Metals in Municipal Landfill Leachate And Their Health Effects

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Abstract: The leachate from five municipal landfills (containing no industrial waste or sewage sludge) was studied in 1975 by the U.S. Environmental Protection Agency (EPA). Copper was not present in concentrations above EPA standards. Zinc concentrations decreased with age of the site and were below standards. The amounts of cadmium and chromium appear to vary greatly from site to site. Lead, selenium, iron, and mercury were present at each site in concentrations above standards, regardless of site age. Although raw leachate contains concentrations of heavy metals in excess of the drinking water standards, it is not clear how likely it would be for these recorded levels to be found in drinking water supplies or for contamination to reach the human body. Before leachate reaches an aquifer, it is subject to the attenuating effect of the unsaturated zone. If municipal solid waste is placed directly into ground water, or if leachate is allowed to drain directly into surface water, severe damage to water quality can result. Further study of the environmental effects of leachate are being undertaken by the Environmental Protection Agency. (Am. J. Public Health 67:429–432, 1977)

A wide variety of wastes from industries, residences, and municipalities have been and will continue to be disposed of on the land. Current practices range from simple dumping of refuse on a readily available piece of property to controlled disposal of waste on designated sites which are designed to minimize the potential for contamination of local water resources.

Solid waste land disposal sites (SWLDS) are sources of local water resources contamination because of the generation of leachate caused by water percolating through the solid wastes. Precipitation falling on a site either becomes runoff, returns to the atmosphere via evaporation and transpiration, or infiltrates into the site itself. This infiltrating water ultimately will form leachate (water that has percolated through the wastes and, through leaching, picked up soluble and suspended contaminants).

The process of leachate formation and subsequent contamination is dependent upon the amount of water which passes through the solid waste. Water which infiltrates the surface of the cover material, assuming daily and final cover are applied, will first be used for soil evaporation and plant transpiration. Any excess water will percolate into the layers of solid waste. Additional surface runoff from surrounding land, moisture contained in the solid or liquid wastes placed in the site, moisture from solid waste decomposition, water entering during waste placement in the site, and ground water entering through the bottom or sides of the site also contribute to the generation of leachate.[1]

According to the latest available estimates, 120 million tons of residential and post-consumer commercial solid wastes are disposed of on the land in the United States annually.[2] The largest component of municipal solid waste is paper, but substantial food waste, yard waste, glass, metals, plastics, rubber, and liquid wastes are also included. Pesticide containers, paint cans, batteries, various cleaning agents, dead animals, disposable diapers, grease and oils, and wastes from health facilities are among the typical potentially hazardous wastes received at municipal sites. Not included in this 120 million tons are sewage sludge, industrial chemicals and tailings, septic tank pumpings, street sweepings, discarded automobiles, construction and demolition wastes, and landclearing wastes. Many of these wastes, such as industrial chemicals, are disposed of in the site without the operator's knowledge.

As noted before, the amount of infiltration from precipitation that falls on a landfill is the major factor affecting the quantity of leachate that can be generated, unless, of course, poor site location was at fault. Therefore, the extent of the potential problem of water resources contamination resulting from leachate is greatest in areas where average annual precipitation exceeds the loss by evapotranspiration. Such areas are generally found east of the Mississippi River and in the coastal region of the Pacific Northwest. About 70 per cent of the municipal sites found in the United States are located in these water surplus areas. These are also areas of high industrial and residential density. Thus, the local water resources of many cites are located near areas where potential contamination due to land disposal sites might occur.

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Leachate generation information has been compiled over a one-year period at five different municipal land disposal sites under an Environmental Protection Agency study.[4] The principal criterion for site selection was that they received only residential and commercial wastes. It should be noted, however, that many land disposal sites do accept some industrial wastes and/or sewage sludge, and many others fail to monitor or record what they do accept. Site location, age, size, type, and annual precipitation were recorded for each study site (Table 1). Site age and method of operation were the major differences between the five sites. Raw leachate was easily obtained in large quantities. Organic, heavy metal, and conductivity data for undiluted, surface leachate are presented for each study site (Table 2).

Undiluted surface leachate was obtained from the collection systems at the California, Washington, and Pennsylvania sites. These collection systems were specifically designed for each site and consisted of tile drains and pipes which discharged into a central storage tank or sanitary sewer system. At the Indiana site, leachate was obtained from a collection system which was specifically designed for this study. At the Tennessee site, leachate was obtained from surface leachate streams which occurred because of poor site design and operation. Samples from each site were collected in polyethylene bottles, chilled, and then shipped to the laboratory for analysis.

From the data presented, certain factors concerning the composition of leachate are evident. First, younger sites (less than five years old) exhibit strong organic content

TABLE 1—Site Characteristics

Site Location	Age (years)	Size (acres)	Type*	Annual precipitation (inches)
Washington	2	83	SLF	57
Pennsylvania	2.5	17	SLF	41
Indiana	3.3	20	SLF	43
Tennessee	5	7	conversion‡	44
California	20	52	conversion‡	40

*SLF—sanitary landfill, following the definition described by the ASCE with regard to public health and safety.[3]

‡Conversion—a site, which has been previously operated as a dump and now, mainly due to cosmetics (addition of cover material), has the appearance of a sanitary landfill.

TABLE 2—Leachate Characteristics*

	Fe	Cu	Pb	Cd	Cr(total)	Zn	Hg	Se	COD	Conductivity
EPA drinking water standard	*.3*	*1.0*	*.05*	*.01*	*.05*	*5.0*	*.002*	*.01*	—	—
					WASHINGTON					
Mean	495	.45	.15	.007	.073	13.6	.0034	.027	14,258	4,636
Range	84–1,126	.01–1.13	.07–.31	.001–.012	.025–.22	3.2–33.0	.001–.008	.005–.1	4,963–30,933	3,350–13,500
					PENNSYLVANIA					
Mean	679	.2	.18	.02	.19	9.1	.018	.08	11,274	5,795
Range	18–1,500	.01–.65	.017–.31	.001–.073	.09–.29	.53–28.2	.001–.061	.01–.33	7,650–17,654	3,780–8,300
					INDIANA					
Mean	618	.43	.26	.015	.11	1.62	.064	.127	12,292	7,148
Range	208–1,237	.01–1.54	.2–.33	.006–.038	.01–.175	.88–2.25	.001–.008	.01–.3	10,341–16,721	5,875–9,300
					TENNESSEE					
Mean	15.2	.25	.16	.008	.10	7.2	.036	.116	2,900	8,035
Range	6.5–34.5	.016–.48	.02–.33	.004–.01	.06–.133	.54–27.2	.0006–.16	.02–.21	845–8,669	6,550–10,080
					CALIFORNIA					
Mean	25.0	.19	.1	.008	.034	3.7	.012	.06	168	2,666
Range	9.9–120	.004–.38	.01–.16	.0013–.01	.01–.09	.07–20.8	.001–.032	.001–.112	79–420	2,050–6,300

*All values in mg/l, except conductivity (micromhos/cm).

(chemical oxygen demand)* and high conductivity.‡ As the site ages and as decomposition declines, COD and conductivity decrease. COD is an important parameter for its usefulness in determining the relative degree of solid waste decomposition, leachate treatment technique, detection of contaminant migration, and organic contamination. Conductivity is important in determining the relative degree of solid waste decomposition and detection of contamination migration.

The leachates contain measurable quantities of specific metals. Environmental Protection Agency drinking water standards are presented in Table 2 for comparison against reported values of metals in leachates.[5] Primary standards have been determined for chromium, cadmium, lead, selenium, and mercury. These standards are related to health effects. Secondary standards are proposed for zinc, copper, and iron. These standards are related to aesthetics such as color, taste, and odor.

From an analysis of the data from this study, several conclusions can be drawn. First, copper is not present in concentrations in this leachate above the Environmental Protection Agency standard. Second, the zinc concentration found in this leachate decreases as the age of the site increases. Third, the amount of cadmium and chromium appear to vary greatly from site to site. And fourth, lead, selenium, mercury, and iron are present at each site in concentrations above the Environmental Protection Agency standards, regardless of site age.

Since Environmental Protection Agency standards are exceeded by certain heavy metals present in leachate, consideration must be given to the overall damage and the individual effect that each contaminant presents. As leachate is generated by solid waste land disposal sites, contamination of ground and surface waters may occur. This leads directly to the problem of contamination of drinking water supplies either by contamination of surface supplies or by contamination of an aquifer or well field.

When water supplies are contaminated with leachate containing heavy metals, the mechanism leading to health hazards is bioaccumulation. Many living organisms, including man, are known to accumulate specific toxicants (chemical pesticides, industrial organics, heavy metals) from the environment. This capability is widespread and the amount accumulated may range from barely detectable concentrations to concentrations that greatly exceed the amount present in the environment, depending on the contaminant and organism involved.

Bioconcentration is considered to be accumulation at a rate which results in a concentration of contaminant greatly exceeding that to which the organism was exposed. The degree of bioconcentration can be described by a concentration factor: the ratio of the concentration of chemical recovered from the organism to the concentration to which the organism has been exposed. This concentration factor may be influenced by several factors such as 1) nature of the contaminant; 2) amount of contaminant in the water;[6] 3) duration of exposure to the contaminant;[7] 4) rates of storage and excretion of the species; 5) size and age of the organism; 6) reproductive condition of the animal;[8] 7) the organ analyzed; and 8) the manner in which the contaminant is accumulated—directly from the water or from the food chain.

It is important to note here that the health effects from leachates are not limited to drinking water but may also occur through the food chain due to the ingestion of other organisms (fish, aquatic plants) that habitate an environment contaminated by leachates.

Classic examples of the effect of bioconcentrated toxicants are the painful and fatal Itai-Itai disease, caused by chronic cadmium poisoning, and Minamata disease, caused by chronic mercury poisoning. In both diseases, the contaminants are concentrated in fishes from industrial wastes discharged into coastal waters. Continued consumption of the contaminated fishes by man permitted accumulation of concentrations sufficient to produce these diseases.

In relation to general water quality, the initial entry of contaminants into a body of water not only degrades it, but also may weaken or kill the biota. Persistent contaminants, which could result from long-term discharge of leachate into a stream, may concentrate and increase over time in the biota or sediments. Some portion of the contaminant may be accumulated and concentrated in living organisms; another portion may be sorbed onto sediments from which it is accumulated by benthic organisms. Death and decay of these organisms would permit recycling and re-entry of contaminants into the water.

In addition to bioaccumulation, certain metals, such as iron, may coat the bottom sediment so that feeding on the bottom is not permitted. SWLDS leachate can thus cut off the food supply from benthic organisms.

In addition to the study to document the specific contaminants in raw leachate, many leachate damage cases have also been recently documented. Specific cases documented by the Environmental Protection Agency are Aurora, Illinois; Islip, New York; and Rockford, Illinois.[9, 10, 11]

At the Aurora site, leachate migration contaminated seven residential wells. The residential wells contained strong, black, odorous leachate which contained high concentrations of chlorides, sodium, sulfate, hardness, and organic acids. Because of these high concentrations, the wells were totally unusable as a residential water supply. The leachate damaged sinks, faucets, and other plumbing fixtures. The residents went 16 months without household water and had to maintain a supply of bottled water for home use. Later, these homes were placed on the city's public water supply. Similar cases are reported in the two other studies at Islip and Rockford.

Many incidents probably go undetected because residents are unaware that their wells are being contaminated by disposal sites. Another source such as septic tanks are gener-

*Chemical oxygen demand (COD) is a measure of the oxygen-consuming capacity of inorganic and organic matter present in water or waste-water. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test.

‡Conductivity is a measure of a water's capacity to convey an electric current. This property varies with the total concentration of ionized substances in a water and the temperature at which the measurement is made.

ally thought to be the cause of the contamination. In the Aurora incident, a tracer dye was used to prove that the source of contamination was indeed the landfill.

It is interesting to note that in reviewing most leachate damage cases, very little information exists on the concentrations of heavy metals. Reasons for this are: 1) initial well contamination is generally caused by high concentrations of iron and organic matter, thus unpleasant tastes and odors indicate that the water supply is not potable and further testing is not performed; 2) many local health authorities are not equipped to do metal analysis because of lack of proper equipment; and 3) there is a lack of information concerning the movement of heavy metals through the soil.

The first two preceding reasons are self-explanatory. The third is currently being evaluated by the Environmental Protection Agency. Research efforts are investigating the rate of specific heavy metal movement within different soil types by means of laboratory soil columns. Also, on-site investigations are being conducted by placing monitoring wells in the direction of ground water flow to determine heavy metal concentrations at various distances from the site.

Conclusion

Undiluted, raw leachate contains substances that are potential threats to human health. Although raw leachate contains concentrations of heavy metals in excess of the drinking water standards, it is not clear how likely it would for these recorded levels to be found in drinking water supplies or for contamination to reach the human body. Before leachate reaches an aquifer, it is subject to the purifying affect of the unsaturated zone (attenuation or dilution). The usual odor and/or color of municipal leachate would be a significant deterrent to using water contaminated by it for human needs.

If solid waste is placed directly into ground water, or if leachate is allowed to drain directly into surface water, it can cause severe damage. It can destroy life in a water resource by coating the bottom sediment so that feeding by the animal population is precluded—iron is a prime example. Toxic metals can build up in the aquatic life and destroy their use by man—selenium and mercury are examples. Therefore, leachate generated by improperly located and managed solid waste disposal sites can destroy drinking water resources making it necessary to locate new sources, at considerable cost.

Finally, in evaluating the data from this study, it should be kept in mind that data were obtained from the monitoring of five municipal solid waste disposal sites that received only municipal and commercial wastes. Many sites never question nor document types of incoming waste. Many sites accept some type of hazardous waste (inorganic and organic chemicals, electroplating sludges, petroleum wastes, pharmaceuticals, etc.) and/or municipal sewage sludges, which tend to be high in organics and heavy metals. This study can only report values that have been observed in strictly municipal leachate. The monitoring of sites which accept hazardous wastes and/or sewage sludge is presently being undertaken by the Environmental Protection Agency.

REFERENCES

1. Fenn, D. G., Hanley, K. J., and DeGeare, T. V. Use of the water balance method for predicting leachate generation from solid waste disposal sites. Environmental Protection Publication SW-168. Washington: U.S. Environmental Protection Agency, Oct. 1975.
2. U.S. Environmental Protection Agency, Office of Solid Waste Management Programs. Resource recovery and waste reduction; third report to Congress. Environmental Protection Publication SW-161. Washington: U.S. Government Printing Office, 1975.
3. ASCE manuals of engineering practice no. 39; sanitary landfill. New York: American Society of Civil Engineers, 1959.
4. Stearns, Conrad and Schmidt Consulting Engineers, Inc. The selection and monitoring of land disposal case study sites. Prepared for the Office of Solid Waste, U.S. Environmental Protection Agency. 1976. [Unpublished report].
5. U.S. Environmental Protection Agency, National interim primary drinking water regulations. Federal Register, 40(248):59566–59588, Dec. 24, 1975.
6. Hansen, D. J., Parrish, P. R., and Forester, J. Aroclor 1016: toxicity to and uptake by esturine animals. Environmental Research, 7(3):363–373, June 1974.
7. Nimmo, D. R., et al. Polychlorinated biphenyl absorbed from sediments from by fiddler crabs and pink shrimp. Nature, 231(5297):50–52, May 7, 1971.
8. Holland, H. T., and Coppage, D. L. Sensitivity to pesticides in three generations of sheepshead minnows. Bulletin of Environmental Contamination and Toxicology, 5(4):362–367, July–Aug. 1970.
9. Shuster, K. A. Leachate damage assessment—case study of the Sayville solid waste disposal site in Islip [Long Island], New York. Environmental Protection Publication SW-509. Washington: U.S. Environmental Protection Agency, June 1976.
10. Shuster, K. A. Leachate damage assessment—case study of the Peoples Avenue solid waste disposal site in Rockford, Illinois. Environmental Protection Publication SW-517. Washington: U.S. Environmental Protection Agency, June 1976.
11. Shuster, K. A. Leachate damage assessment—case study of the Fox Valley solid waste disposal site in Aurora, Illinois. Environmental Protection Publication SW-514. Washington: U.S. Environmental Protection Agency, June 1976.