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Criteria For Municipal Solid Waste Landfills (Section 610 Review)
Submitted to Docket Number F-1999-MLFN-FFFFF

RCRA Docket Information Center
Office of Solid Waste (5305G)
US EPA (EPA HQ)
401 M St, SW
Washington DC202460

Dr. Anne Jones-Lee and I wish to provide comments pertinent to the Agency's current review of the continued need for Subtitle D regulations. We focus our comments on the adequacy of Subtitle D regulations as they have been implemented at the state and local levels to provide protection of public health, groundwater resources and the environment from Subtitle D landfilled wastes for as long as the wastes in a Subtitle D landfill remain a threat. This is a topic that we have been concerned with since Subtitle D was first proposed in 1988. We have published extensively on the fundamentally flawed approach that the US EPA adopted in 1991 with the promulgation of Subtitle D regulations. These comments summarize many of the issues addressed in our publications.

The basis for our concern and comments stems from my more than 30 years of work on the impact .of landfilled municipal solid wastes (MSW) on public health, groundwater resources and the environment. For 20 of these years I was involved in graduate level teaching and research at several major US universities on various aspects of water quality and solid and hazardous waste management. The research included evaluation of the ability of landfill liners of the type used in Subtitle D landfills to prevent MSW leachate from polluting groundwaters for as long as the wastes are a threat. A summary of my professional expertise and experience pertinent to these comments is appended.

Subtitle D Landfill Containment and Monitoring Systems Are a Flawed Technological Approach for Protection of Groundwater Quality

In 1997 we were invited to present a review paper on the problems of Subtitle D landfills at an Air and Waste Management Association (AWMA) conference session devoted to landfilling of MSW. That paper was presented at the national meeting in June 1997 and published in the conference proceedings. A copy of that paper is appended to these comments. Also, in July 1998

we presented a review paper at the US EPA national Water Quality Monitoring conference devoted to the problems of reliably monitoring liner leakage of leachate from MSW Subtitle D landfills before widespread offside pollution of groundwater occurs. A copy of this paper is appended to these comments.

These papers summarize the current state of knowledge on the ability of minimum Subtitle D MSW landfills to protect groundwater from pollution by landfill leachate for as long as the waste are a threat. A summary of the key deficiencies in the current Subtitle D regulations is presented below. Also we present recommendations on changes that should be made in Subtitle D regulations.

- MSW in a Subtitle D landfill will be a threat to public health, groundwater resources and the environment effectively forever. THE US EPA SHOULD REVISE SUBTITLE D REGULATIONS TO CLEARLY RECOGNIZE THE *AD INFINITUM* THREAT OF MSW IN A SUBTITLE D LANDFILL AND, AS DISCUSSED HEREIN, RELIABLY PREPARE TO MANAGE THIS THREAT TO PUBLIC HEALTH, GROUNDWATER QUALITY AND THE ENVIRONMENT FOR AS LONG AS THE LANDFILLED WASTES ARE A THREAT..

- A single composite liner will not protect groundwater quality from pollution by landfill leachate. SUBTITLE D SHOULD BE REVISED SO THAT ALL MSW LANDFILLS SITED AT LOCATIONS WHERE THERE ARE GROUNDWATERS HYDRAULICALLY CONNECTED TO THE BASE OF THE LANDFILL THAT COULD AT ANY TIME IN THE FUTURE BE USED FOR DOMESTIC WATER SUPPLY WILL BE PROTECTED FROM LANDFILL LEACHATE FOR AS LONG AS THE WASTES ARE A THREAT..

- Minimum Subtitle D landfill leachate leakage through the liner cannot be reliably monitored by the approach allowed in implementing Subtitle D regulations involving vertical monitoring wells located hundreds of feet apart at the point of compliance for groundwater monitoring. The current typical Subtitle D landfill groundwater monitoring system is cosmetic and is unreliable as a means of providing offsite groundwater quality protection. SUBTITLE D SHOULD BE REVISED TO REQUIRE THAT A DOUBLE COMPOSITE LINER SYSTEM IS USED. THE LOWER COMPOSITE LINER IN THE DOUBLE COMPOSITE LINED MSW LANDFILL IS TO BE USED AS A LEAK DETECTION SYSTEM FOR THE EVENTUAL FAILURE OF THE UPPER SUBTITLE D COMPOSITE LINER TO PREVENT LEACHATE FROM PASSING THROUGH THE LINER THAT COULD POLLUTE GROUNDWATER.

- The current Subtitle D regulations do not require the long term funding that will be needed to provide the monitoring, maintenance and eventual remediation of leachate polluted groundwater over the period of time that the wastes in the landfill will be a threat. SUBTITLE D SHOULD BE REVISED SO THAT THE SUBTITLE D LANDFILL OWNER IS REQUIRED TO DEVELOP A DEDICATED TRUST FUND OF SUFFICIENT MAGNITUDE TO ADDRESS ALL PLAUSIBLE WORST CASE LANDFILL CONTAINMENT SYSTEM FAILURE SCENARIOS FOR AS LONG AS THE WASTES IN THE LANDFILL WILL BE A THREAT. FOR PLANNING PURPOSES THIS PERIOD

SHOULD BE CONSIDERED TO BE INFINITE. THIS TRUST FUND CAN BE GENERATED FROM DISPOSAL FEES.

- Current Subtitle D landfill covers will not prevent moisture from entering the landfill wastes that generates leachate that will cause groundwater pollution during the time that the wastes will be a threat. The eventual failure of the plastic sheeting layer in the cover cannot be detected by the current landfill cover inspection approach. SUBTITLE D SHOULD BE REVISED SO THAT A LEAK DETECTABLE COVER IS INSTALLED AND RELIABLY OPERATED FOR AS LONG AS THE WASTES IN THE LANDFILL ARE THREAT. THIS WILL REQUIRE THAT ASSURED FUNDING BE DEVELOPED DURING THE ACTIVE LIFE OF THE LANDFILL.

- Subtitle D regulations fail to reliably protect public health, safety and the environment from the adverse impacts of landfill gas generated in a Subtitle D landfill for as long as the wastes are a threat to generate gas emissions. SUBTITLE D SHOULD BE REVISED TO RECOGNIZE THAT SUBTITLE D LANDFILLS WILL HAVE THE POTENTIAL TO GENERATE AND RELEASE TO THE ENVIRONMENT LANDFILL GAS AND OTHER VOLATILE CONSTITUENTS FOR MUCH LONGER THAN THE CURRENT 30 YEAR MINIMUM ASSURED FUNDED POSTCLOSURE CARE PERIOD. THE REVISED REGULATIONS SHOULD PROVIDE FOR MANAGEMENT OF ALL GAS RELEASES FOR AS THE LANDFILL IS A THREAT TO RELEASE GASES/VOLATILE CONSTITUENTS TO THE ENVIRONMENT.

- Contrary to US EPA's statement in the 1991 Subtitle D regulation, this regulation fails to address the justified NIMBY opposition to Subtitle D landfills developed without adequate buffer lands to dissipate the emissions of waste derived components and other impacts of MSW landfills to the those who live and/or use properties within the sphere of influence of the landfill. This area of influence often extends for several miles from the landfill. SUBTITLE D REGULATIONS SHOULD BE REVISED SO THAT THE HEALTH, ENVIRONMENT, WATER AND AIR RESOURCES AND THE INTERESTS OF THOSE WHO ARE POTENTIALLY IMPACTED BY THE LANDFILL ARE FULLY PROTECTED FOR AS LONG AS THE WASTES IN THE LANDFILL ARE A THREAT.
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Adoption of this recommended approach for revising Subtitle D will be a major step toward beginning to manage MSW in a technically valid cost effective manner to protect groundwater, public health and the environment. This approach will put an end to the highly unreliable information the current US EPA administration has been providing the US public about the "safety" of minimum Subtitle D landfills. With high quality construction of the liner and cover systems, this safety applies for a short period of time compared to the time that the wastes in the landfill will be a threat. While this recommended approach will initially cost the MSW generators (public residential, commercial and industrial) more to manage the MSW, the true long term costs of managing landfilled MSW will be less since the "superfund" costs associated with the remediation of the leachate polluted groundwater will be less likely to occur.

Another important impact of adopting these recommended revisions of Subtitle D is that they will cause the true cost of MSW landfilling to become more comparable to practicing the 3Rs. At this time MSW reuse, reduction and recycling (3Rs) is experiencing problems in obtaining public support due to the higher costs compared to the costs of minimum Subtitle D landfill tipping fees. Currently the Agency claims to promote MSW reduction, reuse and recycling yet allows MSW landfilling at costs less than the real costs to those who generate the wastes. The Agency's current approach for landfilling is strongly contrary to the practice of the 3Rs and passes most of the costs of landfilling of MSW to future generations in terms of threats to their health, loss of groundwater resources and having to pay the "Superfund" costs for polluted groundwater resources, and other long term impacts of Subtitle D landfills. Attached is preprint of a paper that I will be presenting at the AWMA June 2000 national conference session devoted to MSW 3Rs that discuss these issues.

The current US EPA efforts to promote landfill leachate recycle should be properly evaluated in terms of the potential to cause increased and more severe groundwater pollution. Attached is a paper that I will present at the AWMA national conference in June 2000 that discusses problems with leachate recycle in minimum Subtitle D landfills. Also discussed are recommended approaches for promoting wet cell MSW landfilling.

Background to these comments and recommendations are provide in the appended papers. Further additional information is presented in papers and reports available from our web site, www.gfredlee.com.

We strongly recommend that the US EPA not continue its current approaches of weakening Subtitle D as occurred with the adoption of less assured long term funding of postclosure monitoring and maintenance. Instead, the US EPA should significantly strengthen Subtitle D so that it provides true protection of public health, groundwater resources and the environment for as long as the wastes in the landfill are a threat.

If anyone attempts to claim that our assessment of deficiencies in Subtitle D landfills is technically incorrect, please have him/her provide written documentation on the technical bases for the claim(s) so that they can be independently peer-reviewed by experts in the field.

Please contact me if there are comments or questions on these comments.

G. Fred Lee, PhD, PE, DEE
Anne Jones-Lee, PhD

Qualifications to Undertake This Review

My (Dr G. Fred Lee) work on municipal landfill impact matters began in the mid-1950s while I was an undergraduate student in environmental health sciences at San Jose State College in San Jose, California. My course and field work involved review of municipal solid waste landfill impacts on public health and the environment.

I obtained a Master of Science in Public Health degree from the University of North Carolina, Chapel Hill in 1957. The focus of my masters degree work was on water quality evaluation and management with respect to public health and environmental protection from chemical constituents and pathogenic organisms.

I obtained a PhD degree specializing in environmental engineering from Harvard University in 1960. As part of this degree work I obtained further formal education in the fate, effects and significance and the development of control programs for chemical constituents in surface and groundwater systems. An area of specialization during my PhD work was aquatic chemistry.

For a 30-year period, I held university graduate-level teaching and research positions in departments of civil and environmental engineering at several major United States universities, including the University of Wisconsin-Madison, University of Texas at Dallas and Colorado State University. During this period I taught graduate-level environmental engineering courses in water and wastewater analysis, water and wastewater treatment plant design, surface and groundwater quality evaluation and management, and solid and hazardous waste management. I have published over 850 professional papers and reports on my research results and professional experience. My research included, beginning in the 1970s, the first work done on the impacts of organics on clay liners for landfills and waste lagoons.

In the 1980s, I conducted a comprehensive review of the properties of HDPE liners of the type being used today for lining municipal solid waste and hazardous waste landfills with respect to their compatibility with landfill leachate and their expected performance in containing waste-derived constituents for as long as the waste will be a threat.

My work on the impacts of municipal solid waste landfills began in the 1960s where, while directing the Water Chemistry Program in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison, I became involved in the review of the impacts of municipal solid waste landfills on groundwater quality. In the 1970s, while I was Director of the Center for Environmental Studies at the University of Texas at Dallas, I was involved in the review of a number of municipal solid waste landfill situations, focusing on the impacts of releases from the landfill on public health and the environment.

In the 1980s while I held the positions of Director of the Site Assessment and Remediation Division of a multi-university consortium hazardous waste research center and a Distinguished Professorship of Civil and Environmental Engineering at the New Jersey Institute of Technology, I was involved in numerous situations concerning the impact of landfilling of municipal solid waste on public health and the environment. I have served as an advisor to the states of California,

Michigan, New Jersey and Texas on solid waste regulations and management.

In the early 1980s while holding a professorship in Civil and Environmental Engineering at Colorado State University, I served as an advisor to the town of Brush, Colorado on the potential impacts of a proposed hazardous waste landfill on the groundwater resources of interest to the community. Based on this work, I published a paper in the Journal of the American Water Works Association discussing the ultimate failure of the liner systems proposed for that landfill in preventing groundwater pollution by landfill leachate. In 1984 this paper was judged by the Water Resources Division of the American Water Works Association as the best paper published in the journal for that year.

In 1989, I retired after 30 years of graduate-level university teaching and research and expanded the part-time consulting that I had been doing with governmental agencies, industry and community and environmental groups into a full-time activity. A principal area of my work since then has been assisting water utilities, municipalities, industry, community and environmental groups, agricultural interests and others in evaluating the potential public health and environmental impacts of proposed or existing hazardous, as well as municipal solid waste landfills. I have been involved in the review of approximately 50 different landfills in various parts of the United States and in other countries.

Dr Anne Jones-Lee obtained a bachelors degree in biology form Southern Methodist University and a PhD degree in Environmental Sciences from the University of Texas at Dallas in 1978. For 11 years she taught and conducted university graduate level environmental engineering and environmental sciences courses and conducted research on various aspects of water quality management. She and Dr. G. Fred Lee have worked together as a team since the mid 1970s.

Dr. Anne Jones-Lee and Dr. G. Fred Lee have published extensively on the issues that should be considered in developing new or expanded municipal solid waste and hazardous waste landfills in order to protect the health, groundwater resources, environment and interests of those within the sphere of influence of the landfill. Our over 40 professional papers and reports on landfilling issues provide guidance not only on the problems of today's minimum US EPA Subtitle D landfills, but also how landfilling of non-recyclable wastes can and should take place to protect public health, groundwater resources, the environment, and the interests of those within the sphere of influence of a landfill. I make many of my publications available as downloadable files from my web site (www.gfredlee.com).

In the early 1990s, I was appointed to a California Environmental Protection Agency's Comparative Risk Project Human Health Subcommittee that reviewed the public health hazards of chemicals in California's air and water. In connection with this activity, Dr. Jones-Lee and I developed a report, "Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment: An Overview" (Lee and Jones-Lee, 1994a), that served as a basis for the human health advisory panel to assess public health impacts of municipal landfills.

In addition to teaching and serving as a consultant in environmental engineering for over 39 years, I am a registered professional engineer in the state of Texas and a Diplomate in the American

Academy of Environmental Engineers (AAEE). The latter recognizes my leadership roles in the environmental engineering field. I have served as the chief examiner for the AAEE in north-central California and New Jersey, where I have been responsible for administering examinations for professional engineers with extensive experience and expertise in various aspects of environmental engineering, including solid and hazardous waste management.

My work on landfill impacts has included developing and presenting several two-day short-courses devoted to landfills and groundwater quality protection issues. These courses have been presented through the American Society of Civil Engineers, the American Water Resources Association, the National Ground Water Association in several United States cities, including New York, Atlanta, Seattle and Chicago, and the University of California Extension Programs at several of the UC campuses, as well as through other groups. I have been and continue to be an American Chemical Society tour speaker, where I am invited to lecture on landfills and groundwater quality protection issues, as well as domestic water supply water quality issues throughout the US.

SUMMARY BIOGRAPHICAL INFORMATION

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EDUCATION

Ph.D. Environmental Engineering & Environmental Science, Harvard University, Cambridge, Mass. 1960

M.S.P.H. Environmental Science-Environmental Chemistry, School of Public Health, University of North Carolina, Chapel Hill, NC 1957

B.A. Environmental Health Science, San Jose State University 1955

ACADEMIC AND PROFESSIONAL EXPERIENCE

Current Position:

Consultant, President, G. Fred Lee and Associates

Previous Positions:

- Distinguished Professor, Civil and Environmental Engineering, New Jersey Institute of Technology, Newark, NJ, 1984-89
- Senior Consulting Engineer, EBASCO-Envirosphere, Lyndhurst, NJ (part-time), 1988-89
- Coordinator, Estuarine and Marine Water Quality Management Program, NJ Marine Sciences Consortium Sea Grant Program, 1986-1988
- Director, Site Assessment and Remedial Action Division, Industry, Cooperative Center for Research in Hazardous and Toxic Substances, New Jersey Institute of Technology et al., Newark, NJ, 1984-1987
- Professor, Department of Civil and Environmental Engineering, Texas Tech University, 1982-1984
- Professor, Environmental Engineering, Colorado State University, 1978-1982
- Professor, Environmental Engineering & Sciences; Director, Center of Environmental Studies, University of Texas at Dallas, 1973-1978
- Professor of Water Chemistry, Department of Civil & Environmental Engineering, University of Wisconsin-Madison, 1961-1973
- Registered Professional Engineer, State of Texas, Registration No. 39906

PUBLICATIONS AND AREAS OF ACTIVITY

Published over 850 professional papers, chapters in books, professional reports, and similar materials. The topics covered include:

Studies on sources, significance, fate and the development of control programs for chemicals in aquatic and terrestrial systems.
Analytical methods for chemical contaminants in fresh and marine waters.
Landfills and groundwater quality protection issues.
Impact of landfills on public health and environment.
Environmental impact and management of various types of wastewater discharges including municipal, mining, electric generating stations, domestic and industrial wastes, paper and steel mill, refinery wastewaters, etc.
Stormwater runoff water quality evaluation and BMP development for urban areas and highways

Eutrophication causes and control, groundwater quality impact of land disposal of municipal and industrial wastes, environmental impact of dredging and dredged material disposal, water quality modeling, hazard assessment for new and existing chemicals, water quality and sediment criteria and standards, water supply water quality, assessment of actual environmental impact of chemical contaminants on water quality.

LECTURES

Presented over 750 lectures at professional society meetings, universities, and to professional and public groups.

GRANTS AND AWARDS

Principal investigator for over six million dollars of contract and grant research in the water quality and solid and hazardous waste management field.

GRADUATE WORK CONDUCTED UNDER SUPERVISION OF G. FRED LEE

Over 90 M.S. theses and Ph.D. dissertations have been completed under the supervision of Dr. Lee.

ADVISORY ACTIVITIES

Consultant to numerous international, national and regional governmental agencies, community and environmental groups and industries.

Surface and Groundwater Quality Evaluation and Management
and
Municipal Solid & Industrial Hazardous Waste Landfills

http://www.gfredlee.com

Dr. G. Fred Lee and Dr. Anne Jones-Lee have prepared professional papers and reports on the various areas in which they are active in research and consulting including domestic water supply water quality, water and wastewater treatment, water pollution control, and the evaluation and management of the impacts of solid and hazardous wastes. Publications are available in the following areas:

- Landfills and Groundwater Quality Protection
- Water Quality Evaluation and Management for Wastewater Discharges, Stormwater Runoff, Ambient Waters and Pesticide Water Quality Management Issues
- State Stormwater Quality Task Force Activities
- Impact of Hazardous Chemicals -- Superfund, LEHR Superfund Site Reports
- Contaminated Sediment -- Aquafund, BPTCP
- Domestic Water Supply Water Quality
- Excessive Fertilization/Eutrophication
- Reuse of Reclaimed Wastewaters
- Watershed Based Water Quality Management Programs:
  Sacramento River Watershed Program,
  Delta -- CALFED Program, and
  Upper Newport Bay Watershed Program
  San Joaquin River Watershed DO and OP Pesticide TMDL Programs

Stormwater Runoff Water Quality Science/Engineering Newsletter

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Municipal Solid Waste Landfills and Groundwater Quality Protection Issues Publications

Drs. G. Fred Lee and Anne Jones-Lee have prepared several papers and reports on various aspects of municipal solid waste (MSW) management and hazardous waste management by landfilling, groundwater quality protection issues, as well as other issues of concern to those within a sphere of influence of a landfill. These materials provide an overview of the key problems associated with landfilling of MSW and hazardous waste utilizing lined "dry tomb" landfills and suggest alternative approaches for MSW management that will not lead to groundwater pollution by landfill leachate and protect the health and interests of those within the sphere of influence of a landfill. Copies of many of these papers and reports are available as downloadable files from Drs. G. Fred Lee's and Anne Jones-Lee's web page (www.gfredlee.com). Copies of these papers and reports listed below as well as a complete list of their publications on this and related topics are available upon request.

Overall Problems with "Dry Tomb" Landfills

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Assessing the Potential of Minimum Subtitle D Lined Landfills to Pollute: Alternative Landfilling Approaches[1]

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Abstract

The US EPA Subtitle D regulations specify as a minimum, MSW landfills be lined with a single composite liner which is part of a leachate collection and removal system. Upon reaching the landfill capacity, a low-permeability cover is installed. A groundwater monitoring system is used to detect liner failure during the 30-year mandated post-closure care period. The waste in a minimum Subtitle D "dry tomb" landfill will be a threat to pollute groundwaters by leachate, effectively forever. The landfill liner and cover have a finite period of time when they can be expected to function effectively to keep moisture out of the landfill that generates leachate and to collect leachate formed within the landfill. The groundwater monitoring systems typically used with monitoring wells having zones of capture of about one foot on each side, spaced hundreds of feet apart, have low probabilities of detecting landfill liner failure that leads to groundwater pollution before off-site pollution occurs. The 30 years of mandated post-closure care is an infinitesimally small part of the time that the waste in a minimum Subtitle D "dry tomb" landfill will be a threat to generate leachate that can pollute groundwater. Fundamentally, the minimum Subtitle D MSW landfill is a technologically flawed approach that, at best, only postpones when groundwater pollution occurs for those landfills sited at geologically unsuitable sites, i.e. those without natural groundwater quality protection. The US EPA Subtitle D regulations also fail to address the justifiable NIMBY associated with active life releases (odors, dust, blowing paper, etc.) from the landfill to the surrounding area. This paper discusses the deficiencies in minimum Subtitle D landfilling of MSW and provides guidance on alternative landfilling approaches that can protect public health, groundwater resources, environment and the interests of those within the sphere of influence of the landfill.

The complete paper is available from www.gfredlee.com.

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1. Lee, G.F. and Jones-Lee, A., "Assessing the Potential of Minimum Subtitle D Lined Landfills to Pollute: Alternative Landfilling Approaches," Proc. Air and Waste Management Assoc. 91st Annual Meeting, San Diego, CA, available on CD ROM as paper 98-WA71.04(A46), 40pp, June (1998). Also available at http://www.gfredlee.com.

Deficiencies in Subtitle D Landfill Liner Failure and Groundwater Pollution Monitoring[1]

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Abstract

The US EPA (1991) MSW Subtitle D landfill regulations require a groundwater monitoring system based on vertical monitoring wells located at a point of compliance for monitoring that is no more than 150 meters from the down groundwater gradient edge of the landfill. The regulations specify that a detection monitoring program be implemented which has a high reliability of determining when leachate-polluted groundwaters reach the point of compliance. A critical review of the implementation of the Subtitle D landfill liner failure detection approach using the typical current groundwater monitoring approach shows that minimum Subtitle D landfills are being permitted with monitoring wells spaced one hundred to one thousand feet apart. The 1990 work of Dr. J. Cherry showed that plastic sheeting lined landfills such as a minimum Subtitle D landfill, will initially produce narrow plumes of groundwater pollution that arise through leachate leakage through the plastic sheeting liner that could readily pass by the typical point of compliance groundwater monitoring well array without being detected by the monitoring wells. This paper reviews the deficiencies in the Subtitle D groundwater monitoring approach in detecting groundwater pollution associated with the inevitable liner failure before widespread, off-site pollution occurs. Also presented is information on alternative monitoring approaches that have a high reliability of detecting liner failure before significant groundwater pollution occurs. The recommended monitoring system involves the use of a double composite liner with a leak detection system between the two liners where the lower composite liner functions as a pan lysimeter for the upper composite liner.

The complete paper is available from www.gfredlee.com.

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Three Rs Managed Garbage Protects Groundwater Quality[1]

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ABSTRACT

There is considerable misinformation on the public health and environmental benefits of the reduction, reuse and recycling (3Rs) of municipal solid wastes. This situation arises from the publication of several popular press articles that claim that are no environmental benefits of practicing the 3Rs. The June 30, 1996 *New York Times Magazine* carried an article by John Tierney entitled "Recycling is Garbage" which is often cited as an authoritative source of information on the lack of environmental benefits of practicing the 3Rs. Since the publication of the Tierney article, there have been a number of other articles that attempt to support Tierney's theme. This paper presents a discussion of several of the fundamentally flawed bases of those who claim that the 3Rs do not produce significant benefits to public health and the environment.

The primary reason for supporting the 3Rs is the protection of groundwater quality from pollution by landfill leachate. In 1988 the US EPA proposed the Subtitle D regulations governing the landfilling of municipal solid wastes (MSW). The agency acknowledged at that time that the single composite liner that was proposed as the minimum liner would eventually fail which would lead to groundwater pollution by landfill leachate. Under threat of litigation by environmental groups to force the Agency to promulgate Subtitle D regulations, in 1991 the Agency adopted minimum Subtitle D regulations that allow the development of MSW landfills that at best will only postpone when groundwater pollution occurs at most landfill locations. One of the primary bases of the Tierney (and others) position of the lack of environmental benefit of the 3Rs is that MSW landfilling can be practiced in minimum Subtitle D landfills at far less cost than using 3Rs managed solid wastes. Tierney and others who advocate this position are considering only the initial tipping fee cost of disposal and ignore the long term "Superfund" like costs of the eventual cleanup of the polluted groundwater that will occur at most minimum Subtitle D landfills. This paper discusses this and other issues associated with the environmental benefits of the 3Rs.

INTRODUCTION

The June 30, 1996 *New York Times Magazine* carried an article by John Tierney entitled "Recycling is Garbage." As professionals who have been concerned with municipal landfill pollution of groundwaters for over 30 years and who spent 30 years teaching and conducting university graduate-level research on a variety of environmental issues including solid waste management and groundwater pollution control, we find that Mr. Tierney has significantly misrepresented the value of waste reduction and recycling as they relate to protecting the groundwater resources that will be available to future generations.

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[1]. To be presented at Air & Waste Management Association national conference Salt Lake City June (2000)

Mr. Tierney states,

> "*Believing that there was no more room in landfills, Americans concluded that recycling was their only option. Their intentions were good and their conclusions seemed plausible. Recycling does sometimes make sense—for some materials in some places at some times. But the simplest and cheapest option is usually to bury garbage in an environmentally safe landfill. And since there's no shortage of landfill space (the crisis of 1987 was a false alarm), there's no reason to make recycling a legal or moral imperative.*"

Mr. Tierney also states that recycling diverts money from other, more significant environmental problems and that,

> "*Recycling may be the most wasteful activity in modern America: a waste of time and money, a waste of human and natural resources.*"
>
> ***
>
> "*Today's landfills for municipal trash are filled mostly with innocuous materials like paper, yard waste and construction debris. They contain small amounts of hazardous wastes, like lead and mercury, but studies have found that these poisons stay trapped inside the mass of garbage even in the old, unlined dumps that were built before today's stringent regulations. So there's little reason to worry about modern landfills, which by Federal law must be lined with clay and plastic, equipped with drainage and gas-collection systems, covered daily with soil and monitored regularly for underground leaks.*"

We find that Mr. Tierney's statement of "facts" is not valid in many aspects. While there are many valid reasons to criticize the highly inaccurate information that Mr. Tierney has presented on the benefits of recycling, the area that we wish to address is the pollution of groundwaters by municipal landfill leachate. Those knowledgeable about today's landfilling practices know that today's landfills, at best, in most situations only postpone for from a few years to a few decades the pollution of groundwaters by municipal solid waste (MSW) leachate. We also address, to a lesser extent, the other impacts of today's Subtitle D landfills and the factors that need to be considered in evaluating the true costs of landfilling MSW. Additional information on many of the topics discussed is provided in a comprehensive review by Lee and Jones-Lee (1998a,b).

THREE Rs MANAGED GARBAGE PROTECTS GROUNDWATER QUALITY

Long-term Reliability of Landfill Liner Systems

Municipal solid waste (MSW) management has evolved in the USA from open dumps to classical sanitary landfills. The landfilling approach adopted in this country in the early 1980s involves what has been appropriately termed "dry-tomb" landfilling. The dry tomb sanitary landfilling approach is basically an open dump where each day's wastes are covered by a few inches of soil (classical sanitary landfill) and where compacted soil (clay) and plastic sheeting (flexible membrane liners - FML's) are used to try to isolate the untreated municipal solid waste from moisture. This containment system is designed to try to collect and manage the leachate (garbage juice) generated within the "dry tomb" that results from the entrance of moisture into the "tomb." Other countries and geographical areas, including some parts of Canada and western Europe, have chosen not to

adopt the "dry tomb" method of MSW landfilling, typically because of the likelihood of the ultimate failure of the "dry tomb" containment (liner) system to prevent moisture from entering the landfill; and the failure of the system to collect all leachate generated in the landfill.

These plastic sheeting and compacted soil liners were chosen not because they had been demonstrated to have properties that would prevent leachate generation within the landfill and the collection of leachate for as long as the waste in the landfill would be a threat. They were selected because they were the next-cheapest thing to nothing (i.e., an unlined sanitary landfill of the type that was used prior to the adoption of the "dry-tomb" landfilling approach).

In the early 1980s, when the current landfilling approach began to evolve, environmental groups and legislators teamed up to dictate to the US EPA how they should design and monitor landfills to prevent leachate generation and/or to collect it once generated. Basically, the environmental groups and some members of Congress did not trust the US EPA to develop landfilling regulations that would carry out the congressionally defined mandate of protecting public health, the environment and groundwater resources from pollution by landfill-derived leachate for as long as the wastes in the landfill represent a threat. Congress instead adopted regulations that told the US EPA the details of how to design a landfill, with plastic sheeting and compacted clay liners. While the inability of compacted clay to prevent leachate from passing through it for as long as the wastes in the landfill represent a threat was fairly well understood at that time, the ability of the plastic sheeting (principally high density polyethylene) to prevent leachate from passing through it for as long as the wastes represent a threat was poorly understood.

It was known then that compacted clay layers would only postpone when leachate passed through them and, therefore, compacted clay liners of the type being used would not be effective barriers in preventing leachate from passing through the liner for as long as the wastes in the landfill would be a threat. In a "dry-tomb" type landfill, where there is limited moisture to interact with the waste, many of the components of the waste will be in a form that represents a threat to groundwater quality, effectively forever.

With respect to plastic sheeting liners, it was only a few years before information began to accumulate which showed that the plastic sheeting used as landfill liners had a finite period of time during which it could be expected to function effectively as a barrier to moisture entering the landfill, which generates leachate, and as an effective system for collecting leachate so that it could be removed in order to prevent groundwater pollution. By the late 1980s, it was clear that the "dry-tomb" landfilling approach for hazardous waste and MSW was a fundamentally flawed technology that, at best, only postponed when groundwater pollution occurred.

The US EPA Solid Waste Disposal Criteria (1988a) state,

> *"First, even the best liner and leachate collection system will ultimately fail due to natural deterioration, and recent improvements in MSWLF (municipal solid waste landfill) containment technologies suggest that releases may be delayed by many decades at some landfills."*

The US EPA Criteria for Municipal Solid Waste Landfills (1988b) state,

> *"Once the unit is closed, the bottom layer of the landfill will deteriorate over time and, consequently, will not prevent leachate transport out of the unit."*

These statements, while published by the US EPA in 1988, are valid today. While no one can predict how long a particular landfill liner system will function to prevent moisture from entering the landfill through the cover or collect the leachate within the landfill once moisture enters, there is no debatable issue about the fact that today's hazardous waste and MSW landfills' cover and liner systems will, under the current approach for landfilling, ultimately fail to protect groundwaters from pollution by landfill leachate.

While the US EPA (1991) claimed in the preamble to the Subtitle D regulations that the these regulations would be protective at all locations including poor locations, when the basis for this claim is examined, it is found that it is based on a unreliable assessment of the threat that the pollution of groundwater by landfill leachate represents to public health, groundwater resources and the environment. The US EPA assumed that there would be only a few people who would acquire cancer from drinking groundwater polluted by the landfill leachate within several miles of the landfill over the next several hundred years.

Lee and Jones-Lee (1997a,b; 1998a,b) have summarized the deficiencies in the US EPA's Subtitle D regulations and Subtitle D landfills as being developed under these regulations. They have developed a set of questions that should be asked of any landfill applicant and regulatory agency that proposes to approve a minimum Subtitle D landfill. These questions, if reliably answered, will demonstrate that many of the sites where Subtitle D landfills are being developed are not suitable sites for this type of landfill. The minimum MSW Subtitle D landfill cover and single composite liner required by the US EPA or the double composite liner and landfill cover used in some states such as New York, Michigan, New Jersey, etc., will fail to prevent moisture from entering the landfill, which generates leachate and will ultimately lead to pollution of groundwaters in the vicinity of the landfill.

Contrary to the statements made by Tierney, today's landfills are not "safe." The regulatory approach adopted in the 1980s for hazardous waste and municipal solid waste landfilling for which Congress dictated landfill design is now a significant impediment toward revising landfilling regulations to consider what is known today about the ability of "dry-tomb" type landfills to protect groundwater resources from pollution by landfill leachate for as long as the wastes in the landfill represent a threat, i.e. effectively forever.

30-Year Post-Closure Maintenance Myth

Another significant deficiency of the Subtitle D regulations is that only 30 years of post closure (after landfilling has stopped) funding is required. There is no requirement that the landfill owner provide funding to pay for groundwater monitoring, landfill cover maintenance and the eventual groundwater pollution remediation. It is likely, considering the characteristics of municipal solid waste and the processes that take place in "dry tomb" landfills, that MSW in a "dry tomb" sanitary landfill will be a threat to public health, groundwater resources and the environment for as long as

the landfill exists (Lee and Jones-Lee 1992, 1993a). The inorganics (metals, salts) and many organics will be a threat, effectively, forever. Lee and Jones-Lee (1994b) have recommended that the minimum 30-year post-closure maintenance and monitoring period should be abandoned in favor of an expanded, perpetual, *ad infinitum* funded maintenance and monitoring. Hickman (1992, 1995) has urged that a dedicated trust fund be developed for all landfills to meet contingencies that may be encountered in the future.

Lee and Jones-Lee recommend that the post-closure maintenance and monitoring funding be developed from additional disposal fees. The funds should be placed in a dedicated trust that can only be used to meet the closure/post-closure maintenance and monitoring needs. They recommend the magnitude of the trust fund be sufficient to eventually exhume (mine) the wastes in the landfill and properly manage these wastes so they do not represent threats to public health, groundwater resources and the environment. Lee and Jones-Lee (1995a, 1998a) have reviewed the problems with current "dry tomb" landfill closure and post-closure maintenance and monitoring approaches and have recommended approaches for closure and post-closure maintenance for classical sanitary and "dry tomb" Subtitle D landfills.

Since, with few exceptions, both of the types of landfills (classical and "dry tomb" sanitary landfills) will pollute groundwaters and the aquifer system hydraulically connected to the landfill, the key to public health and environmental protection is the establishment of a leak-detectable cover that prevents moisture from entering the landfill after closure of the landfill. The current Subtitle D regulations allow the closure of a "dry tomb" sanitary landfill with a cover that does not necessarily keep the wastes dry so that the landfill does not generate leachate that can penetrate the landfill liners and pollute the groundwaters associated with the landfill. Leak-detectable covers are now available from Gundle Lining Systems, Inc., and Robertson Barrier Systems Corps of Vancouver, BC. The development of the funding necessary to operate and maintain the leak-detectable cover is also a key component of proper closure of "dry tomb" sanitary landfills.

Impacts of MSW Leachate Pollution of Groundwaters

Mr. Tierney implies that there are only a few components of MSW that represent threats to groundwater quality. He does not understand domestic water supply water quality issues or the composition of leachates produced by today's MSW landfills. Jones-Lee and Lee (1993) have provided a discussion of the potential impacts of today's MSW leachate on public health, groundwater resources, the environment and the interests of those within the sphere of influence of the landfill. Today's MSW landfills, even with 50% diversion of the waste as it is practiced today, including extensive household hazardous waste collection/diversion, contains a wide variety of hazardous and deleterious chemicals that can render a groundwater unusable for domestic and many other purposes. The current groundwater quality protection regulations do not adequately or reliably address the wide variety of constituents in MSW leachate that can impair the use of a groundwater for domestic water supply purposes.

There is no doubt that, even with a highly effective household hazardous waste collection program and no illegal industrial and commercial hazardous waste disposal, MSW leachate would still be highly hazardous to individuals who use groundwaters polluted by leachate. There is no way to totally divert all hazardous and deleterious chemicals from MSW. Contrary to the statement made

by Tierney, the "poisons" inside MSW are not trapped inside the garbage. All that Tierney needed to do to understand the fallacy of his statement is to examine the chemical characteristics of Subtitle D landfill leachate. Part of the hazardous chemicals, as well as a variety of highly deleterious chemicals, leave a landfill through the liner system and pollute groundwaters, rendering them unusable for domestic water supply purposes.

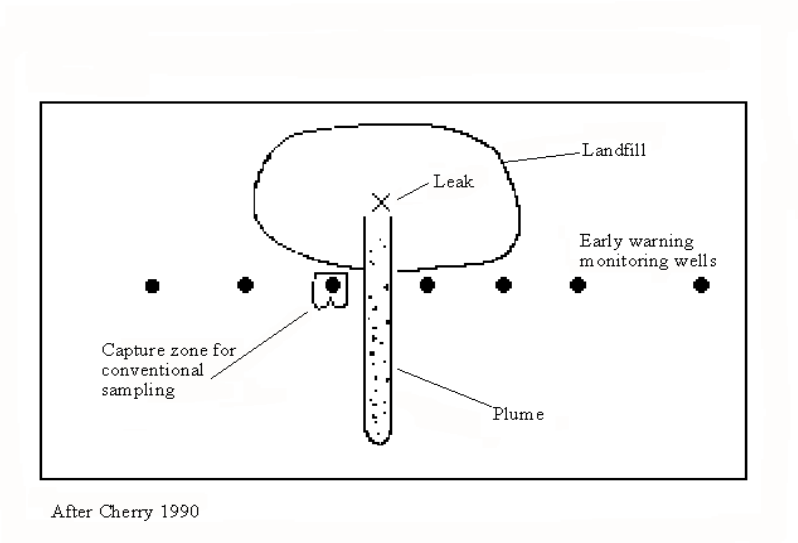
It can be concluded that the basic approach that must be used in managing solid waste in light of the current inadequate Subtitle D regulations is to reduce the magnitude of solid waste that must be disposed of to the maximum extent possible in order to reduce the number of landfills that will eventually pollute groundwaters. Also landfills should be sited where the inevitable pollution of groundwaters is of little or no consequence to the public, who at some time in the future may wish to use groundwaters in the region for domestic water supply purposes.

Reliability of Groundwater Monitoring to Detect Pollution

A key component of the landfilling regulations adopted in the early 1990s was the requirement for groundwater monitoring. The basic approach used by the US EPA for groundwater protection from pollution by landfill leachate was that the groundwaters downgradient from the landfill would be reliably monitored near the landfill in order to detect liner failure. In principle, the near-landfill detection of liner failure (i.e. leachate polluted groundwaters), would occur sufficiently early so that the amount of groundwaters polluted by leachate would be small and would not trespass under adjacent properties. The basic approach for monitoring the new lined landfills was to install a series of vertical monitoring wells spaced so that they would have a high reliability in detecting landfill leachate pollution of groundwater at the point of compliance for groundwater monitoring. In practice, however, the monitoring wells are spaced hundreds to a thousand or more feet apart along the downgradient groundwater edge of the landfill.

Cherry (1990) first pointed out that the groundwater monitoring system developed for unlined landfills of a few wells spaced hundreds of feet apart down groundwater gradient from the landfill is an unreliable approach for monitoring lined landfills. Lined landfills will initially leak leachate through the liner through limited size holes, rips, tears and points of deterioration that will produce finger-like plumes of leachate of limited lateral dimensions. This relationship is shown in Figure 1. Each of the typical monitoring wells has a zone of sampling of about one foot on each side. Therefore, the finger-like plumes of leachate can readily pass between the monitoring wells without being detected. Lee and Jones-Lee (1994a, 1998b) have discussed a groundwater protection strategy that involves the use of a double composite liner of the type used by the state of Michigan. The lower composite liner serves as the base of a leak detection system. When leachate is found in this system between the two composite liners, it is clear that the upper composite liner has failed and action must be taken to prevent groundwater pollution that will occur when the lower composite liner fails. Unfortunately, this approach is not used elsewhere.

Figure 1
Typical Groundwater Monitoring at Subtitle D Landfills



Lee and Jones-Lee (1996) have r discussed the detection of landfill liner system failures. They point out that while often landfill proponents claim that there are no recorded instances of a Subtitle D landfill polluting groundwaters, they fail to point out that one of the primary reasons for this is the unreliability of the groundwater monitoring systems to detect the pollution of groundwaters by landfill leachate. Further, the widespread groundwater pollution that will ultimately occur from today's Subtitle D landfills would not be expected to be detected today because of the short time that Subtitle D landfills have been used.

It is appropriate to question whether today's landfills, with their plastic sheeting and compacted soil liners and monitoring systems that depend on vertical monitoring wells placed hundreds to a thousand or more feet apart, are significantly better than the classical unlined landfills that were used before the "dry-tomb" landfilling approach was implemented. At least with the classical sanitary landfills, the leakage of leachate to groundwater occurred at all locations under the landfill; therefore, it was relatively easy to detect, through monitoring, pollution of groundwaters by landfill leachate. With today's lined landfills and the finger-like plumes of polluted groundwater that are generated from them, the public, and some individuals such as Mr. Tierney, are lulled into believing that they are "safe" landfills, when in fact they are basically time bombs that will ultimately be significantly detrimental to future generations' health, groundwater resources and interests. The "dry-tomb" landfllling approach gives the public a false sense of safety that something permanent in groundwater quality protection is being done in managing solid wastes when it is not.

Unreliability of Landfill Gas Production in Closed Subtitle D Landfills

One of the areas of concern for impacts on public health and the environment with Subtitle D landfills is landfill gas production after the landfill is closed. Subtitle D allows the closure of a landfill with a plastic sheeting layer in the cover as the barrier to moisture entering the wastes.

This plastic sheeting is buried below several feet of cover soil. While a plastic sheeting layer can be constructed in a landfill cover that will be an effective barrier to moisture entering the landfill, over time the plastic sheeting will deteriorate, develop holes and allow moisture to enter the wastes. Typically the approach used to detect problems with the cover involves visual inspection of the soil surface. This approach is not reliable for detecting leaks in the plastic sheeting layer.

Moisture in the solid wastes is the key to landfill gas production. Dry wastes do not produce landfill gas. The closure of a Subtitle D landfill with a plastic sheeting layer in the cover that prevents moisture from entering the landfill will stop landfill gas production. As discussed by Lee and Jones-Lee (1999), this situation leads to an inability to reliably predict landfill gas production over the period of time that the wastes are a threat to produce landfill gas. Since much of the solid wastes placed in a landfill today is present in plastic bags that are crushed but not shredded, the period of time that a Subtitle D landfill will be a threat to produce gas can be well beyond the 30 year postclosure care period. This period will be much longer than that which typically occurs a in a classical sanitary landfill.

A Subtitle D "dry tomb" landfill may not produce landfill gas for many years while the plastic sheeting layer is an effective moisture barrier. However, at some time in the future landfill gas production will start again. This could readily occur after the minimum 30 year postclosure care period when there is no money for landfill gas monitoring, maintenance and operation of the landfill gas collection system. The uncontrolled release of landfill gas that could readily occur with closed Subtitle D landfills is a significant threat to public health, public safety and the environment.

Flawed Technological Approach

It is obvious that the "dry-tomb" type of landfilling is fundamentally flawed if the purpose of landfilling is to manage MSW while protecting groundwater resources from pollution by hazardous and deleterious chemicals that render groundwaters unusable for domestic water supply purposes. It is important to note that several countries, such as some parts of Canada and western Europe, will not allow the construction of "dry-tomb" type landfills for managing municipal solid wastes because of their inevitable failure to protect public health, groundwater resources and the interests of those who own or use properties near a landfill.

With respect to Mr. Tierney's statement about "safe landfills," it is quite clear that there is no such thing as a safe landfill of the type being developed today, where the landfill is sited in an area where there are groundwaters that are or could at any time in the future be used for domestic water supply purposes. With few exceptions associated with landfills sited at locations where there is no useable groundwater associated with the landfill, today's landfills will not prevent groundwater pollution and, therefore, are not safe.

Justified NIMBY

Mr. Tierney states in his article that,

"Landfills are scarce in just a few places, notably the Northeast, partly because of local economic realities (open land is expensive near cities) but mainly because of local politics. Environmentalists have prevented new landfills from opening by propounding another myth... Our garbage will poison us."

Once again, Mr. Tierney has not reliably discussed the issues of justified concern to those who own or use properties near existing or proposed landfills. Anyone who has ever spent any time around a municipal landfill knows that, with very few exceptions, today's landfills are poor neighbors. In addition to polluting groundwaters, today's landfills that meet current regulatory requirements release a wide variety of hazardous and obnoxious materials that are significantly detrimental to those within the sphere of influence of the landfill.

As discussed by Lee and Jones-Lee (1993b, 1994c), the direct sphere of influence of many municipal landfills for such problems as odors, dust, blowing trash, birds, truck traffic and decreased property value is often several miles from the landfill. Current regulatory requirements do not require that those who develop landfills control these releases from the landfill so they do not trespass onto adjacent property owners' lands. Landfill owners/operators are able to construct a landfill within a very short distance of the landfill-adjacent property owners' property line. There is, therefore, inadequate distance between where wastes are deposited and constituents are released from the deposited wastes and the properties of adjacent property owners/users. This leads to a highly justified NIMBY ("Not In My Back Yard.")

The authors have yet to find a single person who would welcome having an MSW landfill sited within a few hundred yards of their property line. This NlMBY is justified. Until such time as effective regulatory requirements are developed and, most importantly, implemented-enforced where adequate bufferlands between where the wastes are deposited and the adjacent property line occur (a mile or more) there will be significant justified opposition to siting landfills in a region. The issue is not just "poisons" as Mr. Tierney states; the issue that must be addressed in eliminating a justified NIMBY is the control of all of the hazardous and obnoxious impacts of landfills on the landfill owners' properties.

Importance of Recycling in Preventing Groundwater Pollution

The deficiencies in Subtitle D landfills have significant implications for the importance of recycling/diversion of wastes from the landfill through reuse, reduction and recycling. It is generally found that it is relatively easy for communities to divert 25% of the MSW stream through recycling, reduction and reuse of waste components. It is also fairly well established that, with aggressive use of the 3Rs, it is possible to achieve a 50% reduction/diversion of the MSW stream. This means that, since each landfill has a finite capacity for accepting waste, if the rate of filling of today's landfills is reduced by 50%, there will therefore be 50% less need for new landfills. With each new landfill there is a certain inevitable groundwater pollution, except for the few landfills sited at locations where there are no useful groundwaters hydraulically connected to the base of the landfill. Such situations are indeed rare. Most landfills sited today are located where groundwater pollution is inevitable, i.e., it is only a matter of time.

Since the groundwater resources of an area are crucial to future generations' water supplies, it is essential that their quality be protected. This is especially important in light of the fact that there is no cleanup of MSW leachate-polluted groundwaters to acceptable drinking water quality once they have been polluted by MSW leachate. Such groundwaters and the associated aquifer areas must be considered permanently damaged and lost effectively forever as a domestic water supply.

Economics of Recycling

Mr. Tierney devotes considerable space to a discussion of the economics of recycling, where he claims that recycling is not cost-effective in terms of benefit to society. Mr. Tierney's analysis of the economics of recycling is fundamentally flawed in that he fails to consider the perpetual monitoring and maintenance costs as well as the Superfund costs of cleaning up the groundwater pollution associated with landfill liner systems that at best only delay when groundwater pollution occurs. Further, he fails to address the significant costs associated with the adverse impacts of landfills on those who own or use properties within the sphere of influence of the landfill. Today's society has been able to force landfills and their impacts on nearby property owners.

As discussed by Lee and Jones-Lee (1993b, 1994c), with the exception of a few impacts such as altered viewshed, truck traffic, etc. it is possible to develop landfills with sufficient bufferlands and control systems to eliminate most of the justified NIMBY. However, the development of such landfills would require a significant increase in the cost of landfill management of wastes. These costs are now being passed on to nearby owners and users of properties near landfills. This is one of the major reasons for justified NIMBY.

A proper economic analysis considers not only the short term active life issues of concern to today's public, but also the long-term issues of concern to the health, welfare and interest of future generations. Fundamentally, today's landfills enable the current society to dispose of their garbage by landfilling at far less than the real cost of landfilling. A substantial part of the true costs and the associated detriments are being passed on to future generations. It is possible to develop appropriate landfills today that can manage the non-recyclable components of waste at a cost of about 10 to 20 cents per person per day more than is currently being paid for MSW management under Subtitle D regulations.

A fundamentally flawed premise in Mr. Tierney's discussion is that the cost of recycling MSW components is not justifled. The facts are that a proper economic analysis would likely show that it is prudent public policy to subsidize 3R activities in order to reduce the magnitude of the true costs of the landfilling of MSW. It is inappropriate to assume that the costs of landfilling are properly reflected in the tipping fees being paid at today's minimum Subtitle D landfills. These tipping fees are kept artificially low by failing to address the true active life costs to those within the sphere of influence of the landfill as well as the true long term costs to groundwater resources, public health and the environment.

Need for Federal Landfilling Regulation (RCRA) Revisions

A critical review of today's MSW and hazardous waste landfilling situations shows that there is an urgent need to revise RCRA (federal regulations governing landfilling of wastes) to address the well-known, highly significant deficiencies in both hazardous waste and MSW landfilling

approaches. While, as discussed by Lee and Jones-Lee (1995b, 1998a), "dry-tomb" landfilling can be made to work if significantly different approaches are taken toward design, closure and long-term funding of these landfills, it is unlikely that today's and future generations will, in fact, provide the funds necessary to properly operate and maintain "dry-tomb" landfills for as long as the wastes represent a threat. For this reason, there is growing recognition that the "dry-tomb" landfilling approach must be abandoned as soon as possible.

Those landfills that have been constructed under current regulations, with the plastic sheeting and compacted clay liners, should be recognized as eventual polluters of groundwaters similar to the classical unlined sanitary landfills. Funds should be set aside from disposal fees, while the landfills are actively receiving waste, to face the inevitable groundwater pollution problems that will have to be addressed.

Today's landfilling regulations should be changed so that it will be possible to construct landfills as biological and chemical reactors, where shredded MSWs are placed in double composite-lined landfills in which leachate, and then eventually clean water, is added to the landfill while the liner system is still effective in collecting leachate, in order to remove those components of the waste that will inevitably be leachable as precipitation enters the landfill in the future. This "wet cell" approach for landfilling is readily implementable, and its costs, while initially somewhat higher, in the long-term are far cheaper than the "dry-tomb" approach (Lee and Jones-Lee, 1993c). The components of the waste that represent long-term threats are removed by this approach through deliberate fermentation and leaching of the waste under controlled conditions.

Today's landfilling regulations are badly out-of-date and represent an early 1980s understanding of the ability of landfill liner systems and groundwater monitoring systems being used to prevent pollution of groundwaters by landfill leachate for as long as the wastes in the landfill represent a threat. Specifically, there is need to change RCRA and/or state regulations to:

- require that a double-composite liner be used for both Subtitle C and D landfills where the lower composite liner is a leak detection system for the upper liner.
- require that, when the landfill owner/operator cannot stop leachate from occurring in the leak detection system between the two composite liners, the wastes in the landfill must be removed (mined) from the landfill.
- require the closure of Subtitle C and D landfills with leak detectable covers that are operated and maintained for as long as the landfill exists.
- eliminate the minimum 30-year post-closure care and maintenance period and require that post-closure care be provided for as long as the wastes in the landfill represent a threat, which is understood in a "dry-tomb" type landfill to be forever.
- require that an adequate dedicated trust fund be developed from disposal fees to ensure that funds will in fact be available when needed for perpetual monitoring and maintenance in order to meet any plausible worst-case contingencies that could occur at a landfill, including waste exhumation and groundwater cleanup, to the extent possible.
- allow *in situ* treatment (fermentation and leaching) initially utilizing leachate recycle followed by clean water leaching of shredded wastes in double composite-lined landfills.

- RCRA also needs to be changed to ensure that all justifiable NIMBY impacts associated with landfills (such as odor, dust, fugitive trash, gull impacts, etc.) are controlled within the property boundaries of the landfill owner.
- Because of the high perpetual, ad infinitum costs associated with "dry-tomb" landfilling that provide for true protection of public health, groundwater resources and the environment, it is recommended that the "dry-tomb" landfilling approach be abandoned as soon as possible in favor of a waste treatment approach that produces residues that do not represent long-term threats to groundwater quality, public health and the environment.

Adoption of the recommended approach for MSW management which maximizes the use of the 3Rs will significantly change the economics of the 3Rs. As long as the myth that Tierney attempted to support continues to exist that the landfilling of MSW can be safely done in a minimum Subtitle D landfill at the costs that are being paid today, society will continue to fail to properly support MSW waste stream component reduction, recycling and reuse. There is an urgent need to stop the current trend of reducing the magnitude of 3R waste diversions arising out of the flawed economic analyses that are being used today to evaluate the benefits of the practice of the 3 R's in MSW management.

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KEY WORDS

municipal solid wastes recycling, groundwater pollution, 3Rs

Appropriate Use of MSW Leachate Recycling in Municipal Solid Waste Landfilling[1]

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ABSTRACT

There is considerable interest today in the so-called "biocell" approach toward municipal solid waste (MSW) landfilling in which leachate is introduced back into the landfill. This approach reduces the cost of leachate management and is said to reduce/eliminate the potential for long term landfill gas production and groundwater pollution. However, a critical review of the typical approach being used today in biocell landfilling in Subtitle D landfills shows that the biocell approach will fall far short of appropriate landfilling of MSW that will prevent long-term gas production problems and groundwater pollution. Today's minimum Subtitle D landfills can cause groundwater pollution at the time of landfill construction due to the inherent rates of leakage of leachate associated constituents through the liner system. Further, over time the flexible membrane liners' (FMLs') ability to collect leachate will decrease as the FML deteriorates. The groundwater monitoring systems allowed by regulatory agencies at minimum Subtitle D landfills have a low probability of detecting leachate polluted groundwaters before significant offsite groundwater pollution occurs. Leachate recirculation in a minimum Subtitle D landfill increases the hydraulic loading of the landfill which can lead to increased groundwater pollution.

One of the principal problems with reintroduction of leachate into today's MSW landfills as a means of decreasing the time for landfill "stabilization" is that a large part of today's MSW is disposed of in plastic bags that are not shredded at the time of burial. These plastic bags "hide" the waste from the moisture which would allow increased landfill gas formation rates and leachate generation during the time that the landfill liner system can possibly be an effective barrier to groundwater pollution. While the addition of moisture to shredded municipal waste can greatly reduce the time of landfill gas production, unshredded solid waste will produce landfill gas and leachate over very long periods of time related to the rate of decomposition of the plastic bags.

This paper discusses the problems with current approaches for leachate recycle (biocell landfilling) and recommends how such landfilling should be practiced to achieve increased rates of landfill stabilization while protecting nearby groundwater resources from leachate pollution. Biocell landfilling should be practiced using shredded MSW in a double composite lined landfill in which the lower composite liner is a leak detection system for the upper composite liner. After landfill gas production has essentially stopped, then clean water should be added to the landfill to wash/leach the solid waste residues to remove potential pollutants. This washing should be done without

[1]. Proc Air &Waste Management Association 93 annual meeting Salt Lake City,UT June (2000)

leachate recycle. Adoption of this “fermentation leaching” wet cell approach will lead to a rapid stabilization of the fermentable waste components in the landfill and remove those constituents from the landfill that can lead to groundwater pollution. While initially more expensive than biocell landfilling, in the long term the cost will be cheaper than the cost of municipal solid waste management in minimum Subtitle D landfills since the long term “Superfund” cost associated with this approach will be eliminated.

KEY WORDS municipal solid waste, leachate recycle, groundwater pollution, landfill gas formation

INTRODUCTION

The US Environmental Protection Agency's (US EPA, 1991) Resource Conservation and Recovery Act (RCRA) Subtitle D requirements for municipal solid waste (MSW) landfilling basically prescribe the placement of MSW in a "dry tomb" landfill. In concept, it is intended that such systems keep the buried wastes dry; as long as the wastes are kept dry, they will not ferment and produce landfill gas, or generate leachate. However, the buried wastes remain a threat to groundwater quality for as long as they are in the "dry tomb."

Lee and Jones-Lee (1993a,b; 1998a,b) discussed the problems with the "dry tomb" landfilling approach that preclude its ensuring protection of groundwater quality for as long as the wastes represent a threat. They noted among other problems that liners of the type currently used leak from the time a landfill is placed in service and deteriorate over time; the leachate collection and removal systems depend on the integrity of the liner system and are subject to biological fouling; groundwater monitoring programs typically used are inadequate to detect incipient liner leakage or incipient groundwater pollution by landfill leachate; inadequate attention is given to sufficiently funding the post-closure care of landfill covers that will be required in perpetuity. At best, "dry tomb" landfills postpone groundwater pollution and pass the costs for corrective action, proper waste handling, and lost groundwater resources on to future generations (see Lee and Jones-Lee, 1993c).

There is growing consensus that the "dry tomb" storage of MSW should be abandoned in favor of *in situ* treatment of MSW so as to remove at the outset, components that could otherwise eventually leak from the landfill to pollute groundwater. The "fermentation/leaching wet cell" (F/L wet cell) shows considerable promise for achieving such treatment in a cost-effective manner. In that system, moisture is introduced into the buried wastes to enhance the stabilization of fermentable organics (those that undergo anaerobic bacteriological transformation to methane and carbon dioxide), and to leach the leachable chemicals from the wastes that could otherwise escape the landfill to adversely affect the beneficial uses of groundwater. A potential source of moisture for the fermentation is leachate generated in the landfill. While recycling leachate through the wastes can aid in waste "stabilization," there is considerable misinformation being advanced today about the role of leachate recycle in the "treatment" of MSW to reduce the potential for the leachate to pollute groundwater. Presented below is a discussion of potential benefits of leachate recycle with particular reference to its potential use in protecting groundwater from pollution by landfill leachate.

APPROPRIATE USE OF MSW LEACHATE RECYCLING IN MUNICIPAL SOLID WASTE LANDFILLING

Leachate Recycle in MSW Management

Lee, *et al*. (1985; 1986), Pohland and Harper (1987), Otieno (1994) and Reinhart and Townsend (1998) discuss that leachate recycle has been used for many years as a means of "disposing" of MSW landfill leachate and to enhance "stabilization" of fermentable organics in MSW. The rate of methane generation is controlled by the amount of moisture present in the waste. In the classical sanitary landfill where no attempt is made to restrict entrance of moisture, landfill gas formation typically takes place for 30 to 50 years. As additional moisture is added to the waste, the rate of methane formation increases. It has been well-documented in the literature that by adding moisture through leachate recycle the period during which methane is generated under ideal conditions in a sanitary landfill can be reduced to 5 to 10 years.

Christensen and Kjeldsen (1989) reported on a study of the impact of the moisture content of MSW on gas production rate. They reported that gas production essentially ceased when the percent moisture in the waste is less than about 20%. The rate of gas production increased with moisture content up to the maximum moisture content evaluated, about 60%. It is possible, although not investigated by them, that higher rates of gas production could have occurred with higher moisture content.

In cooperation with the Sonoma County (CA) Department of Public Works, EMCON (1975; 1976) conducted one of the most comprehensive and definitive studies of the impact of leachate recycle on the chemical characteristics of MSW landfill leachate. A set of landfill test cells (measuring 18x18x2.4m (60x60x8ft)-deep) was developed; each cell was filled with about 477 mtons (525 tons), about 909 m^3 (1000 yd^3), of MSW. Each cell received leachate that had been produced within the cell, or clean water, or no supplemental moisture, or one of various other treatments. The chemical characteristics of the leachate were determined periodically over a 4-year period. It was found that during the test period, the test cell that received recycled leachate produced methane at the greatest rate; by the end of the test, the rate of methane formation had been significantly reduced.

The test cell that received only clean water, with no recirculated leachate, also produced methane at a rapid rate, but the rate was initially somewhat slower than that of the cell that received recycled leachate. Methane formation from stabilization of the fermentable organics in the waste in that test cell was also almost completed during the 4-year period. By contrast, the test cell that received no moisture other than atmospheric precipitation that penetrated the clay cover (which was not designed to be a "low-permeability" cover of the type being developed today for "dry tomb" landfills), produced very little methane by the end of the 4-year test period.

As might be expected, the groundwater pollution potential of the leachate produced in each of the three test cells at the end of the 4-year test period was different. The leachate from the test cell that had received only precipitation that naturally penetrated the cover had characteristics similar to those

of classical MSW sanitary landfill leachate; it contained a wide variety of chemical contaminants in concentrations that would represent a significant threat to beneficial uses of groundwater. At the end of the 4-year test period, the leachate from the test cell that had received recycled leachate also still contained a wide variety of chemicals in concentrations that would represent a significant potential to pollute groundwater. The leachate from the test cell that had received clean water during the test period had somewhat less potential to pollute groundwater than that from the cell that had received recycled leachate. It was evident that the clean-water washing (leaching) of the wastes effected the lowering of concentrations of constituents that represented a significant potential for groundwater pollution. That was not accomplished in the test cell that received recycled leachate.

The Sonoma County studies further demonstrated that recycling of leachate in an MSW landfill does significantly enhance the rate of landfill gas production and stabilization of the fermentable components of the MSW. The stabilized MSW residues developed after leachate recycle, however, were still a significant threat to groundwater quality. These authors (Lee and Jones-Lee) conclude from the Sonoma County studies, as well as the information in the literature, that leachate recycle as it has been practiced will not produce MSW residues that are no longer a significant threat to groundwater quality.

While it is evident from the literature that leachate recycle can significantly hasten the rate of stabilization of fermentable components of MSW, there are significant amounts of material in normal MSW that are not converted to methane and carbon dioxide under anaerobic conditions (i.e., are not fermentable). It is also clear that some of the fermentation residues, as well as non-fermentable materials in typical MSW contain readily leachable components; because of those components, leachate developed has a significant potential to pollute groundwater hydraulically connected to the landfill area. Therefore, leachate recycle *per se* does not address the primary concern about the landfilling of municipal solid wastes, namely groundwater pollution by leachate-derived constituents. This was demonstrated in the Sonoma County study discussed above.

Some landfill owners/operators practice leachate recycle as a means of reducing the costs of leachate treatment. By recycling the leachate back into the landfill, the amount of leachate that must be treated by other means can be lessened. This is especially effective when the leachate is sprayed over the surface of the landfill and given significant opportunity to undergo evaporation and evapotranspiration. However, that approach does not remove many of the contaminants in MSW landfill leachate; re-introduction of the leachate into the landfill replaces the chemical contaminants in the landfill or at its surface where they remain subject to leaching and transport to the surface waters and groundwaters of the region.

Another significant factor that must be considered today in assessing the utility and effectiveness of MSW leachate recycle is the fact that much of the garbage received by MSW landfills is in plastic bags. Such bags significantly obstruct the contact between the recycled leachate and the fermentable components of the solid waste. This would detract from the appearance of accelerated fermentation noted with leachate recycle. The results of the laboratory studies by various investigators, as well as the Sonoma County studies, would be expected to be significantly different if significant amounts of the waste were contained in plastic bags that inhibited contact between the recycled leachate and the waste.

Unreliable Discussion of the Potential Problems with MSW Leachate Recycle

Over the years there are many papers, reports and a book that discuss/promote MSW leachate recycle. With few exceptions the authors of these papers, etc., fail to discuss the potential problems with leachate recycle. These problems have been discussed in the solid waste management literature (see Lee, *et al*.1985, 1986; Lee and Jones 1990; Lee and Jones-Lee, 1993b, 1994a,b, 1995a, 1996) over the past 15 years. States have reviewed these issues and concluded that these problems are sufficient to prevent leachate recycle. Yet these issues are not discussed by many of those who wish to promote MSW leachate recycle. A notable exception is Magnuson (1996). The landfill owners, regulatory agencies and the public are entitled to a balanced discussion of the advantages and disadvantages/potential problems of MSW leachate in minimum Subtitle D landfills sited where the increased groundwater pollution can occur than is occurring today (see Lee and Jones-Lee1995b).

Fermentation/Leaching Wet-Cell Approach

Lee and Jones (1990) and Lee and Jones-Lee (1993b) described an *in situ* fermentation/leaching wet-cell treatment approach by which it should be possible to treat MSW to produce a residue that represents little long-term threat to groundwater quality. The concept is to stabilize the fermentable components of MSW employing leachate recycle, and then to actively leach the residues to remove and treat those components that would otherwise eventually leak from the landfill and pollute groundwater. Wastes would be shredded prior to placement to reduce impediments to contact of the liquid with the waste components. A double-composite-lined landfill with appropriate liner leak detection systems would be used; a reverse groundwater gradient liner system (hydraulic trap) may be employed where indicated to provide additional protection against groundwater pollution.

It is expected that leachate would be recycled through the landfill for a period of 3 to 5 years; that should provide sufficient time for the fermentation of those components that are subject to anaerobic fermentation to methane and carbon dioxide. At the end of the leachate recycle period, clean water would be added to leach the waste; leaching should be practiced until the leachate produced no longer represents a significant threat to groundwater quality. Depending on the design of the landfill cells and the hydraulic loading, it is estimated that a leaching period of 15 to 20 years should be sufficient to produce MSW residues that are no longer a significant threat to groundwater quality. If during the course of the leaching period, leachate were to pass through the upper-composite liner, it would be necessary to stop the leaching process, exhume the wastes, and treat them to produce non-polluting residues.

The fermentation/leaching wet-cell approach for *in situ* treatment will initially be more expensive than the conventional "dry tomb" landfilling owing to the additional costs of treating the leachate produced in the clean-water washing of the garbage. The magnitude of the increased cost is highly site specific and depends on the methods used for leachate management. However, in the long term, the F/L wet-cell approach would be less expensive since it has the potential to eliminate the need for, and very high cost of, providing landfill cover maintenance *ad infinitum*, and since it would

significantly reduce the potential for having to spend funds to try to clean up leachate-contaminated groundwaters near the landfill, and replace lost groundwater resources.

It is important to distinguish the "fermentation/leaching wet-cell" approach discussed by Lee and Jones-Lee (1993b) and briefly described above, from what some refer to as a "wet cell" landfill that only incorporates leachate recycle. As noted above, thorough leaching of the wastes with clean water is essential to reducing the pollution potential of MSW landfill leachate.

Permitting of Leachate Recycle

In the review conducted by Lee, *et al*. (1985), it was found that a number of states, such as New Jersey, prohibited leachate recycle because of the increased potential for groundwater pollution associated with the increased hydraulic loading on the landfill. As discussed by Lee, *et al*. (1985), the more rapid onset of groundwater pollution is a real, potentially significant problem that needs to be properly addressed if leachate recycle is to be practiced. It is clear that leachate recycle should not be practiced in an unlined landfill or a landfill that does not have a highly reliable liner leak detection system.

Lee and Jones-Lee (1994c, 1998a,b) discussed problems inherent in trying to use conventional groundwater monitoring systems, with vertical monitoring wells spaced hundreds to a thousand or so feet apart, for the detection of incipient liner leakage or incipient groundwater pollution from a lined MSW landfill. Based on the manner in which lined landfills leak from point sources in the liners, and the manner in which leachate moves in groundwater systems in "finger" plumes, such conventional monitoring systems have a low probability of detecting incipient groundwater pollution by landfill leachate at the point of compliance before widespread groundwater pollution has occurred.

Because of the inherent unreliability of single-composite liner systems that depend on the monitoring of groundwater to detect liner-leakage of landfill leachate, the authors strongly recommend against the practice of leachate recycle in a single-composite-lined landfill of the type prescribed as the US EPA Subtitle D minimum prescriptive standards.

Leachate recycle should only be allowed at those landfills sited where groundwater pollution by leachate is considered to be of no consequence, or that incorporate a double-composite liner system in which the lower-composite liner is part of a leak detection system designed to determine when the upper-composite liner fails to prevent leachate transport through it. Further, as described by Lee and Jones-Lee (1993a, 1998a), sufficient funds must be available in a dedicated trust fund derived from waste disposal fees to exhume the wastes and treat them to produce non-polluting residues that may be safely buried in a landfill, when the upper-composite liner fails to prevent leachate transport through it.

As a stop-gap approach, a landfill owner/operator may try to prevent further passage of leachate through the upper-composite liner once it is detected in the liner leak detection system, by immediately ceasing leachate recycle and trying to prevent entrance of moisture into the landfill through the cover. While costing more than the amount of money typically provided for landfill

cover maintenance during the post-closure care period, it may be possible to isolate MSW from moisture that can generate leachate for those landfills sited above the watertable by using appropriate leak detection systems in the cover and aggressive maintenance *ad infinitum* as discussed by Lee and Jones-Lee (1998a). It is clear that any leachate recycle project must plan for the inevitable failure of the liner system to manage leachate and have the funds available in a dedicated trust fund to address the failure when it occurs.

It is in the best interest of protecting groundwater resources for future generations to allow properly conducted leachate recycle as part of fermentation/leaching treatment of wastes. As part of revisions of solid waste management regulations, provisions should be included for leachate recycle in double-composite-lined landfills in which the lower composite liner is part of a liner leakage monitoring system, and where adequate funds have been set aside in a dedicated trust fund to properly address all plausible worst case scenarios for liner failure, *ad infinitum*, including waste exhumation and treatment. Leachate recycle should not be allowed in single-composite-lined landfills. Further, leachate recycle should be recognized as only providing stop-gap relief from leachate treatment costs; it will not eliminate or even significantly reduce the potential for groundwater pollution by solid waste components. Regulations prohibiting the *in situ* treatment of MSW should be amended to allow fermentation/leaching wet-cell treatment in properly designed and constructed double-composite-lined landfills of the type recommended in this discussion.

At this time the US EPA is reviewing the need to revise Subtitle D regulations so that it is easier for landfill owners to recycle MSW leachate. If these regulations do not address the numerous problems associated with MSW leachate recycle, then these regulations should not be adopted. Simply discharging MSW leachate into a minimum Subtitle D landfill could increase groundwater pollution.

CONCLUSION

As it has been practiced, leachate recycle does not produce MSW residues that are not significant threats to groundwater pollution. Leachate recycle should not be practiced in a single-composite-lined landfill that relies on groundwater monitoring to detect the failure of the composite liner to prevent significant transport of leachate through it. Leachate recycle can and should be practiced in appropriately designed and constructed double-composite-lined landfills in which the lower-composite liner serves as a leak detection system for the upper-composite liner. Leachate recycle must be followed by clean-water leaching (washing) of the fermented solid waste residues in order to remove those components of MSW that represent threats to groundwater quality by their presence in leachate.

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