MEMORANDUM

TO: David Finley, Administrator, Solid and Hazardous Waste Division, DEQ

FROM: Dale Anderson

SUBJECT: Nature and Current Status of Landfill Impact Problem

DATE: December 17, 2004

The purpose of this memorandum is to provide an expanded discussion regarding the physical setting of the known municipal solid waste (MSW) landfills in Wyoming, the current extent of the groundwater problems caused by MSW landfills, and to describe in general terms environmental impacts that can be caused by disposal of municipal solid waste (MSW). While a bit unusual for a memorandum, an executive summary is provided due to the length of this memorandum.

Executive Summary

The main mechanisms by which groundwater pollution is caused by MSW landfills are through migration of leachate and landfill gas (LFG). Leachate is the liquid that forms from waste decomposition and infiltration of precipitation into a waste disposal area. Landfill gas also forms as waste degrades, and is predominantly composed of methane and carbon dioxide. However, LFG also contains a wide variety of volatile organic compounds at relatively low concentrations. Both leachate and LFG can and do migrate from unlined landfills and cause adverse impacts to groundwater quality.

DEQ has mapped each of Wyoming's 130 landfills and has determined their locations relative to aquifer sensitivity zone**s**. The entire State of Wyoming has been classified (Hamerlinck and Arneson, 1998) into five aquifer sensitivity zones, corresponding to a sensitivity of high (very sensitive), medium high, medium, medium low, and low (relatively un-sensitive). Seventy-one of Wyoming's landfills, or about 55 percent, are located in the first three zone classifications (high, medium high, and medium).

DEQ has also mapped each of Wyoming's 130 landfills relative to their proximity to

groundwater wells. Approximately 80 percent of the landfills have one or more wells within a mile. Forty-nine of 130 landfills (about 38 percent) have more than eleven wells within one mile; six of those 48 landfills have more than 50 wells within a mile.

DEQ believes that taken together, the information presented here demonstrates that groundwater pollution from leaking municipal solid waste landfills poses a significant problem to Wyoming citizens. This information includes: (1) the locations of many of the 130 landfills in areas of the state relative to areas where aquifers are sensitive to becoming impacted from landfill leakage; (2) the proximity of many of the 130 landfills to existing water wells, and (3) the dangers posed by leachate and landfill gas from municipal solid waste landfills.

Current Extent of Wyoming's MSW landfill problem

There are 52 landfills currently operating in Wyoming, and 78 known closed municipal landfills (for a total of 130 landfills). There may be additional closed landfills of which DEQ is not aware. Currently there are 21 municipal solid waste (MSW) landfills in the state with documented groundwater impacts. Of these 21 landfills, 13 are currently operating landfills, and 8 are closed landfills.

How has DEQ determined that 21 of Wyoming's 130 landfills are leaking? There are groundwater monitoring systems in place at 64 of those landfills. Because groundwater quality can vary both temporally and spatially, a statistical analysis of groundwater data is required before there can be any conclusion reached that a landfill has impacted groundwater quality. This precludes, for example, a single elevated test result from being used to 'declare' that a landfill has impacted groundwater. Following a statistically-significant impact, the landfill owner or operator has an opportunity to perform additional groundwater testing to show that the landfill is not the source of the elevated pollutant concentrations. It is only after this additional testing that DEQ formally concludes that a landfill has impacted groundwater quality.

Under current rules, however, DEQ does not require that a landfill owner begin to perform active groundwater remediation simply based upon a determination that there's been a statistically-significant impact to groundwater quality. A 'statistically-significant impact' can be a small or large impact. For small impacts, where groundwater quality does not yet exceed a health-based standard, DEQ may require operational modifications like improvements to surface water drainage, more prompt application of intermediate cover over partially-completed fill areas, or other modifications designed to limit infiltration of precipitation to the landfill. It is only after groundwater has been degraded to a level where the groundwater exceeds a health-based standard that DEQ requires groundwater remediation. Fourteen of the twenty-one landfills or about 67 percent of them, have exceeded one or more health based standards, triggering the need for additional work. Based on recent groundwater data, this number is expected to increase within the next year or two.

The DEQ has been asked to describe how big the groundwater problem is at the current time. The full extent of the problem is not known, in large part because only one of the fourteen facilities has completed an investigation to identify the nature and extent of groundwater impacts. However, even with the incomplete information available, the data show that it is not unusual for pollutants to be detected in groundwater at concentrations of five to forty times above their respective health based standards. The severity of impact and pollutants detected can and does vary between facilities, making generalized statements regarding the nature of the problem difficult. Further complicating the issue is the fact that groundwater monitoring data at impacted facilities sometimes shows increasing trends for one or more pollutants. This fact, coupled with the knowledge that different chemicals travel at different rates in the environment, indicates we have not yet seen the peak or worst case situation at the known leaking facilities, regardless of the fact we have not yet defined the current extent of the problem. In other words, the increasing pollutant trends indicate the problem continues to get worse as time goes by.

When landfill leachate is released from the bottom of a landfill and migrates downward through soils to the groundwater table, soils beneath the landfill attenuate (or lower) the concentration of some pollutants. The pollutant concentrations are further attenuated as groundwater migrates away from the landfill. However plumes of contaminated groundwater can migrate up to a few miles from a landfill (per. comm. WY DEQ staff with Idaho DEQ, 2002), at levels exceeding health-based standards set for groundwater quality. In Wyoming, representative information regarding the complete distance of off-site migration for volatile organic chemicals (VOCs) and inorganic chemicals is not available because, as noted above, only one investigation of the extent of pollution has been completed. With that in mind, a few examples of what is known about the extent of pollution from Wyoming landfills are provided. As previously noted, investigation of the extent of VOC contamination has been completed at only one facility; in that study contaminants were identified about two hundred yards from the landfill. Another on-going investigation has identified contaminants up to 500 yards from the landfill. In the case of a third landfill, contaminated groundwater has traveled about three hundred yards from the landfill and is discharging to the North Platte River.

DEQ's rules for groundwater remediation require an owner to evaluate suitable remedial technologies and to propose one for DEQ approval. Only one impacted facility has started this evaluation, and that evaluation has not yet been completed. Factors that are considered in determining which technology to consider and approve include the types of pollutants exceeding standards, the geology and hydrology of the landfill site, and the proximity of receptors to the contaminated resource (e.g., how close is the nearest drinking water well?). Generally, if geology and hydrology of a landfill site are such that migration of contaminated groundwater is likely to be slow, and if there are no nearby receptors for contaminated groundwater, then remedial technologies that are cheaper, and that take longer to implement, would likely be chosen. For landfills that are close to receptors, higher cost (and more immediately effective) remedial technologies would more likely be needed.

Physical Setting of MSW landfills

DEQ has frequently heard that our landfills are “out in the middle of nowhere”. Because of this, DEQ has looked at the location of the known landfills relative to aquifer sensitivity, and relative to the number of permitted water wells within one mile of the landfill. Maps depicting the locations of the known landfills showing aquifer sensitivity zones and nearby water wells are included at the end of this memo. Summaries of this information are provided below.

MSW landfill locations relative to mapped aquifer sensitivity zones

DEQ has mapped each of Wyoming's 130 landfills and has determined their locations relative to aquifer sensitivity zone**s**. The entire State of Wyoming has been classified (Hamerlinck and Arneson, 1998) in one of five aquifer sensitivity zones corresponding to a sensitivity of high, medium high, medium, medium low, and low (the actual classification ranges from 5 to 1, with 5 being high). An aquifer sensitivity classification of high means that the aquifer in that location is extremely sensitive to pollution from surface sources, like a landfill. All other factors being equal, a leaking landfill in a high aquifer sensitivity zone would likely require a more aggressive and expensive groundwater remediation technology were it to leak. Seventy-one of Wyoming's landfills are located in the first three zone classifications (high, medium high, and medium). The actual distribution is shown graphically in Figure 1.

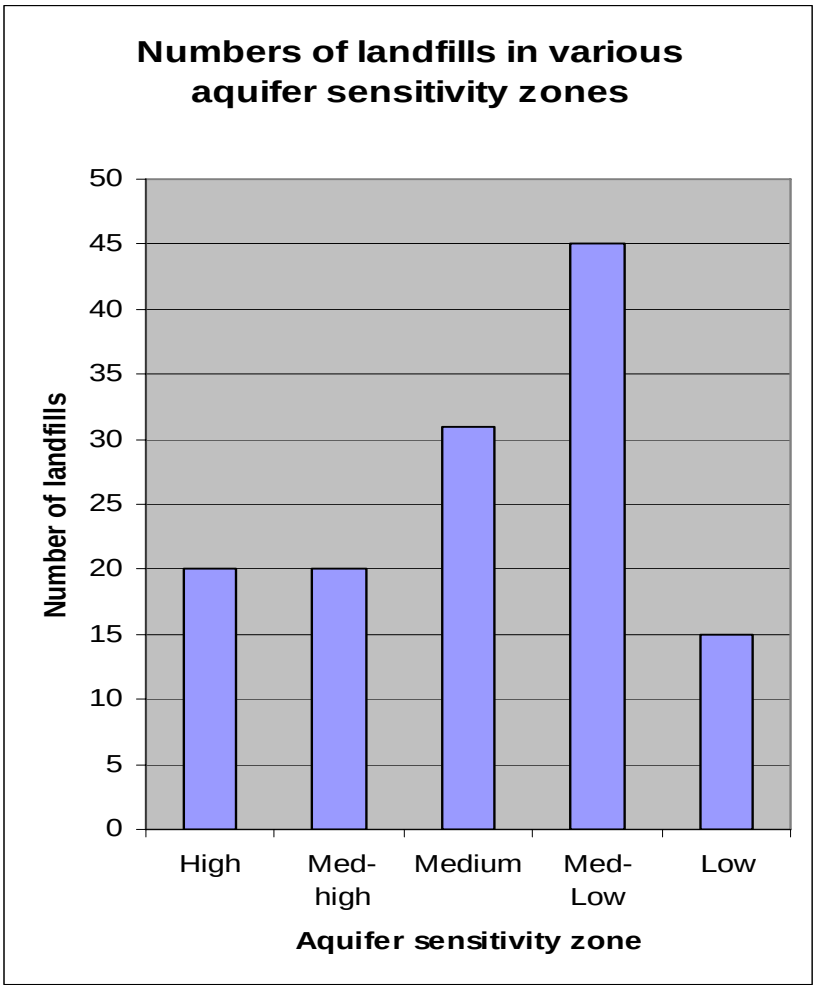

Figure 1. Number of MSW landfills in the five aquifer sensitivity zones.

MSW landfill locations relative to groundwater wells

DEQ has also mapped each of Wyoming's 130 landfills relative to their proximity to groundwater wells. For purposes of this analysis, monitoring wells have been excluded. Wells mapped are those registered with the State Engineer's Office. Forty-nine of 130 landfills have eleven or more wells within one mile; six of those 49 landfills have more than 50 wells within a mile. All but 19 of the 130 wells have more than one well within a mile. The distribution of wells is shown graphically in Figure 2.

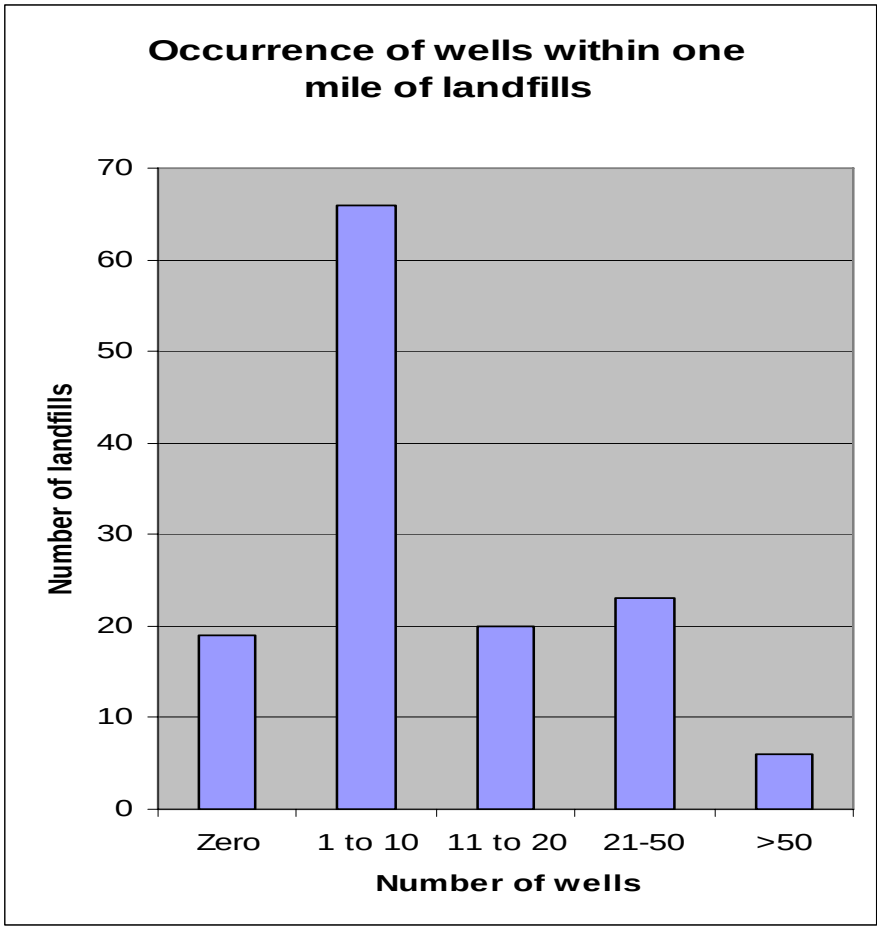

Figure 2. Number of wells near landfills.

In addition to the physical setting of landfills, it is important to know that there are many factors that must be considered that are in many respects independent of the knowledge of current concentrations of chemicals in groundwater. The more significant of these factors, but by no means all of them, are described below.

MSW Composition, Leachate Generation and Composition, and Landfill Gas

MSW Composition

Perhaps the most significant factor related to environmental impacts from MSW landfills is the nature of the garbage in those facilities. In general, much of MSW is composed of household waste such as paper, plastic, food waste, yard waste, diapers, pharmaceuticals, and so on. These are the types of waste that people generally think of as household waste – the "under

the kitchen sink" type of garbage. These "routine" types of household waste are sufficient to cause environmental problems as the waste decomposes. However, it is important to know that MSW in our landfills includes household hazardous waste in additional to the "normal" household waste. In this context household hazardous waste includes things such as used oil, pesticides, and paint, but also can include chemicals listed as hazardous wastes, such as solvents and degreasers. However, because of exemptions provided in Wyoming and federal hazardous waste rules, it is allowable to dispose of these hazardous chemicals in household quantities, or in amounts defined as "conditionally exempt small quantities" by certain businesses. Some of these listed hazardous wastes include methylene chloride, benzene, trichloroethene, acetone, methyl ethyl ketone, and toluene. Were it not for the exemption noted above, typical landfill leachate would be considered a hazardous waste requiring strict management and disposal methods--it certainly would not be allowed to leak untreated into groundwater.

When the current federal MSW landfill regulations were adopted, there was acknowledgment that MSW landfills do receive hazardous wastes from households and small businesses. It was determined to be cost prohibitive to ban all hazardous wastes from being disposed in MSW landfills. This fact, along with abundant evidence of impacts caused by operating unlined MSW landfills around the country, is one of the reasons federal MSW regulations required disposal areas to be lined to prevent releases to the environment.

Currently, Wyoming's MSW regulations, consistent with federal regulations, allow disposal of household hazardous waste into MSW landfills. Current estimates are that household hazardous waste comprises between 0.5% and 1% of MSW (EPA, 2004; EPA, 2003; Minnesota, 2004). This is down slightly from historic levels of 0.9 -2.4 percent in the mid-1980's (SCS Engineers, 1986). Using the current range of 0.5% to 1%, coupled with a 2002 estimate of 682,000 tons of waste generated each year in Wyoming (Wyoming Business Council, 2002) yields an estimate of between 3,400 and 6,800 tons per year of household hazardous waste being disposed in Wyoming landfills at the current time. If one assumes that current landfills have been in operation for an average of about 25 years, the above assumptions would yield an estimate of between 85,250 and 170,500 tons of household hazardous waste that has already been disposed in currently operating and almost completely unlined landfills in Wyoming.

Leachate Generation

The generation of leachate from MSW and its migration from a landfill was historically thought to be the primary way in which a landfill causes groundwater pollution. It was thought that our semi-arid to arid climate was too dry to allow for formation of leachate, so it was expected that operating unlined landfills would not cause groundwater pollution. As time has passed and additional data have become available from the few lined facilities in Wyoming, and from currently lined areas in surrounding states, we now know that leachate can be, and is, generated in our environment. The amount of leachate generated can be highly variable and is dependent on many factors, making it difficult, if not impossible, to make absolute predictions of leachate generation on a site specific basis. However, data from currently operating lined

facilities in Wyoming and surrounding states indicate that leachate generation varies from less than one inch per acre per year to more than 5 inches per acre per year, with a median value of approximately 1 inch, and a mean of approximately 1.7 inches. One inch of leachate per acre per year equals 27,152 gallons, and 1.7 inches equals 46,158 gallons. These quantities, at first examination, appear to be relatively small quantities of liquid. However, when one looks at the chemical composition of leachate, it is clear that leachate is a very concentrated mixture of a wide variety of pollutants, and that small amounts may cause substantial environmental problems. Toward that end, Qasim and Chang (1994) note that landfill leachate contains larger pollutant loads than raw sewage and many industrial wastes.

Leachate Composition

Landfill leachate is a mixture of chemicals that can be naturally-occurring, (e.g., chloride, sulfate, sodium, and potassium) and man-made chemicals (e.g., chlorinated solvents like tetrachloroethane, perchloroethene, and methylene chloride). Pollutants in landfill leachate are comprised of both carcinogenic and noncarcinogenic chemicals. Carcinogenic pollutants in landfill leachate include chemicals such as benzene, arsenic and cadmium. Noncarcinogenic pollutants include chemicals such as methylene chloride, tetrachloroethene, acetone, and methyl ethyl ketone.

The concentration of pollutants in landfill leachate has been measured in a number of studies. These studies typically analyze leachate that has been drained from the bottom of landfills by the leachate collection systems of lined landfills. Landfill leachate pollutant concentrations vary greatly from landfill to landfill, and also vary greatly from a single landfill, depending upon factors such as a landfill's age and local climate, but almost every analysis reviewed by DEQ has shown leachate pollutant concentrations to significantly exceed health-based levels that have been established for drinking water.

Chemical data for leachate from Wyoming facilities are relatively limited due to the small number of lined landfills capable of collecting leachate, so in addition to Wyoming data, the Department has obtained data from other operating landfills in surrounding arid and semi-arid areas, and from literature on the subject. Available data compiled by the Department shows a dozen common leachate constituents have reported concentrations at least twenty-five times their respective health based standard, and five are more than 100 times their respective health based standard. Ammonia, which is a common leachate component, has reported concentrations well in excess of two thousand times its health based standard for groundwater. Depending on site conditions, ammonia in the environment may transform to nitrate; if this occurs the reported concentrations are more than one hundred times greater than the nitrate standard. Much work has been done regarding characterization of leachate and attempts made to predict leachate concentrations. While there is conflicting information on the subject, results of some investigations suggest that the leachate from arid and semi-arid areas will tend to contain higher concentrations of pollutants relative to wetter environments, (Khattabi, et. al., 2002; Rhinehart and Grosh, 1997).

Limited chemical data available from leachate collected in lined Wyoming landfills confirms that a variety of hazardous pollutants are being disposed in our landfills today. For example, leachate samples from one lined landfill that began receiving wastes in 1999 show the presence of eighteen different VOCs. Ten of these VOCs are listed as hazardous waste under federal regulations. The highest concentrations detected were for methylene chloride, at 131 and 413 parts per billion. These concentrations are approximately twenty-five to eighty times its groundwater protection standard of 5 parts per billion. Methylene chloride is still available for purchase and use today. In addition to being available in pure form, is a common constituent of many household solvents such as furniture strippers, paint removers, and other solvents. A recent trip to a local home improvement store by DEQ staff showed that several hazardous chemicals were available for purchase in relatively large (gallon) quantities including methylene chloride, acetone, methyl ethyl ketone, and toluene, to name a few.

It is important to realize that for many hazardous pollutants, small quantities of a pollutant can result in significant groundwater impacts. Consider for example, methylene chloride, one of the chemicals noted above, detected in leachate at a Wyoming landfill. One quart of methylene chloride, evenly mixed with water, is sufficient to contaminate approximately 66,270,000 gallons of water up to the health based standard for methylene chloride. If this quantity of water were in an aquifer with thirty percent porosity as might be expected in an typical sandy aquifer, it would occupy a volume approximately twenty feet thick, three hundred feet wide, and almost a mile long, all from one quart of methylene chloride.

Landfill Gas

As previously noted, landfill gas is comprised predominately of methane and carbon dioxide (roughly 50 % of each). Due to the high concentration of methane the presence of LFG can pose an explosion hazard in the vicinity of landfills, and has caused numerous explosions or fires around landfills in the United States. LFG also contains about 0.5 to 1 percent by volume of trace compounds, which typically include a wide variety of VOCs (Tchobanoglous, 1993). While data regarding VOC concentrations in LFG in Wyoming are very limited (two sites), they are consistent with literature information. For example, one sample of LFG from a Wyoming landfill contained twenty four different VOCs. Samples collected up to two hundred feet from waste at a second site contained eleven different VOCs. VOCs migrate away from landfills in LFG, largely due to subsurface pressure gradients and influences from atmospheric pressure fluctuations. This migration can be become more pronounced after a landfill closes and puts a low permeability cap on the landfill. When LFG migrates from a landfill and comes into contact with groundwater, VOCs can partition, or move from the gas to groundwater, causing groundwater pollution just from the presence of LFG in contact with groundwater. In other words, unlined MSW landfills can cause groundwater pollution even if leachate does not leak from the landfill. This mechanism for groundwater pollution has been documented at one Wyoming landfill, and is suspected at a few others. The extent of this issue is currently not understood at landfills in Wyoming, largely because current LFG monitoring systems are generally inadequate to evaluate the extent of this problem.

The fact that LFG can cause groundwater pollution may complicate identifying the nature

and extent of pollution at a landfill, because pollutants may be found in groundwater in areas that are not downgradient of the landfill, as would be expected if the pollutants were transported by leachate mixing with groundwater. Groundwater pollution may be found in unexpected areas due to the fact that LFG will migrate along the path of least resistance in the subsurface. Pollution caused by LFG may also complicate the selection of remediation technologies at the site, because methods used to remediate a LFG caused problem are not the same as would be used to correct a problem caused by leachate migration.

Conclusion

DEQ believes that taken together, the information presented above demonstrates that groundwater pollution from leaking municipal solid waste landfills poses a significant problem to Wyoming citizens. This information includes: (1) the locations of many of the 130 landfills in areas of the state where aquifers are sensitive to becoming impacted from landfill leakage; (2) the proximity of many of the 130 landfills to existing water wells; and (3) the dangers posed by leachate and landfill gas from municipal solid waste landfills.

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