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SLUDGE MANAGEMENT BY HIGH-ENERGY ELECTRON IRRADIATION PRIOR TO LAND APPLICATION STATE OF THE ART*

By
Rolf Eliassen**

Sludge management by means of the application of digested sludge to the land for agricultural purposes and land reclamation is a high-priority conservation matter that is gaining acceptance in many parts of the world. As will be discussed in this paper, the disinfection of sludge by means of irradiation with high-energy electrons may become an important unit operation in preparing sludge for land application in the future.

As a consequence of Congressional actions within the past decade, the U.S. Environmental Protection Agency (EPA) has been enforcing stricter regulations on municipalities and industries and calling for higher degrees of wastewater treatment. These regulations include the removal of excessive concentrations of heavy metals at the industrial plants. Throughout this paper it is assumed that heavy metals will be within tolerable concentrations [1] in the residual solids (sludge) of municipal treatment plants. With more solids being removed by improved primary treatment and more secondary and tertiary treatment plants being installed, the quantities of sludge being produced are escalating rapidly, as shown in Table 1.

TABLE 1
ESTIMATED INCREASE IN PRODUCTION OF MUNICIPAL WASTEWATER SLUDGE, 1972 to 1985 [2]

	1972		1985	
Sludge type	Equivalent population, millions	Dry tons per year[a]	Equivalent population, millions	Dry tons per year
Primary (0.12 lb/capita/day[b])	145	3,170,000	170	3,720,000
Secondary (0.08 lb/capita/day)	101	1,480,000	170	2,480,000
Chemical (0.05 lb/capita/day)	10	91,000	50	455,000
Total	256	4,741,000	390	6,655,000

a. ton x 0.908 = metric ton
b. lb x 0.454 = kg

*The Thomas R. Camp Lecture, presented at the annual meeting of the Environmental Group, March 30, 1977.

**Honorary Member, ASCE; Professor of Environmental Engineering (Emeritus), Stanford University; and Chairman of the Board, Metcalf & Eddy, Inc.

At the same time that the quantities of sludge are increasing, the methods of disposal are changing. In the future, ocean disposal will no longer be allowed, so greater quantities will have to be disposed of on land by sanitary landfilling, incineration, and land application, as shown in Table 2.

TABLE 2
CHANGES IN DISPOSAL METHODS FOR MUNICIPAL WASTEWATER SLUDGE, 1972 to 1985 [2]

Disposal methods	1972 Percent	1985 Percent
Landfill	40	40
Land application	20	25
Incineration	25	35
Ocean (dumping and outfalls)	15	0

APPLICATION OF SLUDGE ON LAND

If the predictions given in Tables 1 and 2 are correct, by 1985 the amount of sludge to be disposed of on land for agricultural and other purposes may approximate 1.7 million tons (dry weight) per year (1.5 million metric tons). How these quantities of sludge should be processed and where they should be disposed of are matters of great concern to environmental engineers today.

Depending on the moisture content and consistency of the sludge, the method of application to the land could be by sprinkler irrigation, subsurface injection, ridge and furrow trenching, or by other means of spreading and plowing. Reclamation of land and conservation of the humus and nitrogen values of the sludge can be as important as the solution to the problem of ultimate disposal.

The Prairie Plan of the Metropolitan Sanitary District of Greater Chicago for the reclamation of strip-mined land in central Illinois is probably the largest and best known sludge utilization plan in this country. Halderson and co-workers [3] have described the operations involved in disposing of 425 tons* per day of digested sludge to reclaim land that would be considered worthless from the agricultural standpoint. The agricultural cropping program for the growth of corn has proved to be highly profitable for tract farmers. Trace concentrations of heavy metals were found to be tolerable to the corn crop [4]. Of course, sludge must be stored during winter months near the land to be reclaimed and in a manner that protects the water and land environment. The Prairie Plan has been such a success [5] that it won the ASCE Award for the Outstanding Civil Engineering Achievement of 1974.

*U.S. tons (2,000 lb) are used hereafter in this text.

PUBLIC HEALTH CONSIDERATIONS

In the Prairie Plan, disinfection of sludge is not deemed necessary for the farming of corn. However, test wells have been located all over the area, and procedures are carefully controlled. Samples are analyzed for any possible groundwater contamination.

A Draft Technical Bulletin published by the EPA in 1974 provides guidelines for "Acceptable Methods for the Utilization or Disposal of Sludges" [6]. Section 2 of the bulletin indicates that land application of stabilized sludges for agriculture, enhancement of parks and forests, and reclamation of poor or damaged terrain is an acceptable method for the utilization of sludge. A key point is that the sludge must be stabilized prior to land application

> . . . to reduce public health hazards (through substantial reduction of numbers of pathogens) and to prevent nuisance odor conditions. [6]

Further discussion of this subject is provided in a comprehensive report to the National Commission on Water Quality [7].

According to Miller:

> Recycling of sewage, primary and secondary effluents or liquid sewage sludges on land may present a potential health hazard because of the human and animal pathogens which these wastes contain. Among the common pathogens found in these waste materials are the bacterial pathogens *Salmonella, Shigella, Mycobacterium,* and *Vibro comma;* the hepatitis viruses, enteroviruses and adenoviruses; and the protozoan, *Endomoeba histolytica*. . . . Anaerobic digestion of sludge results in a significant reduction in numbers of pathogenic microorganisms, but does not result in complete elimination of pathogens.[8]

Farrell has pointed out:

> In Germany and Switzerland, there has been a substantial use of sludge on agricultural land and a concomitant concern about its potential infection hazard. This has led to regulations that sludge applied to pasture or agricultural land be reduced in pathogens beyond the level attained by digestion.[9]

In the United States, however, the states appear to be relying on federal policies yet to be developed by the EPA. Farrell concludes:

> During the next few years, regulatory agencies at the several levels of government will become concerned with pathogens in sludge applied to land. Codes of practice will require either pretreatment of sludges applied to cropland and pasture to reduce pathogens or special application procedures or practices, such as subsurface application or application only after harvest. To give desired flexibility of operation, some of the communities affected will doubtlessly choose irradiation as a safe and sure method for eliminating pathogens.[9]

IRRADIATION OF SLUDGE

Much research has been done on the effects of irradiation on biological organisms, from microbes to man. The internationally accepted unit of dose for all forms of high-energy particles and radiation is the *rad.* This dosage occurs when 100 ergs of energy are absorbed per gram of matter. For the inactivation of microorganisms in sludge from municipal wastewater treatment plants, experiments have shown that a dosage of over 300,000 rads is required [10]. This can be done with gamma rays from radioisotopes like cobalt-60 or cesium-137 whose radiation energies are low enough (below 5 million electron-volts) to prevent induced radiation in sludge and side effects that might be injurious to the end use of the sludge.

However, it takes a tremendous amount of radioactive cobalt-60 to be of practical use; 70,000 curies of it would be used to produce 1 kilowatt of the ionizing power needed to destroy microorganisms [10]. Cesium-137 is a plentiful radioisotope, but it is even less efficient because 250,000 curies of it would be needed just to match 1 kilowatt of the output of a high-energy electron accelerator. And one must think about 50 kilowatts of power to irradiate 100,000 gallons of sludge per day!

Radioactive isotopes cannot be shut off, they would be an ever-present hazard in a wastewater treatment plant. When electric power is shut off from an electron accelerator machine, there is no residual radiation. Thus, it is reasonable to believe that only machine sources of high-energy electrons have the inherent safety, economics, flexibility, and power output to process sludge from municipal wastewater treatment plants.

In 1975 the International Atomic Energy Agency sponsored a "Symposium on the Use of High-Level Radiation in Waste Treatment" at Munich, Germany. The prospects for the future of sludge irradiation were described at this symposium by Trump and his colleagues [11]. In a summary of the discussions, Farrell [9] concluded that the effects of radiation applicable to sludge treatment included the following phenomena:

- Destruction of microorganisms and parasites
- Radiation-induced oxidation
- Modification of molecular structure (to decrease toxicity or enhance biodegradability)
- Changes in colloid systems (to improve settling or sludge dewatering)

ELECTRON BEAM IRRADIATION

Electrons are the basic negative particles of nature, an essential component in the structure of all matter. In specially designed machines, electrons can be released from a solid metal, such as tungsten, by heating it to a sufficiently high temperature. The electrons are then accelerated in a vacuum by the application of an electrical field of several million volts; hence the machine is called an electron accelerator. These electrons represent a very special form of electrical energy. They can be forced into a beam of directed particles moving at nearly the velocity of light.

In Figure 1, taken from the paper by Eliassen and Trump [10], an idealized conception is presented depicting two opposing electron accelerators

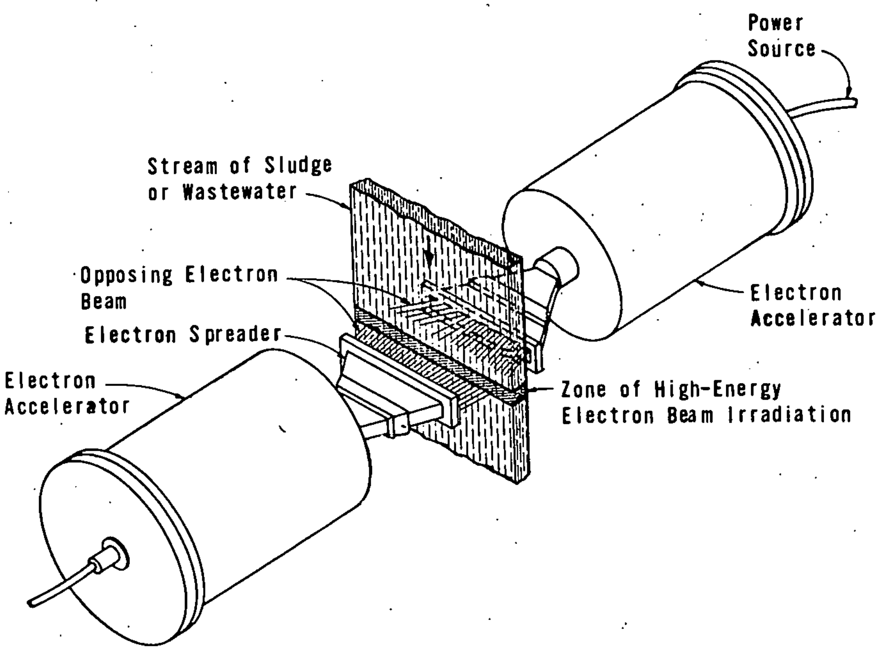


Figure 1: Idealized conception showing high-energy electron beam irradiation of a continuous flow of liquid undergoing disinfection.

and their beams of electrons impinging on a moving layer of wastewater sludge. The energy of the electrons is dissipated in the excitation and ionization of the millions of atoms and molecules which become targets of the electron beams. In practice, only one accelerator would be used.

With sludge, the maximum penetration of such electrons is about 1 centimetre for each 2 million electron-volts (MeV). By irradiating a thin, wide band of rapidly moving liquid with electron beams from opposite sides, as indicated in Figure 1, it is possible to deliver a nearly uniform dosage throughout the liquid stream with little wasted energy.

The electron energy, redistributed among the atoms and molecules, results in the chemical reactions already discussed: oxidation, reduction, dissociation, and degradation of complex molecules. By recombination of hydroxyl radicals, some chemically active molecules, such as hydrogen peroxide and ozone, are formed.

In many laboratories in various parts of the world, it has been proved that this ionization has a direct lethal effect on microorganisms (bacteria, viruses, spores, and molds) and on larger organisms (algae, protozoa, and parasites). These reactions can be initiated in a small fraction of a second as the material flows through the zone of intense ionization produced by the electron beams.

The outstanding safety inherent in the electron beam approach to sludge processing arises from (1) the high output power of the electron accelerators, (2) the localized region in which the ionization is applied, (3) the efficiency with which this power is produced from conventional 60-cycle AC power, and (4) the ease which it can be controlled over the range from fully *on* to fully *off*, at which point radiation ceases. These characteristics contribute to the realization of safe, compact, easily shielded installations that can be made as applicable to small community plants as to large city and regional plants.

Many researchers have produced conclusive evidence on the beneficial effects of ionizing radiation on the processing of foods, medical supplies, and plastics, as well as wastewater and sludges. Nevertheless, engineers, scientists, and regulatory agencies must have these phenomena demonstrated on a large enough scale to determine the applicability of electron beam irradiation to practical problems. This is standard procedure for most unit operations and processes used by environmental engineers: from laboratory, to pilot plant, to demonstration plant, to large-scale installations. Many checks and balances must come into play between conception and application to protect the public health and to assure accomplishment of scientific, engineering, and economic objectives.

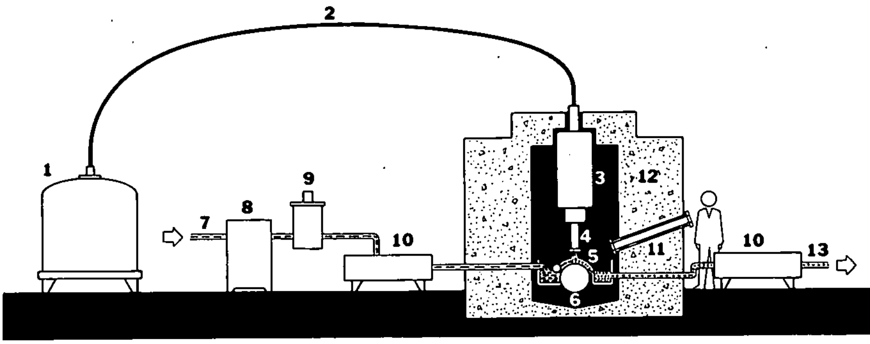
MDC DEER ISLAND DEMONSTRATION FACILITY

Fortunately, such a procedure has been made feasible by the National Science Foundation (NSF) and its RANN program (Research Applied to National Needs). Through its Division of Advanced Environmental Research and Technology within the Applied Research Directorate, the NSF has sponsored many research and demonstration projects of interest to sanitary and environmental engineers. The objectives of these projects were discussed by Dr. E.H. Bryan, the environmental engineer in charge of this phase of NSF activities, in a paper entitled "Management of Municipal Wastewater Treatment Residuals" [12]. One of the outstanding NSF-sponsored projects mentioned by Dr. Bryan is the Deer Island Sludge Treatment Demonstration Plant, which includes a full-scale modular electron research facility installed at the Boston Metropolitan District Commission (MDC) Wastewater Treatment Plant at Deer Island. This project is under the direction of Dr. John G. Trump, with the cooperation of his MIT colleagues from several scientific and engineering disciplines. The NSF has awarded a companion grant to Dr. T.G. Metcalf of the University of New Hampshire to perform virology studies.

This project was made possible by the cooperation of the MDC, the Division of Water Pollution Control of the Water Resources Commission of the Commonwealth of Massachusetts, and the High Voltage Engineering Corporation of Burlington, Massachusetts. Martin Cosgrove is the project coordinator for the MDC.

Figure 2: Aerial view of MDC Deer Island plant with electron research facility location outlined. (High Voltage Engineering Corporation photo.)

The Deer Island plant is a primary wastewater treatment that serves a part of Boston and over 20 surrounding communities. In 1976, it processed an average flow of 330 million gallons per day. A photograph of the plant, with Logan International Airport across the channel and the City of Boston in the background, is shown in Figure 2. The arrow points to the location of the radiation facility building. It is adjacent to, and may draw sludge from,



1. Electron Beam Power Supply
2. High-Voltage Cable
3. Electron Accelerator
4. Electron Beam Scanner
5. High-Energy Electrons
6. Sludge Spreader
7. Input Line
8. Sludge screener
9. Grinder
10. Pump
11. Window
12. Concrete
13. Output Line

Figure 3: Schematic diagram of continuous-flow sludge irradiation system using high-energy electrons.

primary sedimentation basins, sludge thickeners, and sludge digesters. A schematic diagram of the high-energy electron facility is shown in Figure 3. This continuous-flow treatment system was designed to deliver a disinfecting dosage of 400,000 rads to 100,000 gallons of municipal sludge per day (one-third of the Deer Island plant's daily sludge throughput). This electron research facility was brought into operation in April 1976 and dedicated on May 19, 1976. A number of us in this audience were present at that dedication. I served as a representative of the High Voltage Engineering Corporation, of which I am a director, along with Dr. Denis Robinson, chairman of the corporation.

The source of ioning energy is a standard 750,000-volt 50-kilowatt electron accelerator with a 48-inch scanner system. The accelerator was rented to the MIT project by the High Voltage Engineering Corporation. This accelerator system transforms the input 480-volt 3-phase AC power into output electron beam power with a conversion efficiency of 80 percent. The AC power is generated at Deer Island from the methane produced by anaerobic digestion. The DC power is brought by high-voltage cable to the acceleration tube mounted in the upper region of the shielded vault, as shown in Figure 4.

To protect plant workers when the power is on, sludge irradiation is confined to the inside of a concrete-shielded vault. This vault was assembled of 100 large concrete blocks with walls 6 feet thick. The interior vault space is 8 feet wide by 12 feet high and contains all the radiation-producing and radiation-receiving apparatus. The amount of radiation in the environment beyond the concrete shielding is monitored and has proved to be far below radiation standards for humans.

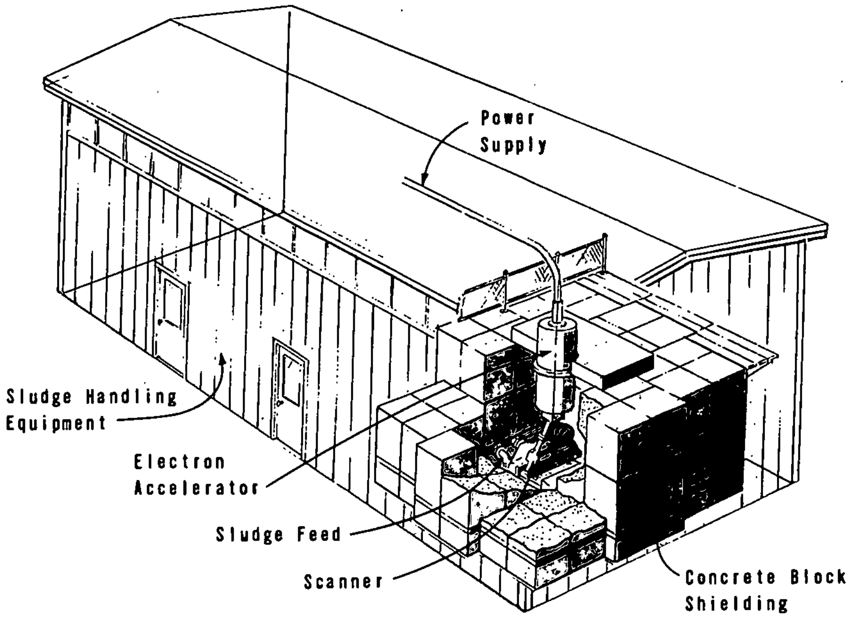


Figure 4: Cutaway diagram showing concrete radiation shield for electron accelerator and scanner at the MDC Deer Island wastewater treatment plant.

Sludge disinfection requires the delivery of an adequate ionization dose to *all* of the material. With energized electrons as the source of ionizing energy, this can be accomplished by spreading the sludge into a thin, wide layer which moves at a steady velocity through the rapidly transversing and scanning electron beam. The electrons must penetrate through the sludge thickness. Therefore, the sludge is carried over the top of a rotating stainless steel drum, as shown in Figure 5. There the sludge is ionized throughout its volume by the downward-directed high-energy electron beam, which sweeps 400 times per second across the full width of the drum. At the irradiation region, the sludge layer is 1.2 metres wide and 2 millimetres thick, and it is moving at the drum surface speed of 2 metres per second. The sludge receives its disinfection dose in this single pass with an exposure time of a few hundredths of a second. During this brief exposure, for a disinfection dose of 400,000 rads, over 10 trillion (10^{13}) energized electrons impinge on each square centimetre of the sludge surface. As they lose energy in collisions with atoms and molecules, the electrons produce ionization which accounts for the powerful effects of disinfection and degradation of chemical compounds. An absorbed energy of 400,000 rads will raise the temperature of water only 1 °C.

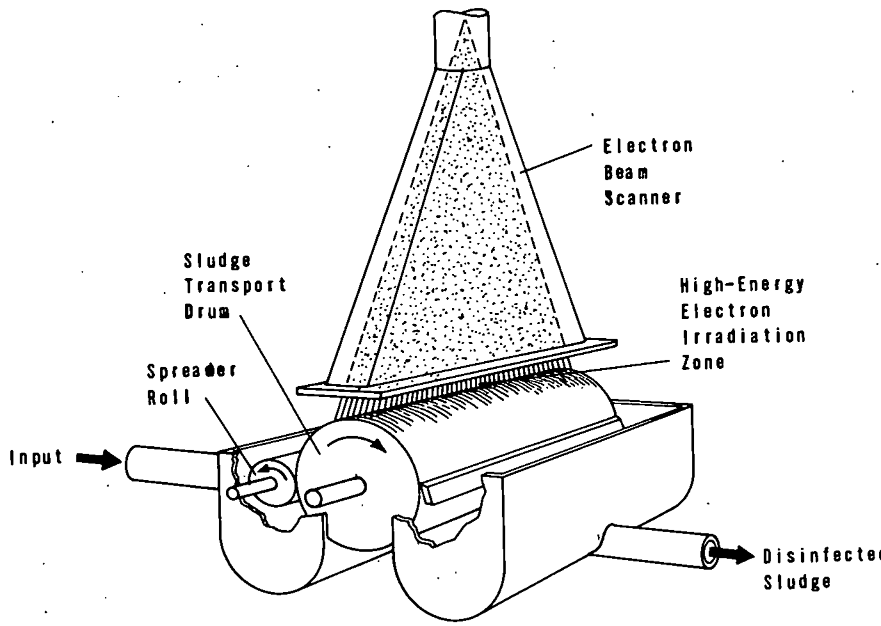


Figure 5: Cutaway diagram illustrating the method of irradiation of a thin, wide layer of moving sludge by a high-energy electron beam.

Primary sludge, liquid digested sludge, and thickened sludge can be irradiated. For thick sludges containing over 10 percent solids, however, the spreader and conveyor system would have to be altered. Secondary liquid sludges, which were not available at Deer Island, could be brought by tank truck and connected to the input line. Wastewater effluents from primary and secondary treatment plants could also be irradiated. But the efficiency would be less because for these low-solids effluents, the lower the solids content, the lesser the number of targets for the electrons and the lesser the ionization effects on the organic materials, including microorganisms.

Although the Deer Island Electron Research Facility has been designed as an experimental unit, it is the most powerful radiation module in existence at any wastewater treatment plant for the irradiation of wastewater and sludge. The rapid flow-through electron irradiation procedure and the small volume of target material exposed at any instant to the intense impinging beam contribute to the compactness and economy of the installation. In addition, the absence of induced radioactivity and the ability to terminate accelerator operation quickly by manual or safety-actuated switching are basic safety advantages over radioactive sources of ionizing energy.

CURRENT STATE OF THE ART

Dr. Trump and his colleagues have reported to the NSF that, during the first year of operation, biological measurements on digested primary sludge irradiated at the Deer Island facility have confirmed the effectiveness of electron disinfection at high flow rates. These measurements were made at the MIT microbiological laboratory and at the virology laboratory of the University of New Hampshire in its coordinated NSF program. They indicate that the destruction of bacteria and viruses at Deer Island closely parallels the disinfection achieved in small controlled quantities irradiated at MIT with its 3 MeV Van de Graaff electron accelerator.

Evidence of a preliminary nature showed destruction by electron irradiation of certain toxic chemicals in water (PCB and monuron, a pesticide). Improvement in the dewatering characteristics of irradiated sludge was also achieved.

Important engineering information has been obtained on many aspects of the operation of the system, especially on the dynamics of presenting a swiftly moving stream of liquid waste to the scanning electron beam for effective penetration and disinfection. Other factors of environmental, operational, and economic importance have been evaluated, including radiation safety, ozone emission, control of the sludge flow rate, averaged long-time bio-sampling, radiation dosimetry, electric power use, accelerator performance, capital and operating costs, disinfection costs per dry ton, and modes of utilization.

It is important to emphasize that the disinfection accomplished is a function of the total quantity of energy absorbed. Recall that this quantity is measured in rads, the absorption of 100 ergs of energy per gram of the absorbing material (in this case, sludge and the microorganisms contained in the sludge matrix). Thus, the dosage in rads depends on the number of electrons per second multiplied by the time of exposure. As stated previously, the Deer Island facility has been designed to provide a retention time of a few hundredths of a second. The total number of energized electrons per square centimetre of sludge is over 10 trillion (10^{13}) in that brief time, giving a dosage of 400,000 rads.

This dosage of high-energy electrons has been adopted after many years of experimentation [9,13], particularly at MIT and at Deer Island. Experiments were conducted on primary, digested, and waste activated sludge. The initial counts of microorganisms in the sludges to be subjected to irradiation are presented in Table 3. The average results to be expected, from thousands of tests, are shown in Table 4. It is obvious from these results that a dosage in the range of 300,000 to 400,000 rads is needed to produce or approach total kills of specific microorganisms.

A particularly interesting experiment was one in which the effects of sludge solids content on irradiation effectiveness were observed. On the basis of total counts, there was no significant difference in the effectiveness of irradiation of sludges with solids contents ranging from 1.4 to 22 percent

(1.4, 8.6, 15, and 22 percent). Initial counts ranged from 10^6 to 10^7 bacteria per gram of sludge.

Virus studies at Deer Island by Dr. Metcalf have begun. Methods of recovering viruses from large volumes of sludge must be improved. However, preliminary studies have indicated that electron irradiation does have a marked effect on Polio II virus and Bacteriophage P-22. The latter showed a survival of only 4 x 10^{-4} percent at a dosage of 300,000 rads.

TABLE 3

INITIAL COUNTS OF MICROORGANISMS IN VARIOUS SLUDGES [9, 13]

Class of microorganisms	Primary	Digested	Waste activated
Total coliforms	6.1 x 10^7	7.8 x 10^5	3.7 x 10^6
Gram V-E bacteria	1.3 x 10^8	1.4 x 10^6	6.6 x 10^6
Salmonella	1.3 x 10^4	—	—
Shigella	10^4	—	—
Fecal streptococci	—	1.9 x 10^3	—
Total count	2.1 x 10^8	6.4 x 10^6	1.4 x 10^8

TABLE 4

PERCENT SURVIVAL OF MICROORGANISMS AT SPECIFIC DOSAGES OF HIGH-ENERGY ELECTRONS [9,13]

Microorganisms in various sludges	Percent survival			
	100,000 rads	200,000 rads	300,000 rads	400,000 rads
Total coliforms				
Primary sludge	10^{-3} [a]	10^{-6}	0	0
Digested sludge	10^{-4}	10^{-8}	0	0
Activated sludge	10^{-1}	3 x 10^{-4}	10^{-4}	0
Gram V-E bacteria				
Primary	10^{-2}	3 x 10^{-4}	10^{-4}	3 x 10^{-5}
Digested	10^{-4}	10^{-8}	0	0
Activated	10^{-1}	5 x 10^{-3}	10^{-3}	0
Salmonella Typhimurium				
Primary	10^{-2}	0	0	0
Shigella				
Primary	10^{-2}	0	0	0
Fecal streptococci				
Digested	1	10p5,9-1	0	0
Total count				
Primary	10^{-1}	10^{-2}	5 x 10^{-3}	10^{-3}
Digested	10^{-1}	10^{-2}	5 x 10^{-3}	10^{-3}
Activated	10^{-1}	10^{-2}	2 x 10^{-3}	2 x 10^{-4}

a. 10^{-3} denotes survival of 0.001 percent.

Preliminary economic studies indicate that the pital cost for a 100,000 gallon per day module for sludge disinfection would be about $450,000 ($300,000 for the 50-kilowatt electron accelerator and $150,000 for the ancillary facilities and building). Operating costs, as currently estimated, would be $130,000 per year (electric power, $21,000; operation and maintenance, $65,000; amortization and interest, $45,000).

Total costs for the disinfection of 153,000 wet tons of sludge per year as currently estimated, assuming normal operation on a relatively continuous basis, would be 85 cents per wet ton. The cost per dry ton would depend on the solids content of the sludge: $17 per dry ton for sludge with 5 percent solids; $9 per dry ton for sludge with 10 percent solids; and about $3 per dry ton for filter or centrifuge cake with 30 percent solids. As stated previously, these are preliminary estimates which will be firmed up by the continuing work at the Deer Island facility.

Only a brief outline of the present state of the art has been presented. Much more remains to be done at Deer Island and in the laboratories of MIT hysical, chemical, and biological studies) and the University of New Hampshire (virology). But the basic facts of high degrees of disinfection have been demonstrated on a treatment-plant scale.

The present installation at Deer Island can be considered a module designed for a sludge flow rate of 70 gallons per minute. A full-scale plant would consist of a number of these modules in parallel. After the persent unit has been perfected, with all of the phases of sludge handling and radiation of optimum design proved in the demonstration plant, consulting engineers and water pollution control authorities can begin to consider the applicability of high-energy electron irradiation to specific problems.

Further work will provide additional data on the economics of sludge disinfection by high-energy electrons. Engineers can then make valid comparisons of the economic and disinfection efficiency of this method with that of other methods of sludge disinfection, including pasteurization, wet sterilization at high pressures, composting, and flash drying, among others.

SLUDGE MANAGEMENT— USING A VALUABLE RESOURCE

Irradiation of sludge is expted to have the greatest impact on that phase of sludge management that deals with the application of sludge on land. In Table 2 it was shown that in 1985, 25 percent of the sludge from municipal wastewater treatment plants would be applied on land, 1.7 million tons (dry weight) per year. But where can it be applied?

As mentioned previously, the Prairie Plan of the Metropolitan Sanitary District of Greater Chicago uses an average of 425 tons per day for reclamation of strip-mined land. The U.S. Energy Research and Development Administration (ERDA) has prophesied as follows:

> It is expected that the current national coal production of 648 million tons will double by the year 2000. The major share of this projected increase will probably come from surface coal mining, because surface, or strip, mining is more economical than underground, or deep, mining.

> In several ways, however, surface mining of coal can be more disruptive environmentally than deep mining. Surface mining can disturb existing ecosystems, affect water quality through drainage of acidic mine spoils, and alter patterns of land usage. There is, therefore, a great need to better understand and evaluate the costs and potential effectiveness of alternate methods for reclaiming and rehabilitating strip-mined lands. [14]

In May 1971, before the National Academy of Science [15], I suggested that the many unit-trains of 100 carloads of coal on eastbound trips from strip mines in the West could return with ashes, municipal solid wastes, and reclaim the land. The sludge would serve as a soil conditioner for the covered and resealed mine areas and give them better soils than they originally had.

This country will soon be producing tremendous quantities of sludge. Could it be used as a valuable export — stabilized sludge, with its humus and nitrogen content, in exchange for oil? This may not be too far-fetched an idea for sludge management of the future!

C.E. Pound and R.W. Crites, vice president and project manager, respectively, of Metcalf & Eddy, Inc., in Palo Alto, California, have published the results of considerable work in the field of land treatment of wastewaters from municipalities and industries [16]. One of their current assignments is to apply these techniques to an agricultural development program for the State of Qatar — a country that is rich in oil but poor in agricultural production [17]. Qatar has a total land area of 10,000 square kilometres, but only about 3 percent has been classified as potentially arable. Of this 3 percent, only a little more than 10 square kilometres are under cultivation at the present time. Consequently, that country of 200,000 people must import all its food.

Why not import stabilized sludge to enrich its barren soils? Why should the oil tankers run full from Qatar to the United States and run empty on their return trips, except for ballast? Why not fill the ballast tanks with stabilized sludge and deliver it to Qatar? Qatar's municipal and industrial wastewaters could also be reclaimed and used for irrigation. Start with the small State of Qatar and then think of reclaiming the desert sands of Arabia and the barren lands of other large oil-producing nations to help them approach self-sufficiency in agriculture. Their oil may be like gold to us, but our stabilized sludge might be like platinum to them!

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A LEACHATE CONTROL PROGRAM FOR SACO, MAINE

By
James S. Atwell and William H. Parker, III,[1]

Introduction

Groundwater contamination can be a serious long-term result of the improper disposal of solid waste on land. In recent years the Environmental Protection Agency (EPA) has been actively studying the environmental effect of leachate resulting from solid waste disposal, especially from hazardous waste migration. Yet many municipal officials remain unaware of this problem, which may already be affecting the ground and surface water quality in their communities.

For many towns and cities, leachate prevention or correction programs are spurred only after a pollution problem has already been observed in a nearby well, lake or stream. This case study for the city of Saco, Maine, was prompted when a property owner adjacent to a city dump reported a deterioration in the quality of water in a small spring feeding a pond on his land. Based on the results of engineering studies, the city had already committed itself to closing the disposal area and was developing final designs for a new sanitary landfill when the water quality problem was found at the site.

Six months after the pollution problem was discovered near the disposal area, the site was abandoned. A location plan of the site and adjacent area is shown in Figure 1.

The abandoned disposal area was in rolling terrain and had been used primarily for agricultural purposes before it become a dump in the late 1950's. The material deposited at the dump during its 15-year operation consisted of residential and commercial solid wastes from the city of Saco, as well as industrial solid wastes primarily from a large tannery, an ordnance and automotive parts manufacturer, and a shoe shop.

As the disposal operation moved toward the easterly corner of the site, a high groundwater table was encountered and refuse was often placed in direct contact with groundwater. Without an operating plan, cover was provided only on an intermittent basis using highly permeable soils. The principal purpose of the cover material was to control blowing papers and to allow vehicle access; it did not prevent surface water percolation. This disposal area was not developed or operated as a sanitary landfill, as defined by the American Society of Civil Engineers or by the Maine Department of Environmental Protection.

The problem became aggravated in 1973, when a primary wastewater treatment plant was placed in operation, serving a large tannery in Saco. The plant produced 4 to 5 tons per day of sludge (dry basis) which was transported to the site for disposal. The solids content in the sludge was generally

[1]Respectively Project Manager and Vice President, Edward C. Jordan Company Inc.

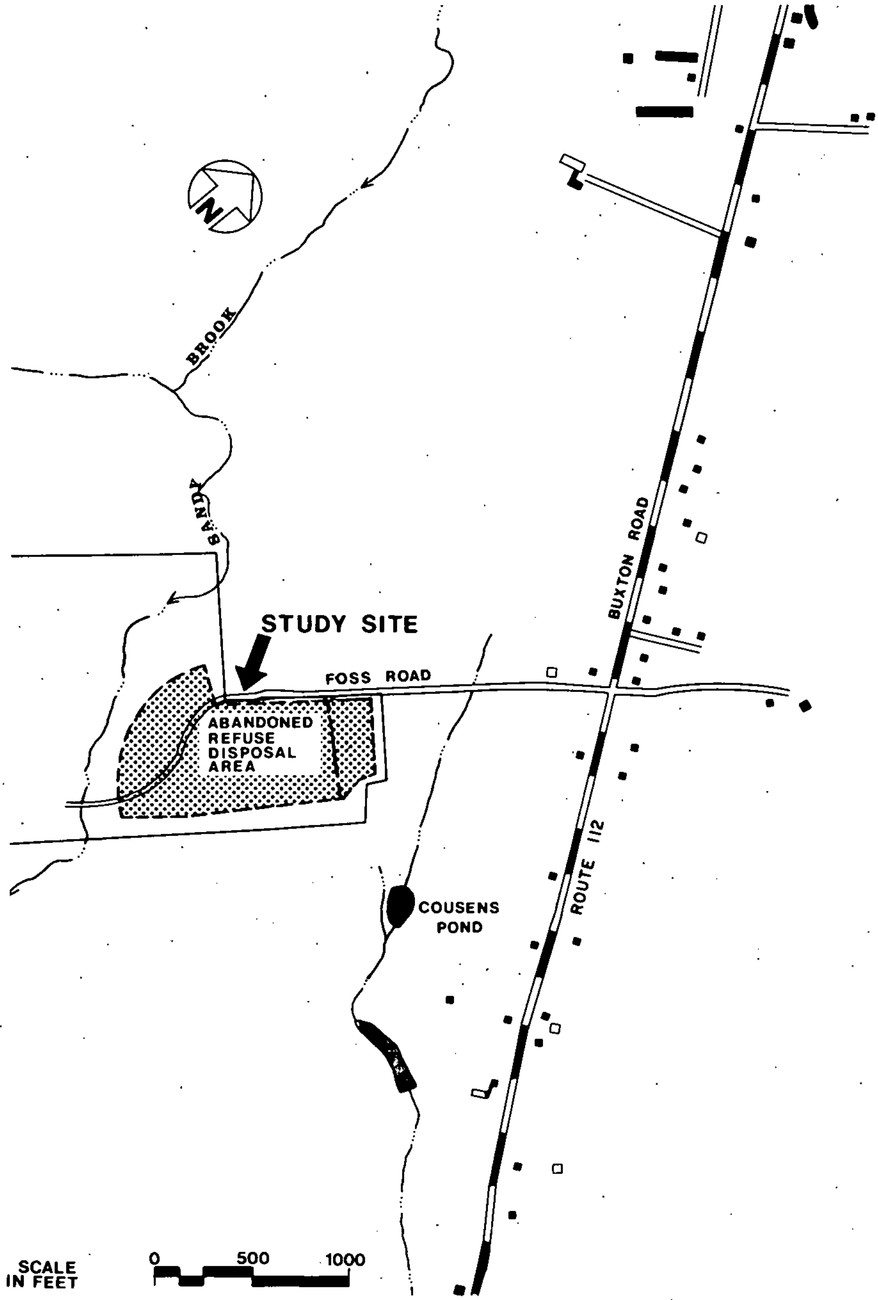

Figure 1: Location of abandoned refuse disposal area Saco, Maine

no more than 5 to 10 percent. The sludge was handled separately from other solid wastes, and was placed directly on the ground or in shallow trenches, occasionally in contact with groundwater. Cover was provided only intermittently.

The complaint of the neighboring property owner about water quality, in April 1974, prompted surface water tests and analyses by the city's engineer and by the Maine Department of Environmental Protection (DEP). This initial study confirmed that leachate was contaminating surface water in the vicinity. In order to arrive at means for correcting the problem that would be most acceptable, environmentally and economically, the city of Saco undertook a program designed to trace the path of the contamination migrating from the disposal area, to characterize the nature of the contaminants, and to develop alternative solutions to the problem. The Edward C. Jordan Company of Portland, Maine, was selected to provide consulting engineering services to the city, as well as testing and laboratory services in conjunction with the Maine DEP.

The city's program was undertaken in two phases:

Phase 1. Hydrogeological investigation.

Phase 2. Evaluation of alternate corrective measures.

The objective of the hydrogeological investigation, Phase 1, was to identify subsurface soils conditions and groundwater levels, and to install groundwater monitoring wells. The wells permitted the measurement of groundwater levels and the sampling of groundwater. In Phase 2 alternative corrective measures were identified and evaluated.

Hydrogeological Investigation and Groundwater Monitoring Program

A subsurface investigation and groundwater monitoring program was designed and initiated by the Jordan Company with approval of the Maine DEP. Thirteen soil borings were made, and monitoring wells installed in eleven of these holes at locations shown in Figure 2. These holes were placed to ring the site as well as to cover the interior of the dump area. In addition, a study was made of the groundwater and surface water hydrology of the area.

A marine clay is found beneath the abandoned disposal area at a depth of approximately 25 feet below ground surface. The clay is overlain by a fine permeable sand. The groundwater level varies seasonally at depths of 5 to 15 feet. Refuse depth averages 10 feet. In several areas refuse was found to be in the groundwater. Where this occurred, the submergence did not exceed 5 feet. The volume of refuse in the dump is estimated at 200,000 cubic yards. During periods of high groundwater, it is estimated that no more than 10,000 cubic yards of refuse are in direct contact with water.

The major groundwater recharge area in the vicinity of the disposal area is The Heath, a large, partly forested land area about 7,500 feet north of the site. From The Heath, groundwater moves outward in a radial pattern, both

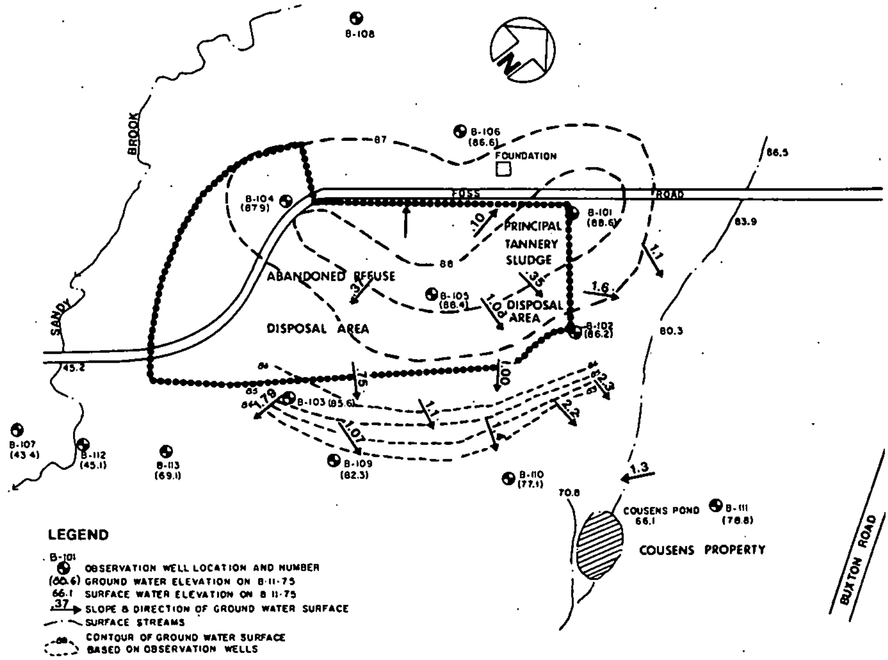

Figure 2: Hydrogeological profile at disposal site

underground and in several small surface streams, one of which is Sandy Brook. The difference in ground elevation between The Heath and the dump is approximately 10 feet.

Groundwater and surface water level measurements were taken to develop the groundwater contours shown in Figure 2. As is typical in most land disposal areas, a groundwater mound has developed beneath the fill area. It is assumed that the mounding results from surface water percolating from above and groundwater moving laterally through the refuse. This mound causes a hydrostatic pressure in all directions; however, the primary groundwater movement is in a southerly direction. The movement is confirmed by groundwater analyses which showed the greatest groundwater contamination to be in this direction. The primary area of leachate contamination lies south of the disposal area between Sandy Brook and the small stream feeding Cousens Pond.

Surface water samples taken over an 18-month period were supplemented by sampling at the new monitoring wells, as well as at several private wells in the vicinity. The wells used in this project did not permit samples to be taken at more than one depth at any point. Since the depth of the aquifer was small, this did not present a major restriction at this site. Samples were analyzed to identify the extent of groundwater contamination and the direction of its movement. The location of the borings and sampling wells is shown in Figure 3.

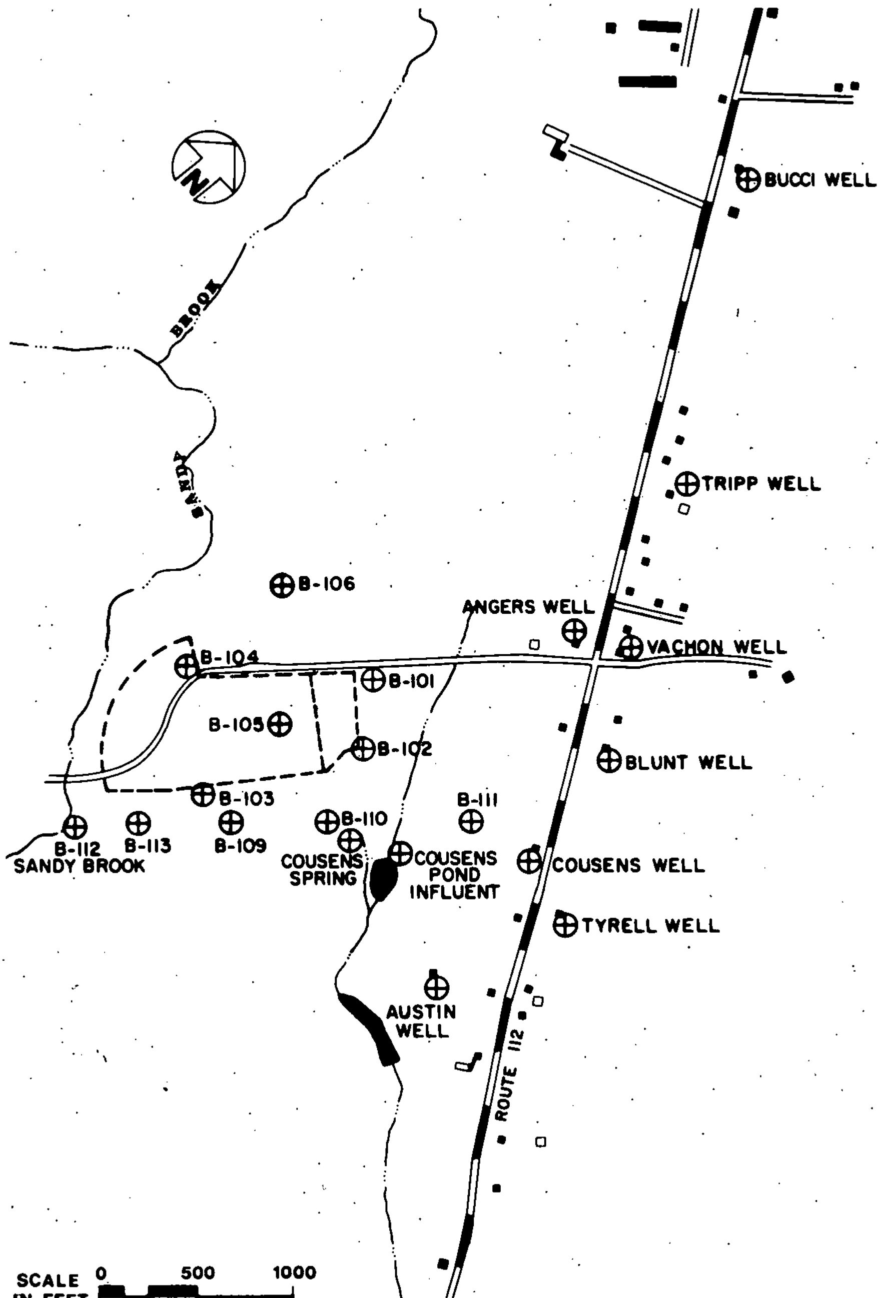

Figure 3: Monitoring points

TABLE I
WATER QUALITY MONITORING DATA*

	Chromium (mg/l)	Iron (mg/l)	Manganese (mg/l)	Zinc (mg/l)	Ammonia (mg/l-N)	Nitrate (mg/l-N)	Conductivity (hos/cm)
Bucci Well	.25	.04	.01	2.63	.03	.11	348.
Tripp Well	.01	.25	.01	.02	.01	2.1	112.
Angers Well	.01	.05	.01	—	.01	9.4	160.
Blunt Well	.025	.05	.025	.71	.02	.7	59.
Tyrell Well	.025	.025	.025	.08	.1	.24	44.
Austin Well	.025	.025	.025	.01	.04	.36	780.
Vachon Well	.025	.025	.025	1.13	.05	2.6	75.
Cousens Well	.025	.24	.04	.01	.01	.29	76.
Cousens Pond Inlet	.025	.23	.03	.6	.26	1.7	130.
Cousens Spring	.04	80.	31.	.17	11.	.77	1,530.
B-101	.27	106.	41.	.92	5.3	.29	750.
B-102	.29	442.	149.	1.6	187.	1.1	4,650.
B-103	.25	817.	28.	1.16	141.	.55	5,760.
B-104	.32	432.	32.	5.1	2.5	.9	1,010.
B-105	.17	323.	32.	1.4	24.	.3	2,630.
B-106	.04	50.	1.3	.89	.52	.7	73.
B-109	.26	642.	129.	.32	.38	.74	5,220.
B-110	.12	139.	2.7	.96	.28	1.8	67.
B-111	.04	19.	.67	1.1	.24	3.7	123.
B-113	.19	123.	6.8	1.6	.24	.7	91.

*Data for each monitoring point have been averaged over the sampling period.

Analytical Methods

Groundwater samples were obtained, for analysis, from private water supplies as well as the monitoring wells. A manually operated pump was utilized to flush each monitoring well and to collect the samples. Private water supplies were collected from house taps. The water was permitted to run for approximately 5 minutes before the sample was collected. Samples were placed in clean containers, preserved if necessary, and transported to the laboratory for analysis. Metal concentrations were determined through the use of atomic absorption.

As shown in Tables I and II, samples taken within the dump and adjacent to it show contamination. This is indicated by higher conductivity and increased concentrations of iron, manganese, chromium, and ammonia. There is some upstream dispersion because of the mounding effect; however, the highest levels of contamination occur south of the site. Based on the groundwater level readings, the topography of the area, and the surface drainage patterns, it is believed that the dump and the immediate vicinity are the major groundwater recharge sources for the area contaminated by the leachate.

TABLE II
WATER QUALITY SUMMARY

	Iron (mg/l)	Manganese (mg/l)	Total Chromium (mg/l)	Ammonia (mg/l-N)	Conductance (hos)
PHS Drinking Water Standards	0.3	0.05	0.05*	—	—
Uncontaminated Groundwater	0.1	0.025	.01	.1-.2	60-80
Contaminated Surface Water	50-75	1-25	0-.05	5-10	1400+
Groundwater Beneath Disposal Area	300-1500	20-300	0.1-2	50-100	1200-7900
Groundwater South of Disposal Area	200-1900	6-100	.1-.3	1-25	100-5000

*Hexavalent

Chromium, believed to be from the tannery sludge, occurred at a peak concentration of approximately 2.0 mg/l in samples taken within or directly south of the area. The high concentrations of iron and manganese do not necessarily indicate that inordinate amounts of these elements were disposed of at the dump site. What they may indicate is that the soil is being affected by the leachate plume. The plume produces low pH levels (5.6-6.7) and reducing conditions in the natural soils. These conditions cause release of iron and manganese from the soil which is then detected in the samples, thus indicating the plume's presence. Laboratory analyses of groundwater samples from the leachate plume show increases in ammonia and zinc, as well as increased conductivity.

Typical seasonal fluctuations in selected water quality parameters for a typical well (B-109) are compared to background data in Figure 4. These data show that the water quality has been severely affected within the leachate plume. Sufficient long-term data have not been developed to allow definitive conclusions to be drawn relative to seasonal variations.

Typical levels of contamination within leachate plumes have been developed by the Environmental Protection Agency and others. The levels of contamination vary considerably depending upon recent rainfall, runoff, and groundwater levels with respect to refuse. The data presented here are within the range of values contained in the literature.

Alternative Corrective Measures

Having determined that leachate from the abandoned Saco disposal area was degrading local water quality, alternative measures for the prevention of further contamination were studied. Two basic approaches were evaluated: (1) leachate collection and treatment; and (2) prevention of refuse-water contact.

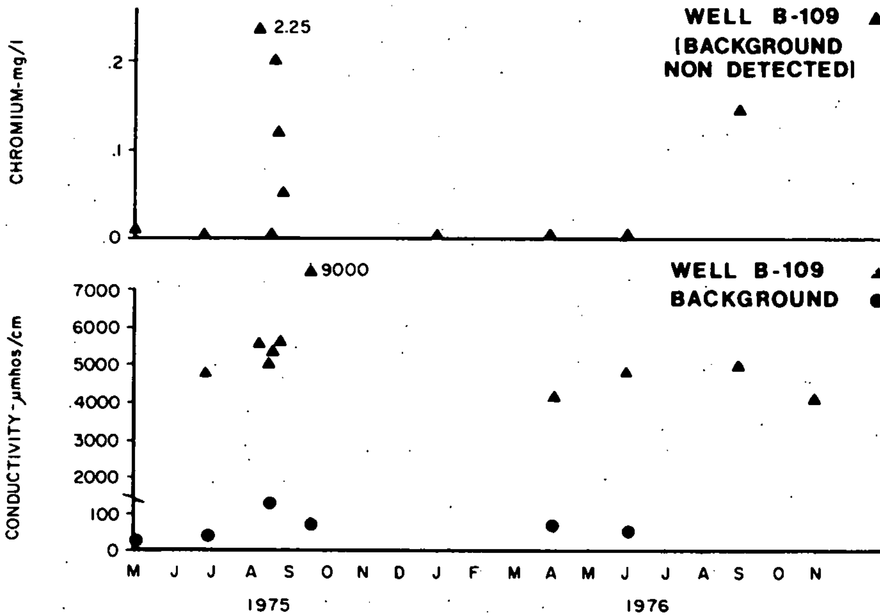

Figure 4: Representative monitoring well test results for chromium and conductivity

The effective use of a leachate collection and treatment system is dependent upon the character of the site. Normally, this alternative is very difficult and expensive to implement once a problem has developed. Prevention of refuse-water contact requires that both surface and groundwaters be controlled. This is a major goal in the design of all sanitary landfills. When no refuse-water contact occurs, leachate will not be a problem. Alternative corrective measures considered for the Saco site are discussed below.

Collection and Treatment

Leachate collection can best be accomplished by installing an underdrain system and associated works surrounding the site, in conjunction with the proper closing and capping of the area. In Saco this system would involve installation of underdrains in the area defined by wells B-101, 102, 103 and 104. During and immediately following installation, while groundwater levels are being lowered, a large quantity of contaminated water would be collected and would require treatment before discharge to Sandy Brook. The leachate collected initially would have been in contact with the refuse for varying periods of time. In addition to the iron, manganese and chrome, the leachate might contain a wide range of complex organic compounds resulting from the decomposition of materials placed in the landfill. Although temporary treatment would be required during this initial leachate collection period, treatment could be discontinued when the system reached a steady state. Steady state conditions would occur when groundwater levels are lowered, so that no water remains in contact with refuse. When that condition is reached, no more contaminated water would be collected.

To treat a temporary flow of leachate economically over a period of perhaps several months, capital expenditure should be minimized. To meet this objective, a treatment system consisting of two holding ponds in series separated by a dike of graded filter and was initially considered. However, systems of this type are still being tested and evaluated. Initial analyses showed that such a system would have difficulty achieving sufficient treatment before discharge to Sandy Brook.

Because of the short-term use of the treatment system, chemical and/or biological treatment processes were not considered economically feasible. In addition, no suitable receiving water was located nearby. Thus collection and treatment was not given further consideration as an overall solution to the leachate problem.

Prevention of Refuse-Water Contact

Leachate formation may be controlled by preventing water from coming in contact with refuse. Water may reach the refuse by percolating through the surface or by lateral movement of groundwater. Both of these sources of water must be controlled to eliminate the formation of leachate. The percolation of surface water into the buried refuse can be controlled by properly grading the surface of the landfill and covering with an impervious layer. The lateral movement of groundwater through the refuse and the movement of leachate away from the landfill may be controlled by constructing a vertical barrier to prevent such movements. These objectives can be met by any of several alternative methods.

Prevention of surface water percolation involves the placement of an impervious cover. Placement of the cover involves several steps: (1) site grading; (2) placement of soil to cover the refuse; (3) placement of an impervious layer (see below); and (4) placement of protective soil if necessary, and topsoil, fertilizer, and seed. The area to be covered at the Saco dump is about 9 acres (42,500 square yards) and is shown in Figure 5. Several alternative surface sealing systems were studied. Since each of these systems is capable of effectively restricting percolation of water into the refuse, cost is the major factor in selection. Cost data are presented following a brief description of alternative systems.

Synthetic Liners. Synthetic materials such as Hypalon and EPDM (Ethylene Propylene Diene Monomer) have been used to contain water in lagoons and holding ponds. These materials would also be effective in providing a watertight seal for surface application. The installation of the liner would have to be handled with care to ensure that no breaks occur.

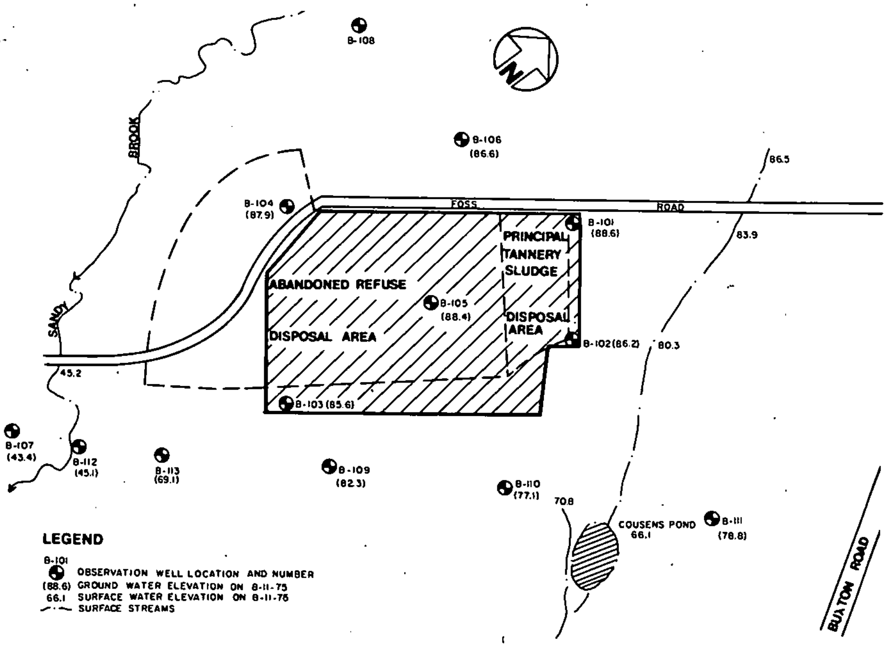

Figure 5: Surface area to be covered

Soil-Bentonite Mixture. Bentonite clay can be used as an additive to native soils to form an impervious barrier. Bentonite is an imported naturally occurring clay which swells enormously when placed in contact with water. When it swells, it fills voids in the soil and reduces permeability. This material has also been used extensively in the construction of ponds and lagoons. When used as a seal over a disposal area, the bentonite is spread over the prepared site, using conventional farm machinery, at an application rate of 1.0 to 4.0 pounds per square foot. The material is mixed with the soil to a predetermined depth (2 to 6 inches), then rolled and covered.

Soil-Cement Mixture. A soil-cement seal would be similar to the soil-bentonite system described above; however, portland cement would be used as the admixture rather than clay (bentonite). Liquid asphalt would be sprayed over the surface at one-quarter gallon per square yard to aid in the curing process.

Natural Clay. Natural marine clays or other impervious soils can be used to form a watertight course. There must be a source of this material within an acceptable haul distance to make this method feasible.

Many of the coastal areas of southern Maine are underlain by an impervious marine clay, and this is an inexpensive source of suitable sealing material, readily available to the city of Saco.

In Saco the use of natural clay would involve grading of the site, placement of 6 inches of soil, placement of a 1-foot layer of clay, and finally placement of a 6-inch soil layer suitable for supporting a grass crop. Minimum surface grade would be 2 percent to encourage efficient runoff. Once the impervious course were covered with topsoil, fertilizer and seed would be added.

In conjunction with each of the above surface sealing systems, provisions would have to be made to improve surface runoff and divert it from the vicinity of the former disposal area. The drainage system would consist of well-defined impervious drainage channels leading to major natural drainage areas in the vicinity. Improved surface runoff would reduce percolation and reduce recharge of the groundwater beneath the disposal area.

In addition to controlling percolation, a complete encapsulation system would include a vertical barrier to prevent lateral groundwater movement. The vertical barrier would extend from the ground surface to the impervious clay layer which lies beneath the disposal area at a depth of approximately 25 feet. Alternative types of vertical barrier are described below.

Slurry Trench. The slurry trench method involves the construction of an impervious bentonite clay wall around the abandoned disposal area. A trench is dug and a bentonite-water slurry is added to stabilize the trench. After the excavation has proceeded for a short distance (about 100 feet), the trench is backfilled with a soil-bentonite mix to form an impervious wall 18 to 24 inches thick. No site dewatering is required. Additives to the bentonite prevent its breakdown in the presence of leachate.

Grouting. A grout wall may be installed by pumping a grout compound into the soil through vertical pipes. As the grout fills the voids, pressure increases and the tubes are withdrawn. Since close spacing is required to form a tight barrier, the quantity of material and the long installation time makes this an expensive alternative.

Imper-Wall. The Imper-Wall system is a proprietary grouting technique which increases the efficiency of grout injection. In this process, a special 24- to 48-inch steel I-beam with a grout pipe attached is driven by a vibrating hammer through the soil to the underlying clay layer. As the beam is driven into and then extracted from the soil, a grout of bentonite is pumped through the pipe into the soil. As the beam is removed, the void space is filled and the grout forms an impervious barrier. Subsequent sections overlap to form a continuous wall. The Imper-Wall method is faster than conventional grouting and requires less material, thereby reducing cost.

Steel Sheeting. Leachate movement may also be controlled by driving interlocking steel sheet piling around the abandoned disposal area and into the clay layer beneath the refuse. The cost of protecting the piles against corrosion and subsequent failure would make this alternate extremely expensive.

Concrete Wall. Construction of a concrete wall would be complicated by high groundwater and unstable soils and would require dewatering of the site. The dewatering process would require the pumping of contaminated water, thus this method would not be feasible even if the difficult excavation problems were solved.

Cost Comparison

Since the cost of the corrective system is a major factor in selection, preliminary cost estimates were developed for the various alternatives.

The capital costs associated with closing the abandoned dump area and placing an impervious cover vary from $152,000 to $231,000 (or from $0.40 to $0.60 per square foot.) These costs include site preparation and grading; soil cover, the impervious course with protection as required; fertilizer and seed; additional wells to monitor the effectiveness of the system; and contingencies and engineering. Most of these costs are the same for any system. The principal factor which leads to differences in cost is the impervious cover and associated protective material. This portion of the cost varies from $179,000 for a synthetic membrane to $100,000 for a natural clay system.

Cost estimates for the vertical barriers were developed from a review of recent contractors' bids for similar projects, and were compared on the basis of cost per square foot of wall. These costs, which include material and installation, are as follows:

Method	Unit Cost	Total Cost
Slurry Trench	$ 6.00/sq ft	$370,000
Imper-Wall	$ 4.00/sq ft	$240,000
Grouting	$15.00/sq ft	$900,000
Concrete Wall	$ 6.75/sq ft	$400,000

Conclusions

Based on a preliminary evaluation of the alternatives presented above, it was concluded that the use of a locally available clay for the surface cover would offer the city of Saco the most cost-effective means of preventing percolation of surface runoff into the refuse. The use of the Imper-Wall techniques with a bentonite barrier would offer the most cost-effective means of constructing a vertical barrier to restrict lateral groundwater movement and to encapsulate the buried refuse.

It was also concluded that phased implementation of a leachate correction program would be the most prudent path to follow. The first phase would include grading and covering the area, in conjunction with improving surface drainage. In addition to preventing percolation of water through the refuse, the impervious cover would reduce groundwater recharge. As a result, groundwater levels would be lowered, possibly enough to eliminate refuse-water contact. Groundwater quality and levels would be monitored to measure the effect of the cover system.

If groundwater contamination persisted, additional steps would be necessary beyond the phase one improvements described above. Because of the high cost of vertical barriers, second-phase implementation measures would include the placement of an underdrain system on the north side of the area to further lower groundwater levels.

Complete encapsulation of the buried refuse was not recommended at this time. The high cost, maintenance requirements, and potential long-term liability of such a system would preclude its implementation without additional evaluation.

Current Status

The engineering report prepared for the city of Saco was submitted to the Maine DEP in November 1975, with a recommendation that the abandoned disposal area be graded, covered with an impervious clay material, and seeded in conjunction with improved site drainage. The Maine Board of Environmental Protection approved this proposal.

The City Council placed a referendum before the residents of Saco requesting authorization to spend up to $147,000 to correct the leachate problem. Following approval of this referendum by a wide majority, the city awarded contracts for the grading of the site and the placement of the impervious cover material.

The initial portion of the project was completed in November 1976. The entire project area is scheduled for loaming and seeding as soon as conditions permit in the spring of 1977.

Additional groundwater monitoring wells will be installed during the winter of 1976/77. Groundwater levels and water quality will be monitored intensively for a period of 18 months to determine the effectiveness of the corrective measures in reducing the generation of leachate. At the end of the 18-month period, a summary report will be submitted to the DEP. Based on that report, the need for additional corrective measures, if any, will be determined.

MEDIATION-ARBITRATION: A NEW APPROACH TO CONFLICT RESOLUTION IN THE CONSTRUCTION INDUSTRY

By
David E. Springer,[1] Thomas Healy,[2] and John P. Gnaedinger[3]

The rational economic man stands as the first citizen of our free-enterprise economy. He promotes economic growth and efficiency — and hence prosperity — by intelligently grasping the economic consequences of his behavior. The rational man weighs the costs and benefits of an enterprise before he embarks upon it. When the probability of his success times his possible rewards sufficiently exceeds the probability of his failure times his possible costs, the rational economic man pursues his venture. A rational system of justice aids the rational economic man's economic calculus by helping him predict the risks of incurring a cost. A rational system of justice promotes enterprise planning by remaining predictable, by acting as a constant in the cost-benefit equation.

Unfortunately, our system of justice has become in many respects irrational. Rather than behaving predictably, our system seems often to assign costs randomly. Where the rational economic man once relied on a roadmap he now faces a roulette wheel. The roulette game of the legal system proves an expensive pastime, for even the rational man needs a high-priced specialist, his attorney, to place his bets for him. Moreover, the randomness of the game strikes the rational man as unfair. But since he is a *rational* economic man in a free economy, our first citizen may devise means of avoiding the legal system's costly and unpleasant roulette game. This essay offers him one escape: "mediation-arbitration."

To put both the problem and the suggested solution in perspective, consider conflicts arising on a construction project. The parties involved in such an undertaking range from owner, architect, and general contractor to sub- and sub-subcontractors and their suppliers. Moreover, behind each party stands his "alter ego," his insurer or guarantor. The chances of disagreement, delay, litigation, and increased costs on a construction project of any size are staggering. No doubt many worthwhile projects never begin — and our economy consequently suffers — because the parties cannot risk the increased costs a protracted dispute could entail.

Conflicts, by definition, arise out of unforeseen events: "acts of God," accidents, changes in plans, or knowing breaches of duty. Whatever their source, all disputes soon resolve into a basic issue: who must pick up the tab? When the rational economic man calls upon the judicial system to answer that question, its unpredictability, costs, and delay subvert his rational plan-

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(3) President, Soil Testing Services, Inc.

ning, raise his cost of construction, and leave him feeling unjustly treated. "Mediation-arbitration," as an alternative, promotes his planning, lowers his costs, and offers him fairness by pursuing the rational man's primary values: economy, speed, and predictability.

When conflicts arise on a construction project, experience and human nature lead the parties to seek as quick and as amicable resolution as possible. The first instinct of rational economic men leads them to seek a reasonable agreement among themselves as to who should bear the costs. This first instinct is a wholesome one: a rational system of dispute-resolution would preserve it. Ours does not. If one party does not readily agree to absorb the costs, perhaps the parties compromise. Familiar with the construction process and each other, expert in their particular fields, and considerate of their associates' stakes in the enterprise, the parties exhibit respect and restraint in their compromise negotiations. Elusive virtues, respect and restraint, merit safekeeping. Our system of justice squanders them, only to place contention and excess in their stead. If the parties still balk at compromise, they may invite an expert and distinterested third party to mediate their dispute. The mediator's expertise spurs the parties to make their demands reasonable, and the chances of accord increase. Our system of justice wastes when it ignores such expertise. The informal means through which parties resolve their disputes demonstrate their intelligence and better instincts. The formal means to which parties must turn when the informal means fall not only ignore those virtues but also import new vices.

Litigation provides a good example of the effects of the darker side of human nature on conflict resolution. As the most familiar avenue of conflict resolution, litigation remains remarkably insensitive to complex problems which arise in commercial and industrial contexts. The method of collecting evidence and presenting it to the trier of fact —judge or jury — constitutes a costly, haphazard, and generally ineffective exercise. Complex conflicts require numerous affidavits, depositions, exhibits, and other documents — the collection of which comprises a process surprisingly called "discovery." Discovery is costly, not only in terms of legal fees, but also in terms of time. Deposition sessions, for example, distract busy individuals from their profitable activities. The mere discovery process often sours any present or future professional relations contending parties might have. Once the discovery process ends, the use to which the judicial system puts its product often alarms the parties.

Discovery produces the raw evidence: the lawyers then digest it and regurgitate it through the mouths of witnesses at trial. With their statements mangled out of context at trial, parties understandably worry about the effect upon the judge or jury. Expert testimony, often crucial in commercial litigation, enters the considerations only indirectly. The rules of evidence bar the expert from offering his expertise to the judge or jury in the manner he knows best, for instance a lecture or discussion. Rather, the expert testifies, his testimony effectively directed by one party's attorney and obscured by the other's. The fact that judges and juries should come to irrational decisions on the basis of such a jumble of evidence should not surprise us. What they say of computers applies equally well to juries: "garbage in, garbage out."

The legal system itself recognizes that litigation does not provide quick, equitable, or economical solutions to some conflicts. Recently Chief Justice Warren Burger urged lawyers, legislators, and laymen to devise new methods of dispute resolution. The Chief Justice noted crowded court dockets, time, and expense as the principle reasons for eschewing litigation, though he could have added growing displeasure with some of the substantive results judges and juries have reached. Mr. Burger's remarks underscore a trend away from sole reliance upon litigation for the resolution of private conflicts. The old common-law disfavor of arbitration as "in derogation of the court's jurisdiction" has given way to judicial willingness to enforce arbitration agreements. In passing the United States Arbitration Act, Congress granted its imprimatur to private-tribunal resolution of disputes arising in interstate commerce. Many state legislatures have enacted the Uniform Arbitration Act, the provisions of which allow parties broad latitude in framing their own methods for resolving controversies. But private citizens in commerce and industry should not wait for judges, lawyers, and legislators to devise new avenues for conflict resolution. As "rational economic men" they should seize upon the Chief Justice's invitation and take the lead — by arranging their own commercial relations to provide for the type of dispute-resolution process which best aids their enterprise planning.

When one thinks of the use of private tribunals to resolve disputes, arbitration naturally comes first to mind. Indeed arbitration is the most common method for resolving specialized commercial, industrial, and labor conflicts. The foundation of the arbitration process is a written contract whereby the parties agree to submit present or future disputes to a mutually-acceptable third party for his decision. Through their contract the parties can choose or provide for choosing an individual or individuals who have experience and expertise in their business. The parties' agreement provides that the arbiter's decision will be final and binding upon them, subject only to the limited appeal provided by law. Should the losing party resist the arbiter's decision, the United States Arbitration Act and the Uniform Arbitration Act authorize courts to reduce the decision to a judgment that the winning party can enforce as he would any other court decision. In effect, through their agreement the parties have created a private, specialized court to hear their dispute and have bound themselves to respect its decision.

Arbitration has become a familiar procedure in the construction industry. The American Institute of Architect's "General Conditions of the Contract for Construction" includes clauses providing for arbitration of disputes. The "Construction Industry Arbitration Rules" of the American Arbitration Association provide an orderly procedure for engaging the arbitration process in the resolution of controversies which arise on the project. Though the procedures work well within their limitations, the limitations have come to convert arbitration into a modified form of litigation.

The infirmities of litigation in the process of collecting and presenting evidence also plague arbitration. Like litigation, arbitration generally provides for the selection of the trier of fact substantially after the conflict arises. In a construction dispute, for example, the project may have long been completed when the parties choose the arbiter. At that point, the arbiter cannot view the problem himself, nor can he collect testimony from witnesses while the facts remain fresh in their minds. Like judges, the arbiters receive evidence only after the attorneys resurrect it through the discovery process. And like litigation, arbitration requires an adversary hearing at which the arbiter receives the evidence. The unavailability of the trier of fact at the time of the controversy requires such a lawyer-directed method of collecting and presenting evidence. Moreover, although the rules of evidence for arbitration hearings are far broader than those of courts — they permit for introduction of much hearsay evidence, for example — they effectively retard the arbiters from making a quick decision on what evidence is relevant. In short, arbitration, like litigation, requires a costly and cumbersome procedure for dealing with evidence.

The weaknesses of arbitration become even more alarming if we consider the following controversy, one which might arise on any sizable construction project. During construction, the architect authorizes changes which prove costly to the contractor. The owner disputes the contractor's claims and simultaneously charges that the contractor installed components which were not suitable for the use for which they were intended. Moreover, the owner charges the architect with acting outside the scope of his authority in approving the changes. The contractor, to counter the owner's charges against him, accuses the architect of defective design.

If that sort of dispute sounds familiar, the news that arbitration cannot adequately handle it will be shocking. The fact remains, however, that arbitration cannot deal with such a dispute quickly and economically. Since arbitration depends upon a contractual relationship between parties, the owner, architect, and contractor could not be required to submit to one arbitration proceeding. Although the agreements between the owner and architect and the owner and contractor might each require arbitration of disputes, no contract governs the relationship between the architect and the contractor. The anomaly becomes sharper when we consider that two separate arbitration proceedings might yield inconsistent results.

Arbitration assumes two contending parties, and unless the underlying contract provides otherwise, it cannot deal with third parties. Yet such "third parties" abound in the construction process. One needs little imagination to conjure up a dispute involving the owner, architect, general contractor, subcontractors, and sub-subcontractors and their suppliers. One needs even less imagination to envision the same situation but in which some parties become involved only through the specious allegations of others. The expertise arbitration imports into the considerations could reduce such conflicts to the genuinely interested parties, but the limited third party practice of arbitration invariably dooms such controversies to litigation. Third-party conflicts thus result either in multiple arbitration proceedings or in a single court case. Neither alternative seems particularly appealing when time, expense and justice are the principle considerations.

The weaknesses of arbitration need not color all attempts to construct private dispute-resolution procedures. Indeed the same legal flexibility which licenses parties to frame arbitration procedures also provides them the freedom to construct a better or certainly alternative procedure: "mediation-arbitration".

"Mediation-arbitration" is an admittedly clumsy name for this alternative process. "Med-Arb," as we will call it, embraces several principles: comprehensiveness, continuity, technical expertise, and timeliness. Upon these principles rests a system of dispute resolution which imports the virtues of private negotiation and compromise, mediation, and arbitration.

To insure its success, Med-Arb requires care in creating a comprehensive contractual relationship among the parties to a project. As in arbitration, the contract between parties both sets out the method for dispute resolution and guarantees, in most States, the enforceability of its results, through Arbitration Statutes. In a construction project, for example, the owner generally first deals with an architect. The owner-architect contract, therefore, should contain three key provisions: first, a detailed description of the mediation-arbitration procedures; second a requirement that the parties submit all disputes arising on the project to the med-arb procedure; and third, a requirement that the parties bind *all other parties* with whom they deal to submit disputes to the med-arb process. Concern for these important details at the beginning of the project can alleviate unpleasant disputes as the project progresses. This offers opportunities for lawyers to participate in minimizing conflicts, rather than devoting much greater energies to resolving conflicts through the litigation process.

The provision setting out the med-arb procedures includes the heart of the whole process. Unlike arbitration, med-arb requires the appointment of a disinterested third party — the *med-arbiter* — *before* any conflicts arise. In their contract, the owner, architect and general contractor select an individual who has agreed to act as the center of the dispute-resolution process. A panel of med-arbiters may be provided for. Provision can be made to permit later participants to request a change in med-arb selection as a condition prerequisite to their signing a contract. When a conflict arises on the project the immediate availability of the med-arbiter brings striking benefits. The parties themselves remain free to negotiate among themselves without the med-arbiter. Their instincts toward amicable settlement are not foreclosed by the availability of med-arb. On the contrary, the presence of med-arb forecloses threats of litigation and facilitates mitigating losses and costs related to solving the problem. Med-arb thus nurtures the natural instinct of the parties to try to reach accord.

If the parties should fail to reach an agreement on their own, they may invite the med-arbiter to wear his first hat — that is, to *mediate* their dispute. Like the traditional expert mediator, the med-arbiter acts as a buffer between the parties, persuading them to temper their more extreme demands and informing them of possible grounds of agreement. But since he is more than a traditional mediator, the med-arbiter can act as a more effective spur to agreement. In the first place, he himself knows many of the facts which gave rise to the dispute. The med-arbiter is sensitive to the complexities of the issues due to his knowledge of technical aspects and construction processes. Should he personally be unfamiliar with a particular technical issue, he would call in additional expertise. Moreover, his knowledge leads the parties to give his opinions more weight. In the second place, the fact that the med-arbiter will become an arbiter if the parties fail to agree leads the parties to restrain themselves and to respect the positions of their associates in the enterprise. By remaining honest with the med-arbiter, the parties remain honest with each other and increase the chances of agreement.

If agreement efforts fail, the med-arbiter puts on his second hat, that of arbiter. He becomes, however, an arbiter with a difference. His familiarity with the project from its beginnings, his familiarity with the construction process itself, and his previous experience as a mediator abbreviates the need for the cumbersome presentations of evidence typical in arbitration and litigation hearings. Moreover, in their agreements the parties agree to waive the right to be present when the med-arbiter collects evidence they think relevant. Since he is cognizant of the complexities of the construction process, the med-arbiter knows which parties properly belong in the hearings and those which do not. The fact that all the necessary parties come before him allows the med-arbiter to exercise the expertise for which the parties engaged him: unlike a judge or lay jury, he can reach a substantive decision likelier to strike the parties as fair and equitable. When he does that, the med-arbiter justifies the efforts involved in constructing the system.

The second element of the underlying owner-architect contract requires the parties to submit all disputes which arise on the project to med-arb. This provision creates the jurisdiction of the med-arbiter and is essential to the integrity of the entire process. As in arbitration, courts will "specifically enforce" a med-arb agreement — that is, issue an order directing a party to submit to med-arb — only when the party is an actual signatory to a written med-arb agreement which explicitly covers the controversy in question. While this problem may seem a picky point, courts regard such considerations seriously before they order someone to submit to a private tribunal. In many states a simple statement that the parties agree "to submit any controversy arising on the project" to med-arb will fail to protect the integrity of the process. Suppose a question arises as to whether the parties agreed to submit a peculiar issue to med-arb. Is that itself subject to med-arb? Many courts have said "no", reserving such issues for judicial determination. Obviously such a loophole could undermine the entire med-arb procedure. Fortunately, the insertion of simple language in the underlying contract eliminates the problem altogether. The operative jurisdictional language in the agreement becomes: "the parties agree to submit all controversies arising on the project to mediation-arbitration, including but not limited to, disputes as to issues properly subject to mediation-arbitration under this agreement." The magic words work, and all conflicts arising on the project *do* remain subject to med-arb.

The third aspect of the owner-architect agreement assures to med-arb what simple arbitration agreements frequently lack: complete third-party practice. The parties to the underlying contract agree to bind all *other* parties with whom they deal on the project to the mediation-arbitration procedures. The owner, for example, would bind the general contractor to the procedures in their individual contract. Similarly, the general contractor would bind subcontractors, subcontractors their sub-subcontractors, and so on. In this respect the insistence upon a written agreement to submit to med-arb by all participants in the project will constitute a departure from traditional industry practice. Subcontractors, for example, may not usually require written contracts of their materialmen. The underlying med-arb agreement could limit third-party practice to sub-subcontractors, however, without seriously limiting the procedure. Alternatively, and indeed preferably, a broad third-party practice including materialmen could educate the industry to the values of med-arb by exposing everyone in the industry to it. The most important consideration, however, remains securing a written agreement to submit to med-arb from those most directly involved in the project. Such an agreement makes the procedure complete, comprehensive, and binding.

Like litigation and arbitration, when mediation-arbitration runs its course, it produces a judgment enforceable at law. But unlike litigation and arbitration, med-arb engages every gradation of conflict resolution: negotiation, mediation, and arbitration. At the first stage is the opportunity to mitigate the losses. Until the very last stage the parties remain the masters of the outcome; they govern the result. Even in the last stage they contribute to the substantive determination, for in choosing an expert as the med-arbiter they have selected a person sensitive to their roles in the project. Vastly different from the roulette wheel of litigation, mediation-arbitration gives parties assistance in planning their enterprise by giving parties some control over the allocation of the costs of some risks. Mediation-arbitration affords a system of conflict resolution the rational economic man can use.

PROCEEDINGS

BOSTON SOCIETY OF CIVIL ENGINEERS SECTION
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Meetings Held — Technical Groups

Environmental Group

May 4, 1977. Tour of Fitchburg, Massachusetts, West Wastewater Treatment Plant Physical-Chemical Process. Afternoon tour followed by dinner and meeting at Old Mill Restaurant in Westminster. Speaker, William F. Callahan, Vice President, Camp, Dresser & McKee, Inc. Attendance 25.

Geotechnical Group

April 19, 1977. POTPOURRI presented by the Geotechnical Forum Committee; dinner at Purcell's restaurant. Participants: John E. Ayres and Jackson Y. K. Ho of Goldberg, Zoino, Dunnicliff Associates, Inc.; R. P. Valee and R. S. Skryness of Stone & Webster Engineering Corporation; and Roger F. Gardner of Geotechnical Engineering, Inc. Topics: Anomalous Occurrences of Highly Compressible Clays in Boston Area; Exploratory Shaft in Artificially Frozen Ground; and Construction of Pond Liner in Pervious Gravel. Attendance 53.

May 17, 1977. Joint Dinner Meeting with the New England Section A.E.G. at the Ledgemont Laboratory of Kennecott Copper Corporation in Lexington. Speaker: Robert J. Farina, Head, Engineering Geology and Special Studies Section, U. S. Bureau of Reclamation, Denver, Colorado. Subject: Failure of the Teton Dam. Attendance 140.

Transportation Group

May 18, 1977. Seminar and luncheon, 9:00 a.m. to 2:00 p.m., held jointly with Boston Transportation Group at Pier 4 restaurant. Presiding, Marvin Miller for BSCES and Bruce Campbell for BTG; luncheon chairman, Robert J. McDonagh. Panel presentation on offshore development with participants, as follows: Ms. Cathy Donaher, Director of Planning, Massport; Mr. Stuart C. Mut, Atlantic Richfield Company; Rep. Thomas C. Norton, 9th Bristol District, Vice Chairman Joint Committee on Energy; Mr. Matthew B. Connolly, Director of Fisheries and Wildlife; Mr. Howard W. Nickerson, Executive Director, New England Fisheries Steering Committee. Luncheon speaker, Dr. Evelyn Murphy, Secretary of Massachusetts Executive Office of Environmental Affairs. Attendance 120.

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