landmark legislation incorporated all of the requirements of the federal 1986 Safe Drinking Water Act Amendments. AB 21 was the first legislation in the U.S. that required public water purveyors to provide an annual report to their customers of the risk of water contaminants. This legislation insured that action level information be presented. In 1996, the California SDWA Amendment (SB 1307) created the first public “right to know”

legislation about drinking water in the U.S. and led EPA to require development of “consumer confidence reports” by all water utilities in the U.S. in the year 2000.

Regulations and research from the early 1970’s to the mid 1990’s was concerned primarily with chemical contamination of drinking water. However, the microbial risk for drinking water became clear with outbreaks of protozoan pathogens, such as the *Cryptosporidium* outbreak in Milwaukee WI. The 1998 EPA Interim Enhanced Surface Water Treatment Rule added new microbial monitoring requirements. The rule specifically set limits on the presence of two protozoan pathogens, *Cryptosporidium* and *Giardia Lambila*. These two pathogens resist disinfection by chemical means, and must be removed by filtration. A general turbidity requirement was created which assures adequate filtration be used at all water treatment plants. (Turbidity results in light scattering from small particles and turbid waters have a cloudy appearance. The presence of turbidity indicates the presence of small particles, which means that protozoans may also be present).

In summary, the EPA and the California DHS are both continually improving our drinking water quality by developing new rules and laws. However, public awareness of drinking water problems has led to a feeling among California consumers that bottled

**In terms of risk,
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water is a safe, albeit expensive, alternative to tap water.

WATER TREATMENT

Concern for potable water is the driving force for the development of the most appropriate and cost effective water treatment technology. Water treatment plant design until the 1970's was concerned with control of microbiological hazards of the raw water, and providing consumers with clear, colorless tap water free of taste and odor. The U.S. Public Health Service mandated that the most pure and pristine water supplies be used for drinking water. Drinking water quality standards, and the use of the most pristine water supply, are underlying tenants of water treatment to this day.

The traditional U.S. water treatment plant processes are shown in Figure 1. The raw water may be disinfected by chlorination at the head of the plant. After screening the water to remove large materials such as leaves, and twigs and pebbles, coagulation and flocculation are used to remove suspended solids. These two processes are designed to create large particles, or flocs, from very small particles. The larger particles can be effectively removed by sedimentation and filtration. Natural organic matter can also be removed. Coagulation includes a rapid mix of

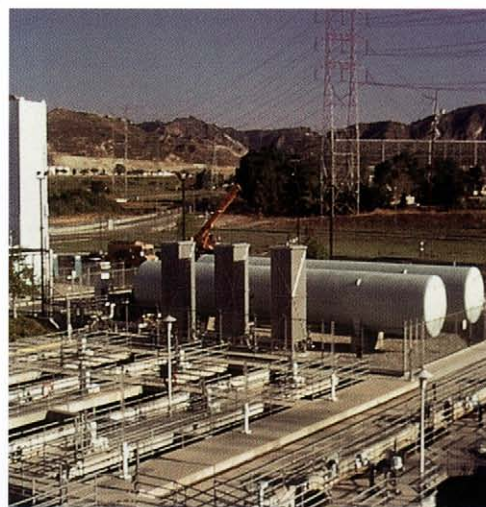


Figure 3: The liquid oxygen (LOX) production facility is a low temperature distillation plant. The LOX plant is on the left. This is the first LOX facility of its kind in the U.S. and has operated successfully for over 10 years. In the foreground of the LOX storage tanks (in the photo on the right) are the flocculation and sedimentation basins at the DWP, LA Aqueduct Filtration Plant.

aluminum or iron salts, which ensures the chemical coagulants are mixed quickly and uniformly. The water leaving the rapid mix flows through a slow flocculation basin with a set of slowly moving paddles. The aluminum and iron salts precipitate to create aluminum or ferric hydroxide flocs, which act like glue. The gentle mixing causes the particles to collide, sticking together to make larger particles. The water then flows to a sedimentation chamber where the large flocs settle out. The remaining particles are removed by filtration. The filters must be periodically back washed. Finally chlorination at the end of the plant enables a residual of chlorine (up to 1-3 mg/L) to maintain microbiological safety as the water is distributed to the tap. The entire process takes only a few hours.

It is important to note these traditional plants had no provisions to remove contaminants such as solvents (e.g., TCE), dissolved heavy metals, and contaminants of industrial origin (e.g., MTBE). It was unnecessary to provide such treatment because the source water was pure. The major difference in water treatment today is the loss of purity of the source water.

UPGRADING WATER TREATMENT IN SOUTHERN CALIFORNIA

Since the 1980s, with the new knowledge of microorganisms, the potential hazard of trace organic chemicals and the formation of disinfection byproducts, new water treatment processes have been tested. These include



Figure 4. Maintenance of the ozone generators, at DWP, LA Aqueduct Filtration Plant.

ozone for primary disinfection, chloramines for safety chlorination in the distribution system, activated carbon adsorption and/or biodegradation of organic chemicals, and membrane technology for turbidity, heavy metal or organic chemical removal. Figure 1 also shows as an insert the treatment modification at the Los Angeles Aqueduct Filtration Plant instituted in the 1990's. This plant uses ozonation rather than chlorine as the primary disinfectant. Ozonation is completed in four large contact basins. The coagulation process then follows this treatment and final safety chlorination occurs before the water enters the distribution system.

Ozonation is used as a primary disinfectant for the more effective control of bacteria, viruses, *Giardia* and *Cryptosporidium*. Ozonation oxidizes harmful chemicals in the water; however, it can produce its own set of disinfection byproducts, some of which can be biodegraded on a sand filter. Certain of the known DBPs of ozone, and especially bromate must be carefully monitored. Ozone treatment has the added advantage of removing compounds that cause earthy and musty tastes and odors due to the algae that grow in Southern California reservoirs. Ozonation costs more than the chlorination, but DWP decided it is the best current approach to address drinking water treatment concerns.

Until recently, the Metropolitan Water District of Southern California has continued to use the traditional approach of chlorination for drinking water treatment. In 1985, a new process called chloramination was added for disinfection and to minimize the taste and odor of free chlorine. Chloramination became the final disinfection step in the plant. After extensive pilot and demonstration scale testing in the 1990's to minimize chlorine DBPs, ozonation was chosen to replace chlorine as the primary disinfectant for the Jensen and Mills Water Treatment Plants. These plants treat State Project Water. Final chloramination is maintained as the disinfectant for distribution system residual, as well as for taste and odor control. MWD has become a world leader in the water treatment industry for developing technology to control taste and odors.

PUBLIC PERCEPTION OF WATER QUALITY

Water of high quality can be characterized by an absence of harmful chemicals or microorganisms. This assumes that the best water source available is used and the water is treated to assure that all drinking water standards are met. However, as better measurement tools are developed, new pollutants are found in drinking water. MTBE

is the most recent example. Therefore, continual diligence is essential.

Consumers tend to correlate drinking water safety with water quality aesthetics. Water purveyors must be concerned primarily about meeting primary drinking water standards, to satisfy the public that the water is safe. These two objectives are not the same. Meeting primary standards does not address secondary aesthetic concerns, which have been shown to be more important to consumer confidence than meeting standards. For example, an evaluation of seven consumer surveys by Torobin and coworkers in 1998 (American Water Works Association Conference Proceedings) showed consumers who reported fair/poor aesthetic water quality were the same ones who had less favorable perception of the safety of their tap water. Also, a low frequency of problems with off-flavors was the strongest predictor of a consumer belief that drinking water met the standards.

THE BOTTLED WATER OPTION

Bottled water is not risk free. Bottled water is considered a food product and is regulated by the U.S. Food and Drug Administration (FDA) rather than by the EPA. Bottled water is produced from a variety of water sources, including tap water. In fact, some cities, such

Table 1. Primary Drinking Water Standards – January 2000

DRINKING WATER CONTAMINANT	NO. OF STANDARDS	POTENTIAL HEALTH EFFECT	TREATMENT
A. Microbes and indicator organisms (e.g. Protozoans, Bacteria, Cysts)	8	Disease	Disinfection and Filtration
B. Inorganic Chemical a. Metals (e.g. Copper, Lead) b. Anions (e.g. Bromate)	20	Toxic Effect, Cancer	Precipitation, Coagulation and Sedimentation and/or Filtration
C. Radionuclides	4	Toxic Effect, Cancer	Precipitation, Coagulation and Sedimentation and/or Filtration
D. Organic Chemicals	60	Toxic Effect, Cancer	Aeration, Adsorption and/or Oxidation
E. Disinfectants (e.g. Chlorine and Ozone)	3 (Max. residual)	Toxic Effect	Limit Addition or Lower the Amount of Residual Disinfectant
F. Disinfection Byproducts (e.g. Haloforms)	Included in B and D above	Toxic Effect, Cancer, Birth Defects	Optimum Disinfectant Usage, NOMs Removal by Coagulation

Table 2. Secondary Drinking Water Standards – January 2000

DRINKING WATER CONTAMINANT	NO. OF STANDARDS	PROBLEM	TREATMENT
A. Taste and Odor Chemicals	1	Aesthetic (Taste and Odor)	Algae Control at Reservoirs, Treatment Options e.g. Adding Activated Carbon
B. Dissolved Solids (Salts)	1	Aesthetic (Taste)	Blending of Waters, Reverse Osmosis

People are voting with their purses and wallets when they buy bottled water. The common preference for bottled water seems aesthetically based: better taste and less odor, especially from chlorine. There is also a perception of greater safety, with an assumed lower concentration of microorganisms and chemical pollutants. However, tap water costs less and is at least as safe as bottled water because of drinking water standards. Water purveyors should value tap water the same as any essential food product, and address off-flavors with the same effort they employ in meeting health standards.

THE "WATER QUALITY REPORT"

Beginning this year (2000), consumers will receive water quality reports from their local drinking water purveyors as mandated by the right-to-know legislation. The "consumer confidence report" (CCR) is a landmark provision of the Safe Drinking Water Act Amendments, passed in 1996. In California, the CCR has been available since 1989, as the California Annual Water Quality Report.

Jim McInerney, Chair of the American Water Works Association's Water Utility Council, and participant in the development of the Safe Drinking Water Amendments, has urged water purveyors to take this require-

as Kansas City MO, are producing their own brand of bottled water from tap water. The source of bottled water is often used for marketing but frequently has no bearing on the safety or taste of the water. Pristine settings such as a natural springs are favorite sources but spring water may contain natural minerals (natural mineral water) or be carbonated (natural carbonated water).

Bottled water receives some type of treatment in a bottling facility. At a minimum bottle water is filtered and disinfected. Each company producing bottled water is free to process the water as it sees fit, sub-

ject to FDA oversight. In almost all cases, a form of ozonation disinfection is used, and no residual chlorine is added. Usually the bottle is sealed while ozone is still present in the water, but ozone soon dissipates. The bottled water industry has experienced recalls from the shelves of supermarkets for bacterial contamination, chemical contamination and taste and odor problems, such as plastic tastes. Bacterial regrowth can occur, and bacteria (such as those measured by heterotrophic plate count, which are usually harmless) can often be cultured from bottled water.



Bottled water is produced from a variety of water sources, including tap water.

ment seriously because of the opportunity it provides. The CCR “represents good management practice.” He urges purveyors to tell consumers what is right and what is being corrected. He stated: “Seize the opportunity with passion. The behavior of future water utilities will be driven by public need.” In effect, he has acknowledged that the public, for the first time, will directly participate in decisions on local drinking water quality. This completes a dramatic philosophical change from water utilities making decisions, “doing the best for the consumer” to “welcoming consumer involvement on water quality issues.”

Does the CCR enable a consumer to make an informed choice between drinking tap water, installing a home treatment device or purchasing an alternative supply of drinking water, such as bottled water? The CCRs are presented in many different formats from the simple to the complicated. Most CCRs present the local water purveyor’s view on its problems. For example, the City of Santa Monica may discuss MTBE in its well water and how it is handling the problem. After evaluating a series of California CCRs, it is clear consumers need a CCR that contains a general description of how well the water purveyor is meeting EPA standards, what this means for consumer safety in under-

standable terms, a candid discussion of the local water quality issues, and how the purveyor is addressing them. It is this author’s judgment that even the most sophisticated consumer will not understand a CCR that just lists the chemicals’ MCLs and simply asserts the concentrations are less than the detectable limits. The CCR should reflect good management practice and address the public’s need to know. Proactive effort on the part of a water purveyor to inform their customers of problems (such as the City of Santa Monica’s efforts to inform their customers of MTBE contamination is appreciated) and will build public confidence in the long run.

The growth of the bottled water industry clearly indicates drinking water is a major health and aesthetic concern. The CCRs are a wake up call to the water industry to include an informed public in their decision-making. It remains to be seen whether the water industry will seize this opportunity.

HOW WELL ARE WE DOING?

Safe, inexpensive drinking water is considered a right by almost every U.S. citizen. Inexpensive drinking water will depend upon maintaining our natural water resources and minimizing microbiological and chemical

contamination. However, the general public must be part of the debate on how to maintain water resources, how much to pay for new water treatment options, and how to help define what is good water quality.

Drinking water quality is usually considered in positive terms defined by the absence of chemical and microbiological pollutants. We have done well utilizing our best water resources for drinking water. However, watershed management is becoming an increasing problem because of population increases and greater recreational demand. Another concern is land development near our reservoirs which is causing increased non-point source contamination.

Over the last 100 years, scientists and engineers have defined “water quality issues” through their ability to detect microorganisms and measure small quantities of hazardous chemicals. We have successfully limited waterborne disease over the last century. Disinfectants work well against many organisms. A few major outbreaks of disease, especially involving *Giardia Lambila* and *Cryptosporidium*, led to the development of new EPA regulations requiring filtration at all water treatment plants, in addition to chemical disinfection. Also, new monitoring requirements have been instituted to document the daily level of protection against these organisms.

Water purveyors should value tap water the same as any essential food product and address off-flavors with the same effort they employ meeting health standards.

Water quality standards have been developed to minimize known chemical and microbial risks. The term "safe" drinking water does not mean risk free; it means risks are very small, at or below our ability to quantify them, or that water quality limits cannot be lowered further by economical water treatment processes.

We have done well to understand the chemistry of disinfection byproducts and limit industrial waste pollution over the last 25 years. However, non-point source pollution remains a problem. The two major water purveyors in Southern California are upgrading their treatment plant to remove chlorination byproducts, while adding a degree of microbiological safety by using ozonation. Besides the identification of hazardous chemicals, new water treatment processes such as membrane filtration, ozonation and biological treatments, are being developed for more efficient water treatment. These methods are costly now, but could reduce risks further.

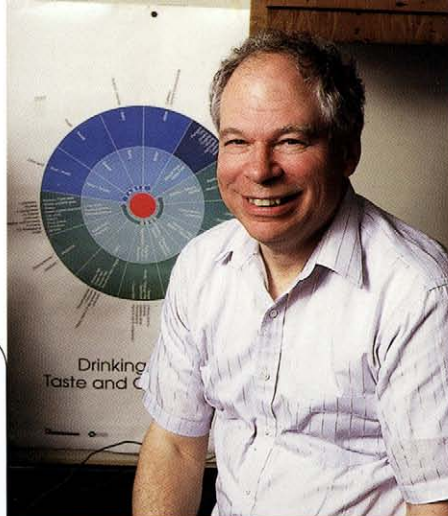
The public has a right to know. The CCRs being developed by the water industry should be used to develop an informed public and enable the public to be part of water quality decision-making. For example, consumers should be informed about the aesthetic quality of drinking water as well its healthfulness. It remains to be seen whether the water industry will seize this opportunity.

GRADES

Regulations: The EPA and the California DHS are both continually trying to improve our drinking water quality. The EPA gets a grade of B because of its slow pace in developing drinking water standards over the last 25 years. California DHS gets a grade of A, leading the nation in developing new laws to protect our drinking water, and for developing the first public "right to know" legislation in the U.S.

Treatment: The Los Angeles Department of Water and Power has upgraded their treatment plants to ozone/filtration and the Metropolitan Water District of Southern California will be upgrading two of its plants in a similar manner. These utilities get an A for their advanced technology (in spite of needing U.S. EPA's prodding), but receive only a C for their inability or unwillingness to involve the public in decision making.

Consumer Confidence Report: At present, CCRs from MWD and DWP are graded B+ and C respectively, based on lack of attention to the public's right to know. Santa Monica's CCR rates A+ as exemplary.



Mel Suffet has been a Professor in the UCLA Environmental Science and Engineering Program and Environmental Health Sciences Department in the School of Public Health since 1991, after 20 years as a Professor of Environmental Chemistry at Drexel University. Dr. Suffet has conducted research on aquatic chemistry in the laboratory and in numerous field studies resulting in more than 150 research publications and seven edited books. He received a Ph.D. from Rutgers University, an M.S. in chemistry from the University of Maryland and a B.S. in chemistry from Brooklyn College. Dr. Suffet has received the American Chemistry Society Zimmerman Research Award, Drexel University's Research Achievement Award and the UCLA Public Health Student Association's Distinguished Teaching Award. Professor Suffet's research emphasizes chemical analysis and elucidation of how organic compounds that are hazardous, or cause off-odors in the environment, interact in natural aquatic or water treatment systems. His current research includes: treatment of MTBE by activated carbon water treatment, the fate of carcinogens and pesticides in storm water runoff into Santa Monica Bay, an understanding of resuspension of hazardous chemicals the cause of off-flavors in drinking water distribution systems.

About the UCLA Institute of the Environment

The Institute of the Environment (IoE) was established at UCLA as an academic endeavor devoted to interdisciplinary research and teaching, aiming at the most daunting environmental problems that we face today. The Institute is composed of faculty from a broad range of disciplines—the sciences, public policy, engineering, law, business, and public health—working together to provide answers to complex and vexing environmental questions.

OBJECTIVES AND GOALS

The overarching goals of the Institute of the Environment are to:

1. Develop a world-class multidisciplinary environmental program spanning the full breadth of relevant disciplines, to address science and policy in depth with creativity.
2. Support and augment existing environment-related research and teaching activities at UCLA, and throughout the community at large, by providing expertise, infrastructure and guidance.
3. Attain, in the twenty-first century, a leadership role in environmental problem solving based on science and technology with social connections and community outreach.



TEACHING

The Institute of the Environment is enhancing the experience of undergraduate students by introducing them to many aspects of the environment within a broad yet consistent framework. The classroom work is augmented by student contact with the Institute's diverse research programs, including fieldwork at remote UCLA facilities such as the Stunt Ranch Natural Reserve in the Santa Monica Mountains and the Ocean Discovery Center on Santa Monica Bay. Graduate students participate directly in a wide range of ongoing research projects, both in the field—at Point Mugu Lagoon, for example—and in the laboratory—including experimentation, computer modeling, and Geographic Information Systems applications.

The Institute is currently developing a series of multidisciplinary courses at all teaching levels at UCLA. Environmental Minors are being organized in six key areas: life sciences, physical sciences, engineering, social sciences, public health, and public policy. A graduate degree program is being planned.

RESEARCH

Institute of the Environment faculty, research scientists and students conduct a broad range of investigations, all of which have an environmental theme, and many of which focus on Los Angeles and Southern California. For example, the Institute's Los Angeles "watershed" project involves a dozen faculty from eight campus units. An even larger "airshed" project, housed in the new Southern California Particle Center and Supersite, now represents the central university-based air quality research program in the LA region. Some other current research initiatives include:

- An Intel-sponsored Regional Environmental Assessment Laboratory and Geographic Information System (REAL/GIS)



laboratory, in which integrated analyses of regional environmental problems are carried out.

- An EPA-funded project to identify the airborne sources of pollution to Santa Monica Bay.
- A number of new research efforts in Lower Malibu Creek and Lagoon, and in the wetlands at Mugu Lagoon.

OUTREACH

The Institute of the Environment continually seeks to reach out to the surrounding communities. This *Southern California Environmental Report Card* provides an annual assessment of the state of the local environment. Through the *GLOBE in the City* program, the Institute brings environmental science directly to the classrooms and lives of K-12 students across Los Angeles. Seminars and colloquia from many different disciplines are also sponsored, where divergent interests and talents can converge. Conferences have dealt with topics such as "Environment, Commerce and Opportunity,"

"The Environment of Southern California in the 20th and 21st Centuries," "The Loss of Nature in an Urbanizing World," "Health, The Environment and Development," and "Where Air and Water Meet." In 1999, the Institute hosted the prestigious National Conference of the Society of Environmental Journalists.

LOOKING AHEAD

Over the next few years, the Institute of the Environment will consolidate its role in interdisciplinary teaching and research at UCLA, and in environmental research throughout Southern California. Large projects are planned in the areas of air quality forecasting, watershed science and technology, coastal ocean resource management, and global earth system modeling. For our students, new courses will be introduced in these areas as well. Further, the Institute will continue to support unique outreach programs such as this Environmental Report Card and the GLOBE educational initiative.

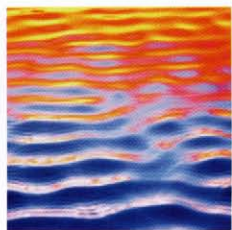


Hershey Hall houses the IOE's offices.

RC 1999 Revisited

GROUNDWATER QUALITY

The RC 1999 article on Groundwater Quality in Southern California triggered an interesting sequence of events. Shortly after its release in September 1999, the Los Angeles Daily News published several articles and an editorial calling attention to the groundwater problems in the San Fernando Valley. These news pieces created an uproar because many people in the Valley had apparently forgotten the designation of the area as a Superfund site well over a decade



ago. In particular, the RC 1999 article inspired the Los Angeles City Council to request a status report on clean-up activities by the Department of Water and Power (DWP), the agency engineering the Valley's groundwater remediation plan. Richard Nagel, working at the Upper Los Angeles River Area Watermaster's Office and DWP at the time, was charged with making the October presentation. He contacted UCLA shortly before that time to invite Institute researchers to attend the City Council Meeting. Phone calls from the U.S. Environmental Protection Agency's (USEPA) Region 9 office, overseer of this Superfund site followed shortly thereafter.

As author of the RC 1999 article, I feel compelled to comment in the wake of these reactions. First, I must admit that I did not anticipate the emphasis that readers would place on that part of the article recounting the contamination of the San Fernando Valley. The discussion of the SF Valley Superfund site was intended solely as an illustrative anecdote. In hindsight, of course, it becomes obvious the average reader might relate most strongly to aspects pertaining to his or her own backyard. Thus, for the record, it is important to note that a substantial amount of work has gone into characterizing the contamination, and starting the remediation of Valley groundwater. The current strategy is to capture the contaminated groundwater at the eastern end of the Valley by pumping a total of about 13,000 gallons per minute. Newly fabricated treatment plants will then employ airstripping, carbon adsorption and disinfection to clean this water. The current plan is to blend the treated water into the existing distribution system. For those interested in details and public hearing information, the USEPA maintains an excellent web site regarding this and other Superfund sites (<http://www.epa.gov/region09/waste/sfund/npl/siteinfo.htm>). A public hearing regarding the drinking water aspects of this project was scheduled for Glendale residents on June 22 (after RC 2000 went to press).

Despite the apparent progress in the San Fernando groundwater basin, it is

important to understand that on-going efforts will control the problem, but will not correct it. The dilute plumes addressed by the pump-and-treat represent less than 1% of the total solvents in the groundwater basin. Substantial volumes of undissolved solvents are scattered throughout the groundwater system and will continue to dissolve for many years. In fact, if we assume there are several hundred gallons of solvent harbored deep in these aquifers, then we expect to have to maintain the new treatment systems for centuries. A more proactive strategy would attempt to locate and remove these residual solvents. If successful, such efforts can have a much greater impact on groundwater quality. With the plumes under control, now is the time to implement such a strategy.

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ENVIRONMENTAL EDUCATION

Unfortunately, there has been no dramatic increase in the attention given to Environmental Education (EE) over the past year. Science education continues to center on the California Science Education Standards (CSCS) that contain no environmental science per se.

However, there is some good news and some bad news gleaned from data on the Advanced Placement (AP) Environmental Science course offered over the past two years in Los Angeles Unified School District (LAUSD) high schools. In the 1998-99 school year, 10 out of the 49 high schools offered



this AP course, 155 students took the test and 60 passed. In the 1999-2000 school year, 15 schools offered the course, 413 students took the test, and 149 passed.

The good news, of course, is the fact that more schools are offering the course and more students are being exposed to an environmental science program. The bad news, however, is that the percentage of students passing has not increased; in fact it has decreased from 39% to 36%.

This may well indicate that an increasing number of high school teachers although willing to teach the course are, for some reason, not adequately prepared to do so successfully. This is not surprising. AP courses have very challenging curricula and most of today's teachers, unless they are new graduates with exposure to environmental science in their college coursework, will not have the appropriate environmental science backgrounds. It would seem that the time is

right for the development of good professional development programs for these teachers, preferably offered by university faculty who have cutting edge experience in this area of science.

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STORMWATER IMPACT

The 1999 Environmental Report Card was presented at a press conference at UCLA in conjunction with the annual conference of the Society of Environmental Journalists.



Similar responses were soon heard from members of Heal the Bay and the Natural Resources Defense Council. Environmental groups and regulators generally felt the grading was too lenient. Agencies responsible for stormwater management agreed with the grade and appreciated the "B" for recognition of the difficulty of the problem.

Soon after the presentation, a well-known and respected journalist said to me: "Where do you get off giving a B for stormwater?"

A lot has happened since the summer of 1999 with stormwater management. Several groups and state agencies have made significant progress in addressing stormwater issues. In November of 1999, I testified at a joint hearing of the California Assembly Coastal Committees on Coastal Protection and Natural Resources. The message was "you can do something about stormwater pollution." As a result of this meeting, a bill was introduced by Assemblywoman Hanna Beth Jackson to authorize and fund a \$500,000 pilot program to evaluate catch basin insert devices (these devices were described on page 19 of RC 1999). The bill includes wording to require consultation with the University of California. The City of Santa Monica has installed several hundred of these devices and their operation will be important in developing this technology. The City also installed a circular screen (also described on page 19 of RC 1999) at the Santa Monica Pier. Early reports show great success in preventing litter and debris from spoiling the Bay.

Interest in stormwater management has dramatically increased in the past year. Heal the Bay pushed legislation to develop sanitary surveys (AB538) to locate unknown sources of fecal contamination of storm-drains. UCLA will be the prime contractor and will lead the effort by working with management agencies to develop the best techniques to quickly detect spills of sewage and other materials into storm drains. The tech-

niques will be based in part on "lessons learned" from previous spills, but also will include new techniques for chemical and biological markers in waters.

Such an unknown source closed Huntington Beach for a large part of last summer. Indicator organisms remained high throughout the summer. It was disastrous for Huntington Beach and cost more than \$1,000,000 in lost revenue alone. Detective work to find the source of the indicator organisms cost even more. The major source is still unknown, and everyone is hoping it does not occur again this summer. Early work established that obvious sources of spills, such as a leak in the Orange County Sanitation District's (OCS D) sewage outfall, were not the culprit. Many small sources, such as public sanitation facilities on beaches, were identified and fixed, but were judged too small to have caused the problem. Low flow stormdrains that discharge into the Talbot Marsh were also implicated. After diversion of this discharge to sanitary sewers, indicator organisms declined, but not enough to produce the desired result. The source has still not been identified. Research is in progress by OCS D and engineers from UC-Irvine that may disclose the source and suggest prevention techniques.

There is a "silver lining" to this event, which is the allocation of new resources to detect and avoid similar problems in the future. The closure of an important econom-

ic resource due to pollution sends an unmistakable message to business and government alike. Many agencies are participating in beach water quality workshops to learn how to avoid similar problems. The State Water Resources Control Board is leading this effort.

Low flow diversions of stormdrains to sanitary sewers (also described on page 19 of RC 1999) continue. The City of Los Angeles has completed diversion of Santa Monica Canyon Storm drain and others are in progress. The Los Angeles County Sanitation Districts is also assisting in low flow diversion. OCS D has implemented a program around Huntington Beach, and new developments such as the Irvine Company's Crystal Cove project are using this technology. This approach to avoid dry-season urban runoff problems is an excellent use of public resources. The initial construction may be expensive, but the beneficial effects are long term and constitute a proven way of protecting beaches from urban runoff.

Other problems with stormwater runoff continue. The number of non-filers for stormwater permits continues to be high because regulators have too little staff to ensure compliance. The good news is the regional water quality boards are hiring new staff to address this problem, as well as developing total maximum daily loads for stormwater pollutants. We will see more action from our regulators.

The most important event in the past year was the adoption by the Los Angeles Regional Water Quality Board of a new requirement for stormwater management. They were encouraged by Heal the Bay as well as many influential stormwater experts. New developments must now either treat, or contain by infiltration, the first three quarter inches of each rainfall. Many areas outside California already have such rules. This requirement may not be easy for all developers to implement, but will provide significant environmental improvement as well as additional flood protection. Some cities and many developers have opposed the rule. The Los Angeles County Department of Public Works is supporting the rule and is holding workshops to help developers comply.

This update resembles the RC 1999 article and the grade assigned. We continue to have a substantial and difficult problem without clear-cut, easily implementable solutions. The solutions will be small scale and will occur over many years. We are pleased to see progress and will do our part to ensure continued improvements.

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RC 2000

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11, 19, 28, 29, 39)
Ernesto Rodriguez (20, 24, 38)
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Joseph Sohm; Chromo Sohm Inc./
CORBIS (9)

Courtesy of South Coast Air Quality
Management District (14)
Michael K. Stenstrom, Ph.D., P.E.
(10, 40, 41)
Tecmap/CORBIS (42)

Figures/Diagrams

Yoram Cohen, Ph.D. (14, 15, 16, 17, 18, 19)
Ecology of the Southern California Bight,
University of California Press, 1993
(22, 27)
Chul Hur (41)
Los Angeles Department of Water and
Power (33)
Keith D. Stolzenbach, Ph.D., P.E. and
Jim McWilliams, Ph.D. (23, 28, 29)
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