quence the entire *Escherichia coli* genome, led by Takashi Yura of Kyoto University, has been folded into this effort but retains independent support. A separate program, funded by the Ministry of Agriculture, is also under way to develop a physical map of the rice genome.

Riken. Japan's first venture into genome research began in 1981 when the Science and Technology Agency funded Akiyoshi Wada to develop automated sequencing technology at the Institute of Physical and Chemical Research, better known as Riken, in Tsukuba City. Now, reported Shimizu, Wada has left and that project has been transferred to the private sector.

Under the new project leader, Yoji Ikawa, the Riken Institute has two programs, with a yearly budget of about $1.5 million. One is a collaborative effort with Maynard Olson and his colleagues at Washington University in St. Louis to sequence a small yeast chromosome. The other is to develop a physical map and, eventually, to sequence human chromosome 21.

Yoken. Japan's equivalent to the NIH, Yoken, is negotiating with the Ministry of Health and Welfare for funds to seek out and then sequence the genes that cause human disease, with an eye toward diagnostic and therapeutic applications. The agency is angling for a budget of $2 million, and the program is expected to begin next year.

Genosphere Project. This year the Research and Development Corporation of Japan, a semigovernmental organization located in Tokyo, launched the Genosphere Project, with a budget of $14 million to $18 million for the first 5 years. The focus is on understanding chromosome function and structure, but the program has a hefty component of technology development as well. Researchers have already developed a laser beam microdissector for slicing chromosomes under a microscope, and they are working on new equipment that will enable them to observe chromosome movement during cell division.

Human Frontiers Science Program. While the genome project does not figure explicitly in the new Human Frontiers Science Program—Japan's international effort in basic research—funds are available for genome research, said Shimizu, "if researchers are smart." The Science and Technology Agency and the Ministry of International Trade and Industry, or MITI, have contributed about $24 million to Human Frontiers for 1990. Under the program, some 2 dozen grants will be awarded to international teams of scientists working in two broad areas: neuroscience and the molecular basis of biological functioning.

■ LESLIE ROBERTS

Mud-Slinging Over Sewage Technology

Scientists in Boston and San Diego have recommended a money-saving technology for treating waste water, but EPA is opposed

MIT ENGINEEER DONALD HARLEMAN ought to be the most popular Bostonian since Carl Yastrzemski roamed Fenway Park. Though he has not proved a heavy hitter for the city as yet, he's suggested a way to clean up infamous Boston Harbor while saving local taxpayers $2.5 billion in sewer construction costs.

Sound too good to be true? That's the way the city's environmentalists and the Environmental Protection Agency (EPA) see it. They have rejected Harleman's contention that Boston, whose notoriously dirty harbor was made an issue in last year's presidential elections, should use an innovative—and, he contends, far cheaper—method to treat waste water. Harleman's persistence in pushing his proposal has rankled them so much that the current chief of the White House Council on Environmental Quality (CEQ), Michael Deland, when he was the EPA's regional director in Boston, wrote a letter to the president of MIT, complaining that Harleman was "fomenting public dissatisfaction" with federal plans to clean up Boston Harbor.

If Harleman is giving EPA headaches, it's not because he lacks credentials. He is the current chairman of one of EPA's own advisory committees—the one that evaluates federal researchers' modeling of the Chesapeake Bay—and he is also the former director of MIT's water resources and hydrodynamics laboratory and a member of the National Academy of Engineering.

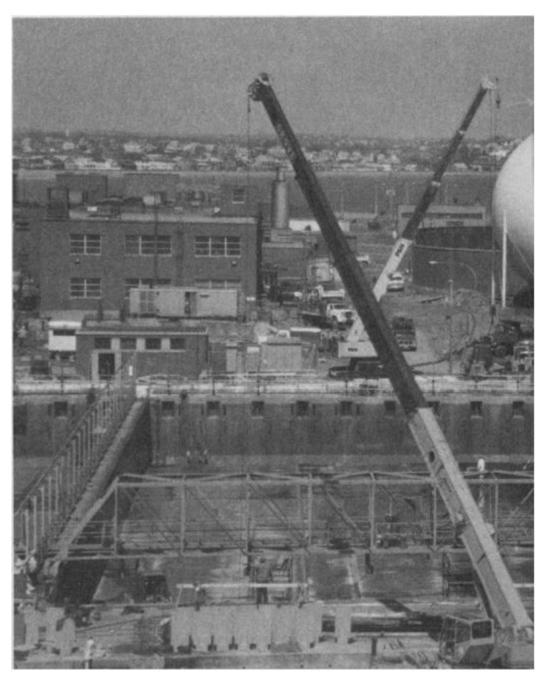
Harleman is only one of several notable researchers who claim that there is a better way for some coastal cities to get rid of waste water. For example, several scientists at Scripps Oceanographic Institution, including former director Roger Revelle and chemist Edward Goldberg, recently became embroiled in San Diego politics when they voiced strong support for the very method Harleman has been touting back in Boston—advanced primary treatment with polymer technology.

But their battle is a different one from Harleman's. For one thing, their hometown sewage plant at Point Loma has been using an advanced primary system with polymers since 1985. To the Scripps scientists, it's a good method and the city should stick with it. But because San Diego is still out of compliance with federal water quality standards—its offshore waters have high coliform counts in a kelp bed—the city has been sued by the EPA to compel it to build a secondary system.

As Harleman has argued for Boston, Revelle, Goldberg, and several other Scripps scientists have argued in the San Diego case that the construction of a secondary treatment plant at Point Loma would be squandering a fortune. They have said that the proposed plant would cost $750 million to build but would do only a marginally better job than the current system. The Scripps scientists also contend that the EPA is mistaken in claiming that effluent from the advanced primary plant at Point Loma has harmed the marine environment.

EPA has fired back. It argues that Point Loma's effluent has changed the marine ecology near the outfall. Who's right? The city set up a task force to tell it whom to believe.

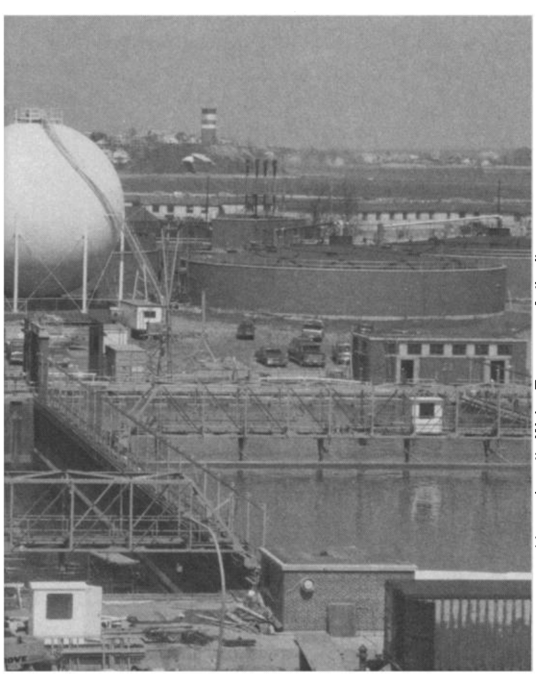
On 12 September, the verdict was announced and the scientists won the day—at least for the present. The task force recommended to the city council that the construction of a secondary treatment plant at Point Loma be delayed for 25 years and that the city instead spend funds on water reclamation.



Coincidentally, that very same day Harleman won his own victory. Largely at his urging, the governing board of the National Research Council approved a proposal to undertake a 2-year, wide-ranging study of various waste water treatment methods, including advanced primary treatment. Even if the research council eventually endorses advanced primary treatment, it would be too late for the many cities that have already built secondary treatment plants.

But for coastal cities with growing populations, such a verdict, if it were incorporated in the nation's environmental laws, could save an enormous amount of money and big environmental headaches in the future. Construction costs for sewage treatment plants, in fact, are already increasing dramatically at the local level because 2 years ago a provision in the Clean Water Act mandated a phase-out of federal subsidies for sewer construction, shifting the burden to states. The federal contribution has now dropped from 75% to 55% of capital costs and will be halted by the end of fiscal year 1990. Instead, the federal government is providing grants to states to create a fund from which municipalities obtain loans for sewer construction. But federal grants to this program will be phased out by 1994.

The problem now facing Boston and San Diego goes back 17 years. When Congress passed the Clean Water Act in 1972, it mandated that all cities that dump waste into waterways treat their sewage through secondary treatment. At the time the advanced primary method was in its infancy as a technology. Secondary treatment, however, was already an established method to remove a majority of the suspended organic particles and substantially lower the biochemical oxygen demand (BOD) in waste water. BOD is a measure of the organic material in the water, which, if too high, can lead to fish kills.



Massachusetts Water Resources Authority

Boston primary. *New city sewage plants under construction—and under fire.*

In the absence of alternatives, today nearly every major city (Boston and San Diego are the glaring exceptions) has, or will soon have, secondary plants on line. To the EPA, that's quite an accomplishment. Tudor Davies, director of EPA's office of marine and estuarine affairs, says, "There have been enormous benefits from secondary treatment." Many waterways have made a biological comeback as a result of secondary treatment, including the once fetid Potomac River, he says.

But Harleman and the Scripps scientists say that the federal law stipulating that all major cities build a secondary system is anachronistic and unnecessarily rigid, given the gains in advanced primary treatment. Secondary plants, which rely on the addition of biological organisms to remove organic material left over after primary treatment, aren't merely very expensive to build, operate, and maintain, they also create an enormous amount of sludge. Every day in some major metropolitan areas, a hundred tons or more of sludge are generated—a mass of organic material that has become a double-edged sword.

On one hand, sludge formation coincidentally removes toxic chemicals from the treated effluent before it is flushed into rivers, lakes, or the sea. But, on the other, the disposal of sludge laced with toxics poses a huge environmental problem that is only going to get worse (*Science*, 28 October 1988, p. 507). Cities are putting their contaminated sludge into landfills, for which space is increasingly hard to find; burning it, which critics say pollutes the air; or dumping it back into the ocean far offshore—a practice that EPA will no longer permit after 1992. Uncontaminated sludge that meets EPA cleanliness standards is sold as fertilizer to sod farms and golf courses, for example.

According to Harleman and others, advanced primary treatment has two major advantages over secondary processing: it doesn't require major outlays in capital, provided that a city's primary treatment system is already in good working order; and it generates much less sludge.

The trade-off is that advanced primary treatment removes about 10% fewer suspended particles from the waste. But along the Boston and San Diego coasts, at least, the ocean currents dilute the additional pollutants rapidly enough to avoid environmental problems, Harleman and the Scripps scientists say. The same may apply to future, newly expanded coastal urban areas.

Norman Brooks, an engineer at the California Institute of Technology who has consulted for Boston and San Diego, says that the sea can handle the small proportion of additional waste that advanced primary treatment does not remove. The ocean "is an ecosystem that already handles waste and it's a big reservoir of dissolved oxygen," Brooks says.

But to Peter Shelley, an attorney for the Conservation Law Foundation, a Boston-based environmental organization, sacrificing sludge formation isn't worth it because more toxic chemicals end up in the ocean. Even though secondary treatment generates more sludge, "on land, you can monitor contamination easier because it's contained" in a landfill. "It is too unpredictable what happens if waste or sludge is released in the ocean," he says. Harleman and Goldberg's response is that toxics should be kept out of city sewers in the first place.

What exactly is advanced primary treatment? The concept first arose in the late 1970s when sanitation engineers tried adding various chemicals, including alum, lime, and ferric chloride, to primary-treated waste water to remove more suspended particles. The method worked, but operation and maintenance expenses were too costly. So the method was not widely adopted.

But in the past few years, the development of new polymers has substantially improved advanced primary treatment, Harleman says. "It's the technology of the future," he says. The polymers—long, charged hydrocarbon chains mixed with ferric chloride—electrochemically precipitate out suspended particles. The process doesn't produce as much sludge as secondary treatment because the polymers take up less volume than the biomass created by bacteria. San Diego's advanced primary system produces an average of 117 dry tons of sludge a day, while a secondary plant would generate about 145 dry tons, city officials say.

This isn't just theory. Three large municipalities in the nation, including San Diego, already use an advanced primary system with polymers and ferric chloride. (The other two are also in southern California: Orange County and Los Angeles County.)

So why is EPA suing San Diego to build a secondary system on top of its state-of-the-art primary one? EPA's regional office in San Francisco has argued that federal law requires it and that the coliform counts from the effluent are unsafe for skin divers who swim in kelp beds near the outfall.

But Susan Hamilton, deputy manager of San Diego's water utilities department, says, "We spent 2 years studying whether divers got sick from diving in kelp beds. There's no direct correlation between diving in the kelp beds and illness." Nevertheless, the city is now proposing to extend the plant's outfall pipe a mile beyond the kelp beds.

Fred Leif, chief of compliance of EPA's regional water division based in San Francisco, says that the agency is also concerned about the changes in the ecosystem of marine organisms. To obtain a federal waiver from secondary treatment, San Diego would have had to demonstrate that an alternative method will not cause a change in the "balanced, indigenous population" of marine organisms—a very stringent test, Leif concedes.


MIT

Donald Harleman

But the effluent has caused a drop in the population of brittle stars, for example. Scripps scientists don't deny the change, but contend that it is localized and has not been harmful. Paul Dayton, a marine biologist at Scripps, says that brittle stars, which are as abundant in the ocean "as grass in prairie," are not the least bit endangered.

He adds that he has not observed any changes in the health of the kelp forest near the outfall. These plants may be some of the most sensitive indicators of marine pollution, says Dayton, who has studied the kelp forest for more than a decade.

Goldberg presents a different argument: altering the ecology around the outfall "is a small price to pay" for the reduction in sludge. "You should place sludge where it least affects the environment, and the ocean is extremely useful as waste space." Hamilton says that putting sludge in landfills is a waste of precious space and also risks contamination of ground water.

To Harleman, San Diego's track record provides the best evidence that the polymer technology can work for Boston. The method currently gets rid of an average of 75% of the suspended solids. "We could go to 80%, but it creates too much sludge," contends Hamilton. A secondary treatment plant removes about 85% when it is operating properly.

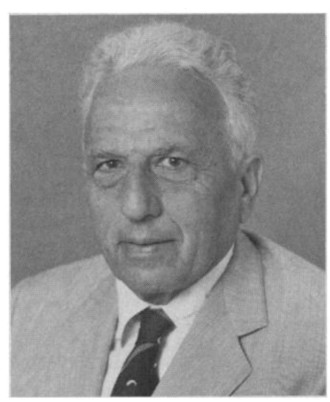
EPA officials on the East Coast aren't buying, but their reasons for rejecting advanced primary treatment differ from those of their West Coast colleagues. They have raised legal objections. Boston applied twice for a waiver to the secondary treatment requirement, but was denied. Then a federal court ordered the city to install a secondary plant. Davies of EPA says, "We have a process of law. The regulations were challenged and they were upheld. It's the law of the land now" that Boston must comply.

As a result of the court order, Boston is now building a whole new primary and secondary system, an endeavor that constitutes the biggest public works project in New England's history. Boston's present primary treatment system is so antiquated that it currently dumps 500 million gallons of partially treated waste water into Boston Harbor. (In fact, the Smithsonian Institution asked city officials if it could acquire one of the city's sewage system's 100-year-old steam-driven pumps for museum display, but Boston's Metropolitan Water Resources Authority had to decline because the pump is still in use.)

Deland of CEQ says that Harleman's justification for advanced primary treatment is "a regurgitation of arguments long since refuted." EPA officials say that Boston officials considered advanced primary treatment as an option when it applied for a waiver, but decided the process was too expensive. Deland says, "It wasn't labeled as such in the waiver, but it's now just dressed up in a different name. We've seen nothing new that wasn't in the waiver request."

This annoys Harleman, who was a consultant to the city water agency during the waiver process, and he says that the polymer technology evolved after Boston applied for an exemption.

But that argument didn't stop EPA's region 1 office from writing a technical rebuttal of Harleman's arguments this summer in response to an inquiry by Representative Edward Markey (D–MA). The agency said advanced primary treatment was unacceptable because it would not remove enough suspended solids, organic material, or toxic chemicals. Although Harleman contends that suspended solids would disperse in Massachusetts Bay, EPA concluded that the particles would clump during their 9-mile journey through the outfall tunnel and then settle near the end of the pipe.



Edward Goldberg

Harleman says that EPA isn't paying attention to the gains in polymer technology. He says that if the city used advanced primary treatment, it could save $2.5 billion (in inflated dollars) if it does not spend money on steel, concrete, and other capital to build a secondary plant. He says the savings should be used instead to improve the city's dilapidated sewer and storm system, which constantly overflows with raw sewage during heavy rains and causes frequent closings of beaches and shellfish beds.

Other experts say it is too difficult to sort out who's correct on the technical issues without a lengthy analysis. James Stahl, deputy manager of the Los Angeles County sanitation district, says that sedimentation velocity is "very tricky to predict. It's site-specific and depends on waste water."

"Harleman raises some interesting issues, but no one knows if he's right," says Michael Connor, director of harbor studies at the Massachusetts Water Resources Authority.

They can also differ—endlessly, it seems—on economic issues. EPA and Harleman dispute the costs of building and running an advanced primary plant. EPA estimates that an advanced primary plant could cost as much in capital and in operating and maintenance costs as secondary treatment. Harleman says that the agency's figures are "ridiculously high because they're based on the old lime and alum technology." Stahl of Los Angeles County and Hamilton of San Diego were skeptical about EPA's estimates, but added that calculating these kinds of costs is complicated.

So, if reasonable people can differ, should the whole issue be declared moot? CEQ chief Deland, in his letter to Paul Gray, said, "The time for challenging the EPA waiver determination has come and gone. Professor Harleman, however, has not given up the ghost. . . . Upon proper proof, he may persuade Congress; until those changes are made, however, fomenting public dissatisfaction through the press falls well short of our expectations for a senior MIT professor."

Paul Levy, director of the Massachusetts Water Resources Authority, says it's pointless for his agency to evaluate advanced primary treatment now. The method "isn't relevant because the judge has ruled. Unless there's a change in federal standards, we as the defendant, aren't going to go back into court and argue for [advanced primary treatment]. It's wasted energy."

But changing the Clean Water Act is just what Harleman and others hope to do. San Diego councilman Bruce Henderson, a strong supporter of advanced primary treatment, says, "The critical difficulty in dealing with EPA is that they've been given criteria by Congress that are inappropriate."

Harleman is hoping that the study by the

National Research Council will vindicate his views about the virtues of advanced primary treatment and be influential enough to stop Boston's construction of the secondary plant, which is scheduled to begin in 1992.

Harleman says, "Fortunately, during the next several years, there is time to bring scientific and political pressure to force the new EPA administration and Congress" to rethink the secondary treatment requirement. "When EPA was footing three-quarters of the bill [for secondary treatment] and threatening massive retroactive fines, there was little incentive to argue. Now there is every reason to insist that local funds be used to achieve the best environmental solution rather than one that adheres to a narrow and outmoded regulation."

Asked whether he is essentially advocating that dilution is the solution to pollution, Harleman responded, "We have to ask what are the trade-offs. You have to compare the marginal benefits of the additional suspended solids removal from secondary treatment to the sludge problem. The incremental benefit isn't worth it."

Demographers predict that by the year 2000, 70% of the nation's population will live within 100 miles of coastal waters. Demands for better sewage treatment methods are sure to mushroom as more and more people move close to the nation's oceans. To Harleman's frustration, research in sewage treatment technologies is being "stifled by EPA's mandate, 'Thou shalt build secondary plants.' " ■ MARJORIE SUN

Bush Awards Science, Technology Medals

On 18 October, President Bush presented the National Medal of Science and the National Medal of Technology to 27 scientists and engineers for outstanding work in their fields.

Recipients of the National Medal of Science are:

Arnold O. Beckman, California Institute of Technology. For his leadership in the development of analytical instrumentation, and for his deep and abiding concern for the vitality of the nation's scientific enterprise.

Richard B. Bernstein, University of California, Los Angeles. For his development and use of the technique of molecular beams, which have played a significant role in shaping the field of modern chemical dynamics.

Melvin Calvin, University of California, Berkeley. For his pioneering studies in the mechanism of photosynthesis and bioenergetics, and for the application of scientific theory toward the solution of the most fundamental problems of the age—energy, food, chemical and viral carcinogenesis, and the origin of life.

Harry G. Drickamer, University of Illinois. For his discovery of the "pressure tuning" of electronic energy levels as a way to obtain new and unique information on the electronic structure of solids.

Katherine Esau, University of California, Santa Barbara. For her extensive contributions to plant biology, spanning more than six decades, including her pioneering research on plant structure and development, and her superlative performance as an educator, role model, and mentor for aspiring plant biologists.

Herbert E. Grier, CER Corporation, La Jolla, California. For his pioneering scientific contributions and his leadership role in ultrahigh-speed electronic stroboscopy, electrooptic innovations, national defense, and aerospace sciences.

Viktor Hamburger, Washington University, St. Louis. For his work which led to the discovery and understanding of normally occurring neuronal death, nerve growth factor, and competitive relationships in the vertebrate nervous system.

Samuel Karlin, Stanford University. For his broad and remarkable research in mathematical analyses, probability theory and mathematical statistics and in the application of these ideas to mathematical economics, mechanics, and population genetics.

Philip Leder, Harvard Medical School. For his innovative studies that have significantly advanced knowledge and provided new directions for research in molecular genetics, immunology, and cancer etiology.

Joshua Lederberg, Rockefeller University. For his work in bacterial genetics and immune cell single type antibody production, his seminal research in artificial intelligence in biochemistry and medicine, and his extensive advisory role in government, industry, and international organizations.

Saunders Mac Lane, University of Chicago. For his collaboration in the creation and development of the fields of homological algebra and category theory that revolutionized modern mathematics, and for outstanding leadership and contributions to education.

Rudolph A. Marcus, California Institute of Technology. For his fundamental, far-reaching, and eminently useful developments of theories of unimolecular reactions and of electron transfers in chemistry and biochemistry.

Harden M. McConnell, Stanford University. For his seminal contributions in developing the power of nuclear and electron magnetic resonance spectroscopy, the introduction of the spin labeling technique, and for original discoveries on the structure, properties, and functioning of cell membranes.

Eugene N. Parker, University of Chicago. For his fundamental studies of plasmas, magnetic fields, and energetic particles on all astrophysical scales; for his development of the concept of solar and stellar winds; and for his studies on the effects of magnetic fields on the solar atmosphere.

Robert P. Sharp, California Institute of Technology. For his research that has illuminated the nature and origin of the forms and formation processes of planetary surfaces, and for extensive contributions to education and leadership in science.

Donald C. Spencer, Princeton University. For his original and insightful research, which has had a profound impact on 20th-century mathematics, and for his role as an inspiring teacher to generations of American mathematicians.

Roger W. Sperry, California Institute of Technology. For his work on neurospecificity which showed how the intricate brain networks for behavior are effected through a system of chemical coding of individual cells, which has made fundamental contributions to the understanding of human nature.

Henry M. Stommel, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. For his original, penetrating, and fundamental contributions to the physics of ocean circulation.

Harland G. Wood, Case Western Reserve University. For his pioneering work on the biochemistry of CO®MDSDπ_2 fixation, for leadership in biochemistry at the national and international level, and major contributions to medical education.

Recipients of the National Medal of Technology are:

Herbert W. Boyer, University of California, San Francisco, and **Stanley N. Cohen**, Stanford University. For their fundamental invention of gene splicing techniques allowing replication of biomedically important new products and transformed plant materials. Their discovery has transformed the basic science of molecular biology and the biotechnology industry.

Jay W. Forrester, Massachusetts Institute of Technology, and **Robert R. Everett**, MITRE Corporation. For their creative work in developing technologies and applying computers to real-time applications which proved vital to national and free world defense and opened a new era of world business.

J. Ritchie Orr, Helen Edwards, Richard Lundy, and **Alvin Tollestrup**, Fermi National Accelerator Laboratory. For their contributions to the design, construction, and initial operation of the TEVATRON particle accelerator, designed to explore the fundamental properties of matter. The TEVATRON has been crucial to the design of the Superconducting Super Collider.