Department of Energy
Washington, DC 20585

NOV 3 1998

U.S. Environmental Protection Agency
UIC Class V, W-98-05 Comment Clerk
Water Docket (MC-4101)
401 M Street, SW
Washington, DC 20460

Dear Sir or Madam:

The Department of Energy has reviewed the proposed regulation - Revisions to the Underground Injection Control Regulations for Class V Injection Wells (**63 FR 40586**). Enclosed are the Department's comments.

If there are any questions concerning these comments, please contact James Bachmaier of my staff at 202-586-0341 or james.bachmaier@eh.doe.gov.

Sincerely,

Carol Borgstrom/for

Raymond P. Berube
Acting Director
Office of Environmental Policy
and Assistance

Enclosure

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DEPARTMENT OF ENERGY COMMENTS ON PROPOSED UIC CLASS V REGULATIONS (40 CFR PARTS 144, 145, AND 146)

The U.S. Department of Energy (DOE) supports some of the proposed modifications to the Underground Injection Control (UIC) program published by the U.S. Environmental Protection Agency (EPA) on July 29, 1998 (63 FR 40586), but strongly recommends that additional flexibility be incorporated into the final rule. DOE particularly commends EPA for its efforts to craft regulations using a plain English style of writing. However, additional flexibility is needed in setting standards for protection of ground water - the proposal adopts the Maximum Contaminant Levels (MCL) - and in specifying to which types of wells and in which locations relative to sources of drinking water these rules would apply. These points are explained in the comments that follow.

While DOE supports EPA's proposed strategy of regulating high-risk wells, DOE cautions against a long-term, open-ended approach under which other types of wells may be subject to additional regulatory requirements, such as closure or strict permitting requirements, through periodic iterations to the Class V program. DOE believes that EPA should maintain the philosophy of "authorized by rule" to the greatest extent possible in Class V regulations. DOE recommends that EPA determine which types of wells need to be subjected to the more stringent requirements and adopt regulations to address those wells, either in this rulemaking, or, given EPA's legal deadlines for this rulemaking, in one additional round of Class V regulations. We also encourage EPA to consider requiring Best Management Practices in lieu of injectate limits and restrictions. Flexibility in the approach taken to regulating any well injection practice, regardless of the class or sub-class, is currently provided in the UIC program. This flexibility should be maintained to the greatest extent possible.

Additionally, DOE believes that there are numerous inconsistencies in the standards, definitions, and regulatory approaches used in the national UIC program. Examples are noted in the comments that follow, including the definition of an Underground Source of Drinking Water (USDW) and the various exemptions provided in 40 CFR Parts 144, 145, and 146. DOE suggests that EPA undertake an agency-wide effort to adopt consistent standards and definitions for such terms as "aquifer", "drinking water", "injection well", "dose", and "radioactive waste", as they are used in the Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act, and Comprehensive Environmental Response, Compensation, and Liability Act regulatory programs.

DOE notes that EPA is in the process of revising the National Primary Drinking Water Regulations (NPDWR) in the spirit of the "Reinventing Government" effort. Two separate rulemakings are under development to reformat the existing NPDWR structure and to streamline the monitoring requirements for 64 chemical contaminants. EPA intends to simplify and improve the cost effectiveness of these requirements and make them easier to understand. DOE supports these efforts and suggests that similar streamlining and reformatting be considered for the UIC regulatory program as well.

DOE also notes that States and Tribes are preparing their plans for performing Source Water Assessments of existing drinking water systems, as required by the SDWA Amendments of 1996, and that EPA is proposing to implement this Class V Well rule in State-designated source water areas. It is quite likely that one of the consequences of this approach will be to increase the complexity of the national regulatory program, especially if States and Tribes adopt, and EPA approves, substantially different methods of identifying and classifying source waters. An effort to reformat and streamline the existing UIC regulations should focus on adopting consistent definitions and standards, while preserving State and local flexibility.

SPECIFIC COMMENTS

The following specific comments, which DOE believes will improve and clarify the proposal, include reiteration of some comments that were previously submitted to EPA on its August 28, 1995 proposed Class V rulemaking (60 FR 44652).

Definition of "Well"

The existing definition of "well" (40 CFR 144.3) is:

> "a bored, drilled or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension."

The proposed revised definition of "well" maintains these elements, but adds other elements also:

> "(1) A bored, drilled, or driven shaft; (2) A dug hole whose depth is greater than the largest surface dimension, (3) An improved sinkhole; or (4) A subsurface fluid distribution system."

DOE is particularly interested in the fourth element. DOE recognizes that it has been EPA's intent to consider drain fields and leach fields as injection wells and that this new language attempts to clarify that point. We do not disagree with that intent. The proposed definition for "subsurface fluid distribution system":

> "an assemblage of perforated pipes, drain tiles, or other mechanisms intended to distribute fluids below the surface of the ground"

is not specific as to whether trenches or drains that do not contain pipes or tiles are covered under that definition. It also could be interpreted as including storm water management systems that consist of an assemblage of underground piping that is intended to distribute, but not release, fluids below the ground surface.

Some DOE facilities utilize disposal structures such as trenches, french drains without piping or tiles, seepage pits that are shallower than any surface dimension, cribs, and infiltration ponds for various purposes, including the management of treated liquid waste effluents that may contain radionuclides. (A typical example is the discharge of a treated liquid waste that contains low levels of tritium, - a radionuclide with a relatively short half-life for which no practicable treatment technology exists. Under the environmental and geologic conditions found at some DOE facilities, discharge of such a waste to the shallow subsurface may be a management practice that results in lower risk to human health and the environment and to on-site workers than storage and handling of the waste in an above ground facility.) Such practices are subject to internal DOE regulatory control under Atomic Energy Act (AEA) authority, and are managed at DOE sites to ensure protection of the general public and the environment and to be consistent with SDWA. DOE recommends that EPA further clarify the definition of "well" by excluding structures that do not contain pipes or tiles that distribute fluids below the surface of the ground. DOE further recommends that such structures be explicitly excluded from coverage under the UIC program.

Also, the proposed definition of "subsurface fluid distribution system" should be clarified to include only such systems that are designed to "release" fluids to the subsurface. A storm water management system, as an example, also includes piping and other mechanisms intended to distribute, but not release, fluids below the ground surface, and should not, therefore, be included in a definition of well under the UIC regulatory program. DOE recommends that the definition of "subsurface fluid distribution system" be clarified to apply to systems intended to "distribute and release" fluids.

Distinction between "Industrial Wells" and "Other Industrial Wells"

In proposed Section 144.81, EPA establishes two classes of wells that could receive industrial-type injectate – "industrial wells" and "other industrial wells". Industrial process wastewater and stormwater contaminated by spills and leaks clearly fall into the "industrial well" subcategory while non-contact cooling water falls into the "other industrial well" subcategory. There are other common types of wastewater that fall into a gray area between these two subcategories, such as cooling tower blowdown where toxic chemical additives have not been added to the cooling water, boiler blowdown, steam condensate, and fire hydrant test water. DOE recommends that EPA modify the description of the "other industrial wells" subcategory so that it is not limited to just four types of fluids. Other innocuous fluids, such as those described below, could be placed into the "other industrial wells" subcategory at the responsible agency's discretion.

Most cooling water is treated with non-hazardous additives to inhibit scaling and corrosion of piping systems. It is believed that the use of these types of additives would have a minimum impact on the environment and that the regulation should be revised to include non-contact cooling water containing non-hazardous additives that are used to prevent corrosion.

Other types of industrial discharges such as condensate from steam lines, steam heating systems, air compressors, air conditioning, ventilation, and ice machines would also fit into this category. This type of steam condensate would have lower concentrations of contaminants than other types of industrial discharges. It is recommended that this type of condensate be included in the "other" industrial category.

Additionally, investigation-derived wastes (IDW) that are not RCRA hazardous wastes, such as ground water monitoring well purge water, ground water discharged during pumping tests, drilling fluids, or decontamination fluids, could also be placed in "other industrial wells" with little or no impact on the subsurface environment.

Classification of Drainage Wells at Commercial or Industrial Sites

This section of the proposed rule defines certain wells at commercial or industrial sites as drainage wells, not as industrial wells, if they are intended for stormwater management, even if the well may have the potential to receive insignificant amounts of waste due to unintentional small volume leaks. EPA requested comments on this section, and indicated that, based on comments received, EPA may classify all drainage wells at commercial or industrial sites as industrial wells in the final rule. DOE believes that a distinction can and should be made between drainage wells that could potentially receive some waste products and those that are not likely to receive waste in more than insignificant amounts. For example, runoff from car parking lots in an industrial area to a drainage well should not receive the same level of regulation as a stormwater runoff well that is located next to a potential source of significant contamination (e.g., gas tanks). The degree of controls applied to such drainage wells should be commensurate with the potential risk of contamination.

Meeting MCLs at the Point of Injection

EPA seeks comments on its proposal to require that industrial and motor vehicle waste disposal wells either be closed or accept only injectate that meets MCLs. DOE favors regulatory approaches that provide the greatest degree of flexibility while still protecting the environment. Therefore, DOE supports the concept of some alternative to well closure for industrial wells and motor vehicle waste disposal wells that receive injectate that does not meet MCLs. DOE conditionally agrees that injectate going to these types of wells, *when the wells are located in source water protection areas for public drinking water systems that use a ground water source*, should be treated to ensure that the source waters are not impaired to the extent that the MCLs may be exceeded at any public water system. These source water areas are worthy of such additional protection.

However, DOE does not agree that injectate going to these two types of wells that may be located within source water protection areas universally needs to meet MCLs at the point of well injection. Attenuation of persistent chemical contaminants in the soil column above the USDW, three-dimensional dispersion in the aquifer, and chemical and biological transformation of organic constituents, as well as radioactive decay of radionuclides, can and should be considered in estimating potential impacts on the USDW. These physical (or 'natural attenuation") processes reduce or eliminate the concentration of contaminants as the injectate migrates horizontally and vertically from the outlet of the well to the USDW. In many cases, the dilution or natural attenuation occurring during transport of fluids from the well to the USDW can be substantial.

This section of the proposal indicates that the well must either be closed or that fluids in the well must meet the primary MCLs listed in 40 CFR Part 142 or other health-based limits selected by the Director for contaminants without primary MCLs. The background section of the Federal Register notice provided an in-depth discussion of this issue. Some of the panel members working on the proposed rulemaking suggested that EPA consider the possibility of allowing the injectate to meet some higher multiple of the MCLs at the point of injection. EPA indicated that its approach of meeting the MCLs at the point of injection is appropriate. This conclusion was based in part on the premise that developing a set of conditions within which a Class V well owner or operator could inject waste that exceeds drinking water standards without endangering drinking water sources would not be a viable option for most small entities (i.e. the difficulties and costs involved in collecting the site-specific hydrologic, geologic and soil information that is necessary to determine if waste above the MCL could be injected without endangering the underlying USDW may be prohibitive). However, larger entities (such as many DOE and other Federal sites) may have the resources available in order to obtain the necessary site-specific information to support this kind of determination, as well as the assurance that institutional

controls would be in place to prevent unrestricted access to the subsurface. Flexibility should be incorporated into the regulation to allow a site-specific determination to be made, thus allowing the regulated entity to decide if making such a determination is practicable.

The ability to allow injection of materials above the MCLs, if it does not impact the underlying source water, should be left up to the State programs. Washington State, for example, has a permitting program for wastewater discharges to the soil column and it has implemented an anti-degradation policy for ground waters of the State. Each discharge is evaluated through the permitting process, and discharge limits are established based on site specific information. States that have or are willing to develop their own program should be allowed to set appropriate standards for the injectate and evaluate wells on a case-by-case basis. The standards adopted in this rulemaking should allow such flexibility to State programs.

[1] Veil, J.A. and D. Tomasko, 1995, "Approaches for Estimating Attenuation and Dispersion of Wastes Injected into Class V Wells," *Journal of Applied Ground-Water Protection*, 2(2):19-24.

An additional consideration is that naturally occurring constituent concentrations may already be above the MCL concentrations in ground water or surface water that is used as the source in an industrial activity. One example involves ground water that contains naturally occurring concentrations of a metal that exceeds the MCL. In accordance with the proposed rule, this water could not be reinjected into the ground water from where it was originally extracted, because it exceeds the MCL. Another related example involves the use of surface water that may contain concentrations of constituents above MCLs that is used as the industrial source water and re-injected into the aquifer adjacent to the river. This water would require additional treatment prior to use and/or injection, even though the water would be subsequently discharging to the river, where the concentration would likely be greatly diluted. Some flexibility needs to be included in the requirements to address such situations where the source water may contain concentrations above the MCLs but will not increase concentration levels in the receiving waters.

Completion of State Source Water Assessments

DOE is also quite concerned that not all states will have their source water assessments prepared and approved by May 2003. In such cases, the proposed rule requires that all industrial wells and motor vehicle waste disposal wells throughout those states will be subject to either closure or meeting MCLs at the wellhead, regardless of their location relative to source waters for an existing drinking water system. This Class V proposed rule is a good example of the possible perverse consequences to the regulated community of an agency failing to meet a deadline, even when it has made a good faith effort. There are many things that can derail or delay development of state-wide source water assessment plans or the implementation of the assessments that this proposed rule anticipates. It is unfair to penalize Class V well operators for a state's failure to develop and submit a source water assessment by the May 2003 deadline. DOE recommends that states that have not met the May 2003 deadline be allowed to make case-by-case determinations of whether wells must be subject to closure or meeting MCLs before injecting, or demonstrating that the USDW is protected due to natural attenuation. Use of existing wellhead protection programs can serve as a starting point for such decisions.

EPA's economic analysis for the proposed rule assumes that all states will have submitted source water assessments by May 2003. The preamble acknowledges that the cost of the rule could increase several fold if a few highly populated states do not meet the deadline. Conceivably, more than just a few states could fail to meet the deadline, thereby greatly increasing the costs of the regulation. The burden would be felt most heavily by small businesses. DOE encourages EPA to include extensions beyond May 2003 or other forms of waivers that would allow states additional time and not permanently remove other alternatives.

Areas to Which Class V Rules Should Not Apply

EPA seeks comments on whether the new Class V requirements should apply to areas beyond delineated source water protection areas. DOE does not support universally applying the Class V rules to areas beyond delineated source water protection areas. Agencies with UIC authority have the option of requiring closure or permits for Class V wells whenever there is a concern about endangerment of a USDW. This discretion and flexibility should be left to those agencies.

Treatment of Stormwater Drainage Wells

EPA seeks comments on its proposal to distinguish between stormwater drainage wells at industrial or commercial facilities that receive contaminated runoff from those that receive primarily clean runoff. DOE supports the idea of classifying stormwater drainage wells at industrial or commercial facilities that have the potential to receive insignificant amounts of contaminants from small leaks, drips, or spills as drainage wells rather than as industrial wells. As reflected in other comments, DOE supports the greatest degree of flexibility possible and prefers providing discretion to UIC permitting agencies rather than having prescriptive national requirements.

Definition of Sanitary Waste

DOE supports the new proposed definition for sanitary waste that clarifies that sanitary waste from industrial or commercial facilities, as long as it is not mixed with industrial waste, can still be considered sanitary waste.

Radioactive Waste Disposal Wells

The existing UIC regulations classify wells that inject radioactive waste into or above a USDW as Class IV wells (40 CFR 144.6 (d) (1) and (2)). All other wells that receive radioactive wastes are classified as Class V wells (40 CFR 146.5 (e)(11)).

The proposed regulations would reclassify radioactive waste disposal wells that inject fluids below the USDW as Class I wells. DOE does not object to this reclassification. We commend EPA for following DOE's previous suggestion and clarifying that wells receiving naturally occurring radioactive materials (NORM) from oil and gas wastes are considered to be Class II wells. However, we are concerned that EPA may be overlooking other groups of wells that intentionally or incidentally inject radioactive waste. DOE suggests that the revised Class V regulations, in concert with the existing UIC regulations, must also address and clarify the three situations described below.

> *1) Wells that inject radioactive wastes into or above exempted aquifers.* As a general rule, radioactive or hazardous wastes injected into or above a USDW cause the injection well to be a Class IV well, based on 40 CFR 146.5(d) (1) and (2). In both of these sections, the presence of either radioactive or hazardous waste triggers the Class IV determination. It is interesting to note that 40 CFR 146.5(d)(3) describes a third group of wells that are considered Class IV wells, but it only makes reference to hazardous wastes and not to radioactive wastes:
>
> > "Wells used by generators of hazardous waste or owners or operators of hazardous waste management facilities to dispose of

> hazardous waste, which cannot be classified under §146.05(a)(1) or §146.05(d) (1) and (2) (e.g., wells used to dispose of hazardous wastes into or above a formation which contains an aquifer which has been exempted pursuant to §146.04)."

40 CFR 146.5(d)(3) intentionally includes otherwise unclassified hazardous waste disposal wells as Class IV wells, but is silent on otherwise unclassified radioactive waste disposal wells. These wells are not included in the definition of Class IV wells, and cannot be Class I wells since they do not inject below the USDW. Therefore, DOE suggests that this category of wells should be Class V wells. DOE recommends that EPA clarify the status of this category of wells.

2) Wells that inject radioactive wastes into or above a formation where no USDW exists within 1/4 mile of the well bore. As in the first situation, the definition of Class IV wells at 40 CFR 146.5(d)(3) includes wells that inject hazardous wastes into a formation where no USDW exists within 1/4 mile of the well bore, but the definition is silent on otherwise unclassified radioactive waste disposal wells. Wells injecting radioactive waste into or above a formation where no USDW exists within 1/4 mile of the well bore are not included in the definition of Class IV wells, and cannot be Class I wells since they do not inject below the USDW. Therefore, DOE suggests that this category of wells should also be Class V wells. DOE recommends that EPA clarify the status of this category of wells.

3) Class III wells that reinject fluids used in uranium mining that may have radionuclide concentrations higher than the levels in 10 CFR Part 20, Appendix B, Table II, column 2. Some Class III wells are used for uranium solution mining. It is possible that some of the uranium recovered in the mining process could be reinjected through Class III wells at levels higher than the levels triggering inclusion under the definition of "radioactive waste" from 40 CFR Part 146.3 (higher than levels in 10 CFR Part 20, Appendix B, Table II, column 2). There are no SDWA regulations that specifically control injection of radioactive materials into Class III wells. DOE recommends that EPA clarify in the final regulation that fluids used in solution mining of uranium may be discharged to Class III wells even if they contain radionuclide levels in excess of 10 CFR Part 20.

<u>Definition of Class II Wells</u>

DOE recognizes that the portions of the UIC regulations dealing with Class II wells are not open for comment under this proposal. We do feel compelled, however, to comment on the new proposed definition for Class II wells contained in Section 144.80 (b):

> "Class II wells inject fluids connected with oil or natural gas recovery or production or for the storage of liquid hydrocarbons".

This definition is not the same as the existing Class II well definition found in Section 144.6 (b):

"wells which inject fluids:

(1) *Which are brought to the surface in connection with natural gas storage operations, or conventional oil or natural gas production* and may be commingled with waste waters from gas plants which are an integral part of production operations, unless those waters are classified as a hazardous waste at the time of injection.

(2) For enhanced recovery of oil or natural gas; and

(3) For storage of hydrocarbons which are liquid at standard temperature and pressure." [italics are added to emphasize the key phrase]

DOE is concerned that having different definitions at two places in the same set of regulations will be misleading for both operators and regulators. We much prefer the new proposed definition as it eliminates an inconsistency between the UIC program and the RCRA hazardous waste program, which exempts oil and gas exploration and production (E&P) wastes and other associated wastes from hazardous wastes status. Wastes that are associated with E&P activities, but that do not come to the surface in connection with oil and gas production (e.g., tank bottoms, contaminated soils) are still exempted from RCRA's hazardous waste requirements but do not meet the definition of wastes eligible for a Class II well. Some EPA regions and oil- and gas-producing states have dealt with this inconsistency through administrative means or policy decisions but the issue remains unresolved. Another example in which the existing Class II well definition is inadequate is the emerging technology of downhole oil/water separators. These devices separate oil from produced water at the bottom of an oil well and inject the water without ever sending it to the surface. Because the produced water never is brought to the surface, downhole oil/water separators do not meet the current definition of a Class II well either. Regulators are presently debating how to regulate these separators, which provide additional protection to USDWs.

DOE encourages EPA, whether in this rulemaking or in another forum, to revise the existing Class II well definition. The new proposed definition at Section 144.80 (b) is a better definition.

Approaches for Estimating Attenuation and Dispersion of Wastes Injected into Class V Wells[1]

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Abstract

As the U.S. Environmental Protection Agency (EPA) develops new regulations for Class V injection wells, permit requirements are likely to become more rigorous for those types of wells that pose the greatest risk to underground sources of drinking water (USDWs). The most conservative approach that EPA, state, or tribal permitting agencies could employ would be to require the discharges to meet maximum contaminant levels at the point of injection. This paper describes a variety of methods that can be used to estimate dilution and dispersion of the injected fluids from the time they leave the well until they reach the USDW or a downstream compliance point in the USDW. By taking dilution and dispersion into account, permit limits can be made less restrictive while still protecting the USDWs. This provides potentially great cost savings.

The simplest approach is to use standard dilution factors taken from the literature. This paper gives an example of how permit limits can be calculated with and without the use of a dilution factor. This paper briefly describes a variety of models, ranging from simple mass-balance calculations that require little site-specific information to complex, multidimensional finite-element or finite-difference formulations that usually require a large amount of hard-to-get, site-specific information.

Introduction

Hundreds of thousands of injection wells are in use in the United States. An injection well is essentially a hole in the ground, deeper than it is wide, that receives wastes or other fluid substances. The U.S. Environmental Protection Agency (EPA) categorizes all injection wells into five classes in its Underground Injection Control (UIC) regulations (40 *Code of Federal Regulations* 146). These regulations contain detailed operating and closure requirements for Class I, II, and III wells and prohibit operation of Class IV wells except in limited circumstances. However, EPA has not developed comprehensive operating and closure regulations for Class V wells, which are defined as all injection wells not fitting into any of the other four classes. Generally, Class V wells are shallow wells used actively or passively to inject nonhazardous substances into or above the uppermost drinking water aquifer or underground source of drinking water (USDW).

As part of a consent order between EPA and the Sierra Club, EPA was scheduled to propose regulations on permitting Class V wells by March 15, 1995. The deadline has since been extended to August 15, 1995. Based on earlier conference presentations by EPA staff, the proposed Class V regulations would have authorized by rule certain types of wells thought to have limited environmental impact. These types of wells include:

- septic systems and cesspools serving more than 20 persons;
- experimental technology wells;
- drainage wells;
- mine backfill wells;
- in situ and solution mining wells, other than those considered Class II wells;
- noncontact cooling water discharge wells;
- car wash and laundromat wastewater disposal wells;
- wells receiving waste from extraction or beneficiation of ore or minerals;
- beneficial use wells;
- fluid return wells; and
- wells receiving sewage treatment plant effluent.

For other types of Class V wells, particularly industrial waste disposal wells and automotive service station wells, EPA planned to require that injectate meet the maximum contaminant levels (MCLs) for each contaminant at the point of injection.

On January 19, 1995, EPA's Office of Ground Water and Drinking Water held a stakeholders meeting to announce its intention to restructure many of its regulations. Included in this effort were the Class V regulations. At the March 1995 meeting of the Ground Water Protection Council, EPA announced it would not issue a prescriptive set of Class V regulations by the March 15 deadline. Instead, EPA planned to propose a less comprehensive and more streamlined set of regulations. Much of the details would be outlined in an accompanying technical support guidance document.

EPA may still encourage or require closure of those wells that pose the greatest risk, such as industrial waste disposal wells and automotive service station wells. EPA could augment the closure efforts by providing technical assistance to the regulated community, through pollution prevention programs and management controls, to keep disposal out of the high-risk categories.

If wells of these types continue to receive wastes, permit conditions will need to be set to prevent contamination of any USDW. As a conservative approach, an EPA, state, or tribal permitting agency may require that injected fluids meet MCLs at the point of injection. This will ensure that MCLs are met at the USDW; however, this approach may be overly stringent and costly. This approach does not account for the attenuation of some contaminants in the soil column above the USDW, the three-dimensional dispersion of fluids from the point of injection, and other mechanisms that can greatly reduce the concentration of contaminants that reach the USDW. Permitting agencies may be interested in calculating discharge limits. They may also be willing to allow Class V well owners or operators to demonstrate that discharge limits less stringent than MCLs will still allow MCLs to be achieved at the USDW.

Since the future proposed Class V regulations are likely to impose much stricter requirements on thousands of wells nationwide, technical guidance is needed to estimate actual concentrations of contaminants reaching the USDW and to assist permit writers in establishing injectate limits that truly reflect the risk of USDW contamination.

The concept of modeling the dilution, fate, and transport of contaminants is not new. This approach is widely used in National Pollutant Discharge Elimination System (NPDES) permits for discharges to surface waters. Some state programs follow this approach when writing UIC Class V permits. Veil and Tablada (1990) describe the state of Maryland's approach to writing Class V UIC permits, which continues to be followed today. The permit writer calculates both a technology-based limit and a water quality-based limit for each pollutant of concern. The technology-based limit is determined by the availability of economically reasonable and demonstrated treatment technology. EPA's effluent guidelines program has generated extensive industry-specific information on treatment technologies.

The water quality-based limit is calculated by multiplying the MCL by the estimated dilution or dispersion between the point of injection and the USDW. The calculated limit that is more stringent for each pollutant is set as the UIC permit limit.

This paper presents a preliminary overview of several approaches and models that can be used to estimate levels of contaminants that reach the USDW.

Use of a Dilution Factor for Metals

Veil and Tablada (1990) provide an example of how discharge limits are calculated using a simple dilution factor. At the facility in question, industrial wastewater containing copper and chromium is discharged into a Class V well. The first step is to calculate technology-based limits. Patterson (1981) suggests that copper and chromium can be economically and reasonably treated to 0.4 mg/L and 0.5 mg/L, respectively. The second step is to check the MCLs for each metal. At the time, the proposed MCL for copper was 1.3 mg/L. Because the technology-based limit for copper is stricter than the proposed MCL (even before considering a dilution factor), the permit limit is set at 0.4 mg/L.

The MCL for total chromium at the time was 0.05 mg/L, which is stricter than the technology-based limit. At this point, the permit writer applied a dilution factor of 22:1 for metals, based on EPA (1986) guidance. After applying the dilution factor, the technology-based limit was stricter and was chosen as the permit limit. By considering a dilution factor for chromium, the permit limit was relaxed from a potential limit of 0.05 mg/L to 0.5 mg/L. The lower limit may not have been technically or economically achievable, and the discharger would have been forced to close the well and seek an alternative disposal method.

Modeling Approaches

Some UIC permitting agencies may be reluctant to apply general dilution factors to all situations. In some cases, modeling must be conducted to account for site-specific conditions. Two conceptual models can be used to describe the injection geometry for Class V wells. In the first model, the discharge is assumed to occur above the USDW. The discharged fluid must then pass through a combination of vadose zone (unsaturated) material and other potential zones of saturated water that are not classified as USDWs. In the second model, effluent enters the USDW directly, i.e., the well is completed in the drinking water aquifer, and effluent discharges directly into the zone of saturated water.

The following sections present discussions on methodologies for estimating the contaminant concentration at a point of compliance corresponding to the top of the USDW (injection above the USDW) and points of compliance within the USDW (e.g., at a point directly below the injection well, the site boundary, and the nearest drinking water well).

Injection Above the USDW

In the first conceptual model, the Class V well discharges effluent above the USDW. Depending on the hydrostratigraphy above the USDW, transport of the contaminant to the aquifer of concern may be very complex (e.g., injection may occur in the unsaturated zone above intermediate, unconfined, semiconfined, or confined aquifers that isolate the injection well from the USDW by alternating layers of low- and high-conductivity material).

For this conceptual model, the most conservative contaminant concentrations can be obtained by assuming they are equal to the injected concentrations of the effluent (point of compliance at the point of injection). A less conservative approach would be to define a point of compliance at the top of the USDW. By adopting this definition, dilution and degradation of the contaminant along the flow path from the point of injection to the top of the USDW would be taken into consideration.

For injection above the USDW, a number of approaches can be taken to estimate the concentration of the contaminant at the top of the USDW. These approaches include zero-dimensional hydrogeochemical estimation, one-dimensional analytical techniques, and multidimensional numerical methods. The methodology chosen depends on the complexity of the hydrogeology of the site, the degree of accuracy desired for the evaluation, and the availability of site-specific data.

From a pathway perspective, the simplest of the above approaches involves estimating (1) the contaminant concentration at the top of the USDW using chemical and physical information on the properties of the water in the vadose zone, (2) the geochemical properties of the matrix material, and (3) the thermodynamic properties of the contaminant of concern. The chemistry of the subsurface aquatic system is evaluated independently of physical mass transport processes (EPA 1993). In general, these methods calculate a contaminant concentration using either thermodynamic equilibrium or nonequilibrium and such parameters as pH, E_h, and principles from acid-base chemistry, coordination chemistry, oxidation and reduction reactions, and precipitation and dissolution (Snoeyink and Jenkins 1980; Stumm and Morgan 1981). Some of the more frequently used models include PHREEQE (Parkhurst et al. 1992), WATEQF (Plummer et al. 1984), EQ3/EQ6 (Wolery 1988), MINTEQ (Felmy et al. 1987), and WATEQ2/WATEQ4F (Ball et al. 1991).

While hydrogeochemical modeling can estimate the concentration of a contaminant at the top of the USDW, the results will have some degree of uncertainty because of the potentially large number of reactions (at times in the hundreds), omission of important thermodynamic data from the model's database, and uncertainty in the thermodynamic data itself (EPA 1993).

Another complex pathway methodology for estimating the contaminant concentration at the top of the USDW involves the use of one-dimensional solutions to the advection/dispersion equation. Solutions such as those given by Javandel et al. (1984) and Tomasko (1991, 1994) can be used to estimate the concentration of a contaminant at the top of the USDW if the velocity term is replaced with the effective rate of recharge (or the rate of passive injection). Analytical solutions to the one-dimensional transport equation are well suited to simple geometries (i.e., injection into a homogeneous, isotropic vadose zone that overlies the USDW). If the heterogeneity or anisotropy of the system are significant, or if other unconfined or confined aquifers exist between the point of injection and the USDW, more complex numerical methodologies may be required.

Numerical methods that have been used to estimate contaminant concentrations at the top of a USDW frequently employ two- and three-dimensional finite-difference and finite-element techniques (Anderson and Woessner 1992). Some of the models used for numerical evaluation include SATURN (Huyakorn et al. 1985), FEMWASTE (Yeh and Ward 1987), SUTRA (Voss 1990), and TRACR3D (Travis 1984). These models are all capable of making accurate predictions of contaminant concentrations at the top of the USDW; however, they all require a great deal of accurate, site-specific input data, an advanced computer capability, and skill and experience in performing numerical modeling.

Direct Discharge to the USDW

In the second conceptual model, fluids are discharged from a Class V well directly to the USDW. In its simplest and most conservative form, dilution is disregarded, and the point of compliance is the point of injection. MCLs or other regulatory concentrations, C_p are thus compared with concentrations in the effluent without considering the effects of dilution or degradation.

A less conservative approach would evaluate the effluent concentration adjacent to the injection well after mixing with initially clean groundwater in the aquifer (i.e., the point of compliance is groundwater in the aquifer adjacent to the injection well). Provided the injection well does not significantly alter the natural hydraulic gradient (passive injection), the dilution resulting from complete vertical mixing across the thickness of the aquifer, D_f, can be approximated:

$$D_f = \frac{V_d t}{ID\Phi} + 1 \quad , \tag{1}$$

where

- D = Diameter of the injection well (ft),
- I = Discharge velocity of the injection well (ft/s),
- t = Thickness of the USDW (ft),
- Ö = Effective porosity of the aquifer (ft³/ft³), and
- V = Darcy velocity (ft/s) in the saturated aquifer given by the expression

$$V_d = - K\nabla h \quad , \tag{2}$$

where K is the hydraulic conductivity of the saturated zone (ft/s), and h is the hydraulic gradient (ft/ft) of the USDW.

Using Equation 1, the concentration of the effluent in the USDW, C_{gw}, is then

$$C_{gw} = \frac{C_i}{D_f} \quad . \tag{3}$$

Depending on the characteristics of the USDW and the injection rate and size of the injection well, dilution can be significant.

If the point of compliance is an extraction well, a conservative estimate of the contaminant concentration can be obtained by using a simple mass-balance approach. That is,

$$D_f = \frac{Q_o}{Q_i} \quad , \tag{4}$$

where Q_o is the volumetric extraction rate, and Qi is the volumetric rate of injection. This approach is applicable for an extraction well located in the vicinity of the injection well or for a contaminant that is conservative (i.e., the contaminant does not readily sorb to the material in the porous medium and does not undergo any significant physical, biological, chemical, or radioactive degradation).

If the point of compliance is located downgradient of the injection well, injection is passive, and the contaminant is nonconservative, approximate concentrations in the groundwater can be obtained using the results of appropriate one-dimensional analytical solutions, such as those presented by Javandel et al. (1984), Domenico and Schwartz (1990), Luckner and Schestakow (1991), and Knox et al. (1993).

If the effluent is injected into the USDW under pressure, the passive analytical solutions discussed above are no longer appropriate and more sophisticated expressions are required. Analytical solutions developed to incorporate forced injection usually assume axisymmetric flow conditions and employ a cylindrical coordinate system in their formulation (Ogata 1961; Hoopes and Harleman 1967; Tang and Babu 1979; Chen 1985). In either case, the analytical solutions have been developed for simple geometries and homogeneous conditions in the aquifer. The estimated concentrations, however, are reasonably accurate (and useful when little site-specific information is available).

If the USDW is complex (e.g., heterogeneous aquifer properties, partial penetration of the injection well, significant leakage from the aquifer), or if more accurate solutions are desired, multidimensional numerical modeling methods, such as finite differences or finite elements, can be employed (Water Science and Technology

Board 1990; EPA 1992, 1993). Some three-dimensional numerical models many users employ to estimate solute transport in the saturated zone include CFEST (Gupta et al. 1987), SWIFT (Dillon et al. 1982), HST3D (Kipp 1991), and DYNTRACK (Riordan et al. 1992). While all of these models can be used to simulate very complex geometries, they also require a large quantity of accurate, site-specific information, an advanced computer capability, and experience in their implementation.

Conclusions

The approaches described above have been used to estimate dilution and dispersion of materials passing through soils and aquifers. Some of the models rely on simple mass-balance calculations that require little site-specific information, while others employ complex, multidimensional finite-element or finite-difference formulations that usually require a large amount of hard-to-get, site-specific information. With the exception of the dilution factor approach, we are not aware of any of these approaches being used to calculate UIC Class V permit limits.

Whether EPA proposes prescriptive regulations that place strict discharge limits on Class V wells or issues less restrictive permit regulations combined with technical guidance, simple and inexpensive approaches are needed. These approaches can be used by permit writers to obtain less conservative, more realistic estimates of contaminant concentrations in the USDW resulting from wastes injected to Class V wells. Any such approaches should be based on good scientific principles and should not jeopardize contamination of USDWs. EPA should compile a directory of existing methods and sponsor research on new low-cost methods to estimate dilution and dispersion.

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