GSI Job No.: 4827

GSI ENVIRONMENTAL

6 December 2019

Mr. Richard P. Cobb, P.G.
Acting Manager, Division of Public Water Supplies
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Avenue East
Springfield, Illinois 62794-9276

RE: Response to Request for Additional Information Regarding the Timing of Dissolved Methane Concentration Decline and the Use of Gas Relief Wells, Groundwater Management Zone (GMZ) Application for Manlove Natural Gas Storage Field. People v. People's Gas Light and Coke Co., Champaign County, 17-CH-218

Dear Mr. Cobb:

At the direction of Peoples Gas Light and Coke Company (Peoples Gas), GSI Environmental Inc. (GSI) is submitting this letter to respond to the Illinois Environmental Protection Agency's (Illinois EPA's) request for additional information regarding the anticipated timing of dissolved methane concentration decline and the potential effects of gas relief wells within the referenced GMZ.

In this response, we review the general geochemical and physical factors that control the rate of methane dissipation in groundwater, discuss the conceptual model for the transport of released natural gas at the Manlove site, and explain how our proposed remedial action program will serve to expedite the removal of this gas from water wells in the affected area.

Overview of Geochemical and Physical Factors Affecting Methane Occurrence and Persistence

The persistence of released natural gas (herein referred to as "stray gas") in groundwater aquifers is largely a function of the natural conditions that were present in the aquifer before the stray gas incident occurred. Aquifers that naturally contain elevated levels of microbial methane commonly lack the geochemical and microbiological conditions (e.g., sufficient dissolved oxygen, aerobic bacteria, etc.) necessary to rapidly consume dissolved methane. For this reason, naturally present methane persists in such aquifers, whereas, in an aquifer that is highly oxygenated, aerobic bacteria rapidly consume methane. If additional thermogenic methane is introduced to such an aquifer, this new thermogenic methane may also persist for an extended time period.

The effectiveness of remedial actions is also constrained by pre-existing aquifer conditions. For example, efforts to extract and/or treat the new thermogenic methane must also extract and treat any naturally present microbial methane. Additionally, attempts to reduce gas concentrations in groundwater can be complicated by the highly dispersive nature of methane. Because of this aspect, the locations of gas pockets and/or localized

Exhibit 3a

areas of elevated dissolved methane can be difficult to predict over a large area with complex stratigraphy. These and other technical factors must be considered in planning and executing a remedial strategy at sites like the Manlove Field, where microbial methane is naturally pervasive throughout the complexly interbedded Mahomet Aquifer system.

GSI's proposed investigation program is intended to characterize these factors to the extent practicable so as to employ a remediation strategy that effectively preserves the beneficial use of the Mahomet Aquifer system. We currently anticipate that this remedial strategy would entail selective use of "gas relief wells," in combination with passive well vents and gas-water separation at the groundwater point of use.

Conceptual Model of Stray Gas Incident

Because of the dispersed nature of stray gas impacts within an aquifer, remediation of elevated methane concentrations in groundwater can be challenging. Unlike other common groundwater contaminants (petroleum hydrocarbons, chlorinated solvents, etc.), methane enters groundwater as a free gas that can rapidly move through preferential pathways under the influence of both source pressure and fluid buoyancy. Once the release is terminated, or the source pressure is relieved, discrete gas pockets can remain trapped beneath impermeable strata. These remnant free gas pockets gradually dissolve into groundwater, serving as a localized source of methane until completely dissolved. At the same time, dissolved methane concentrations will decrease at a rate controlled by microbial degradation, dispersion due to the advective movement of groundwater, and diffusion.

Remnant free gas pockets can be potentially re-mobilized and vented by declining hydraulic head conditions, such as when extended pumping of a water well significantly lowers the water level within the well casing. These lower head conditions can result in the sudden entry of free gas into the wellbore. Such wells may be used to relieve gas pressure in the aquifer (i.e. a "gas-relief well"). In some cases, there may be sufficient gas pressure such that pumping is not required. Because stray gas incidents are a relatively new environmental challenge, there is little publicly available information on the efficacy of gas relief wells. However, gas relief wells have been used to relieve gas pressure in groundwater at sites impacted by a stray gas release in Louisiana (De Soto Parish, KTBS 2018) and Texas (Gaines County, GSI 2017) in the past two years. Performance data from the Louisiana relief wells are still pending. However, the Gaines County location relief well was observed to produce nearly 50,000 cubic feet of gas per day during pilot testing.

Remedial Measures for Stray Gas Issues

In GSI's experience, the typical response required by most state regulatory agencies to address stray gas has been point-of-use treatment. This entails:

- The installation of passive vents on water wells to ensure gas does not accumulate within the well casing;
- The use of gas-water separators to reduce dissolved gas concentrations within potable water; and/or
- Other gas mitigation methods.

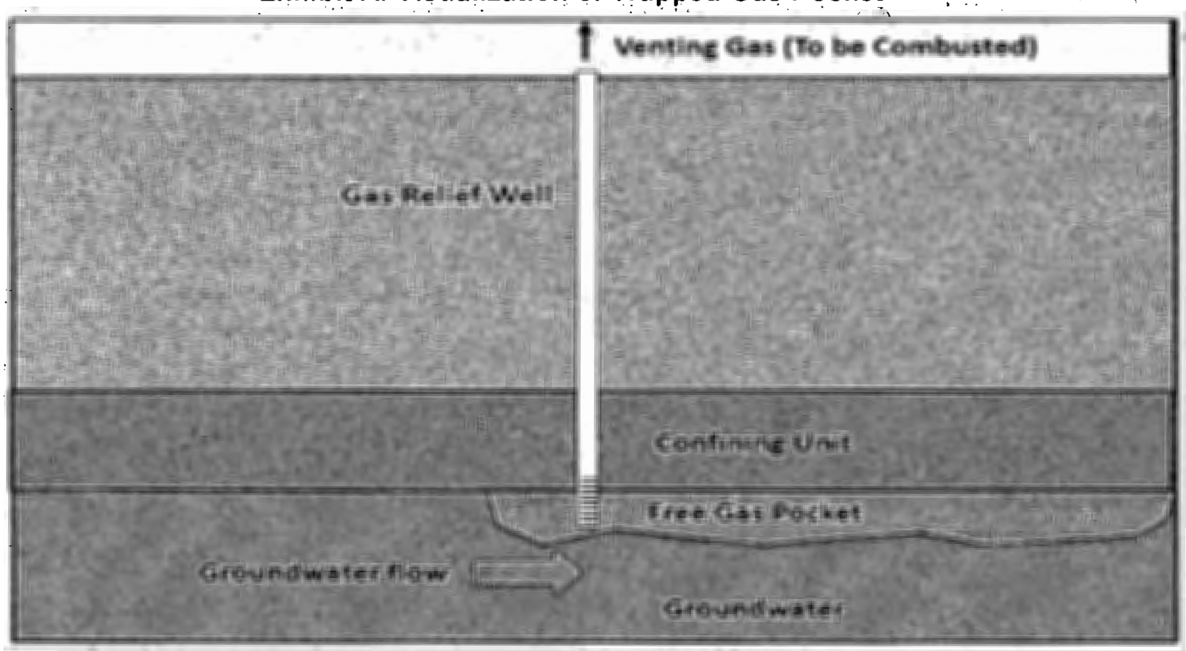
These measures are used at locations exhibiting elevated dissolved and/or well headspace methane concentrations. These systems provide a very high degree of confidence that the excess gas will be intercepted and removed from the water supply prior to use, thereby preserving the beneficial use of the water supply.

In cases where pockets of pressurized gas are encountered, the remedial response can be expanded to incorporate gas relief wells. Factors that may aid in the identification of a potential zone of free gas accumulation include: 1) the sustained presence of elevated dissolved methane concentrations in a localized area, and 2) identification of natural potential gas traps (e.g., stratigraphic highs confined by impermeable strata). In the Manlove Field, GSI has identified four such areas that match one or more of these criteria (GSI 2019). Specifically, these areas represent those portions of the Mahomet Aquifer or shallower sand strata that extend to the highest elevation in the shallow subsurface (i.e., the "peaks" of the sand layer). GSI believes these peaks may act as the equivalent of structural traps for gas accumulation. This is supported by the presence of a high density of elevated dissolved methane concentrations water supply wells in the southern-most "peak."

Conceptually, the operation of gas relief wells within these areas will potentially serve to reduce gas pressures in the aquifer, as well as the ultimate duration of the dissolved gas sourced by the free gas. As a simplified example, Exhibit A shows a trapped gas pocket in contact with a steady flow of groundwater through an aquifer. In this situation, the water in the aquifer becomes saturated with methane as it flows across the free gas pocket.

If the free gas pocket were removed by a gas relief well, there would be no continuing source of dissolved gas. In this case, the lifespan of the dissolved gas would be much shorter.

Exhibit A. Visualization of Trapped Gas Pocket



Once the gas pocket is no longer present, the rate of dissolved gas diminution is a function of redox conditions, as well as advection and diffusion in the aquifer. Redox conditions control the ability of microbes to consume methane. Specifically, in an oxygenated aquifer, the rate of aerobic biodegradation of dissolved methane is controlled by the availability of oxygen, which in turn is a function of the rate of oxygen flux into the aquifer via groundwater recharge (McMahon and Chapelle 2007; Humez et al. 2016). In aquifers with high rates of groundwater recharge and flow, dissolved methane may dissipate relatively quickly, with no intervention.

In low-oxygen environments, the microbial degradation of the methane proceeds more slowly than in aerobic conditions, by means of nitrate, manganese, iron, and/or sulfate reduction (McMahan and Chapelle 2007; Molofsky et al. 2016). In this case, the rate of natural biodegradation of the dissolved methane will be controlled by the availability of these electron acceptors, as well as the rate at which they are recharged into the impacted zone via groundwater flow.

In aquifers that lack oxygen or other electron acceptors, and are therefore considered highly reducing, methane may be stable for years or decades. This is particularly true for aquifers where methane is naturally generated, i.e., under methanogenic conditions.

Considerations for Investigation and Remediation at the Manlove Site

Groundwater in the Mahomet Aquifer is present under naturally methanogenic conditions, which accounts for the widespread occurrence of microbial methane naturally found in this aquifer (e.g., Hackley et al. 2010, Sanderson and Zewde 1976). Under such conditions, both microbial and thermogenic methane will be relatively stable, and unlikely to quickly degrade over time. This is supported by local observations of naturally present microbial methane at concentrations in excess of 60 mg/L.

Therefore, the rate of decline of dissolved thermogenic gas will largely depend on i) the rate of dissolution and/or removal of any pressurized free gas pockets, and ii) site-specific advection and diffusion of the dissolved methane.

The time required for these processes are difficult to predict in advance, since they depend on both site-specific and location-specific characteristics that often cannot readily be determined with precision. Both aspects will be better understood following pilot testing, and better still after an initial period of full-scale operation of gas relief wells. If we assume that free gas removal requires 2 to 4 years to reach a point of diminishing return, then we would expect that dissolved concentrations would decline minimally, if at all, during that period due to the methanogenic conditions of the aquifer, and because a source of residual free gas is still present and dissolving into the groundwater.

Once the free gas removal is effectively concluded, then advection and diffusion would begin to gradually reduce dissolved phase concentrations. Given available information on the natural groundwater velocity and the confined nature of the Mahomet Aquifer (Hackley et al. 2010), the decline of dissolved methane due to physical displacement and mixing with lateral will likely be a relatively slow process. GSI expects that the gradual decline of dissolved phase concentrations following relief well operation will likely require years to over a decade to reach an asymptotic state. A more precise analysis of the timing of this decline curve may be provided following the further investigation and modeling simulation proposed in the GMZ application.

We hope that this provides you with the additional information requested to complete your review of the GMZ Application.

Best Regards,

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