NOVA SCOTIA
Environment

Environmental Best Management Practices for Formation Water from Coal Bed Methane Exploration and Production Activities

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I. PURPOSE

The intent of this document is to identify issues associated with the proper environmental management of waste formation waters from exploration and production activities in Nova Scotia. Further, this will outline treatment and disposal options with the goal of requiring parties which produce or manage formation wastewater to meet or exceed environmental performance and responsible care requirements.

II. LEGISLATION

Activities Designation Regulations

s. 3 (1)

Any activity designated in these regulations requires an approval from the Minister or an Administrator designated by the Minister.

s. 17(2)(f)

a compressor and pumping station for the movement of a hydrocarbon fluid by means of compression or pumping

s. 21

The treatment or processing of wastewater and wastewater sludges is designated as an activity.

III. BACKGROUND INFORMATION

Exploration and extraction of petroleum hydrocarbons - specifically natural gases (coal gas [CBM], methane, shale gas etc.) - is not a new industry worldwide. However the resource potential has only been gaining attention in North America in the past two decades as more conventional resources become depleted.

Considerable environmental concern exists with regard to the potential impact of discharged untreated formation waters from exploration and extraction operations on aquatic ecosystems, groundwater resources and soils. Other jurisdictions have experienced problems with certain disposal methods for these types of wastewater. In order to understand the potential environmental impacts of formation waters, their physical/ chemical properties must first be understood. To this end a brief description of formation waters is given below.

Formation water is the naturally-occurring water which is contained within the geological formation itself. In order to extract the methane/natural gas resource within the formation, often large volumes of water must be pumped to the surface. The quantity and quality of the formation water can both be problematic. Depending on the formation, each well can produce in the range of 5 to 80 litres of water per minute, which equates to 7200 to 115,000 litres per day per well. Over time, the water volume should decrease as the gas volumes increase. Formation water has been found to contain high levels of chlorides, arsenic, iron, barium, manganese, TPH, PAHs and may even contain naturally occurring radioactive materials (NORMS). Chlorides in some cases have been found to be in excess of four times the level of concentrations found in the ocean.

Discharge of these waters into streams which are not saline would be lethally toxic to aquatic life. Discharge onto the land can have an adverse effect on soil structure and negatively impact vegetative growth. Sodium-induced dispersion can cause reduced infiltration, reduced hydraulic conductivity and surface crusting of soils. Excess salinity in soil water can decrease plant- available water and cause stress to vegetation. Livestock or humans cannot utilize water with high levels of chlorides due to cellular disruption. High levels of arsenic and barium can be lethally toxic to animal and aquatic life. Elevated levels of iron and manganese can cause accelerated bacteria growth in freshwater systems and reduce ground and surface water quality.

Other jurisdictions have permitted discharge of untreated formation waters directly into surface waters. Pollution caused by these discharges has been common. Many of those jurisdictions have since amended their regulations and policies to prohibit direct discharge of untreated formation waters into any surface water body. Discharge of highly saline formation water, such as those found in Nova Scotia, led to serious pollution of surface waters in central England (Lemon, 1991). In the former Kent coalfield, leakage of lagoons holding highly saline mine formation waters led to serious contamination of a potable aquifer (Headworth et al, 1980). Similarly saline waters from the Selesian coalfield in Poland contained radioactive isotopes which led to elevated radioactive levels in the receiving watercourse (Lebecka et al, 1994).

IV. REGULATORY FRAMEWORK

International

In the United States, individual states regulate natural gas exploration and development however, the Federal US Army Corps of Engineers issue permits which govern the construction of dams and reservoirs to dispose of wastewater, specifically from coal bed methane production wells, under the Federal Clean Water Act. These dams and channels were often built in channels of seasonal streams which eventually would flow and overflow wastewater (e.g. into the Powder River and it's tributaries). Recent court decisions in Wyoming have caused issuance of these permits to be suspended until the Corps corrects it's permit process to take into account the environmental impact of the formation waters.

Canada

Produced water in British Columbia is predominantly surface discharged. The developer does not require an approval or permit prior to discharge provided the *Code of Practice for the Discharge of Produced Water from Coalbed Gas Operations* is followed. This *Code of Practice* allows for discharge of produced water to perennial streams, seasonal streams or the ground by percolation through the ground under specific conditions.

Alberta has several coal and shale formations which exist at different elevations. With the varying elevations comes varying water qualities. The shallowest seams have water quality which would be considered fresh water, based on salinity. Fresh water is regulated by Alberta Environment and must be conserved, so this would require pre-treatment for other parameters of concern before discharging. The lower coal seams have water qualities very similar to those in Nova Scotia. These formation waters are currently, exclusively being reinjected. In Alberta, produced water is reinjected in deep previously evacuated oil and gas reservoirs. This is regulated by the Alberta Energy Utilities Board with specific requirements for hydraulic isolation from ground and surface water supplies. As a result of the requirement for treatment, the shallower seams are not currently being exploited.

Nova Scotia
Regulation of all waste effluents from exploration and production operations in Nova Scotia lies with Nova Scotia Environment. Some of the common methods of disposal which are permitted in other jurisdictions are not suitable to the geology, hydrogeology, land area and topography of Nova Scotia. Currently, the Province does not support a "pollute up to" approach to waste management, therefore any discharges would be required to meet the Canadian Council of Ministers of the Environment (CCME) *Guidelines for the Protection of Freshwater Aquatic Life (FWAL)* or the CCME *Drinking Water Quality Guidelines (DWQG)* prior to discharge or re-injection into any area which may have the potential to enter potable groundwater or any surface water. Nova Scotia does not have any previously exploited reservoirs which would allow for reinjection disposal. For Nova Scotia to consider re-injection as an option, the re-injection zone would need to be in isolation, hydraulically, from all surface waters and potable groundwater. The potential of the historic mine workings themselves to act as a disposal reservoir has been raised, however, the coal seams in Nova Scotia dip between 42 and 45° back to surface. Many of the abandoned mine workings discharge to surface, making the hydraulic isolation an impossible achievement.

All treatment and disposal operations on-shore would require a formal approval from Nova Scotia Environment, issued under the *Activities Designation Regulations.*

V. CBM FORMATION WATER TREATMENT TECHNOLOGIES AND DISPOSAL OPTIONS

As previously stated, Nova Scotia requires wastewater effluent discharges meet, at a minimum, the CCME FWAL Guidelines or CCME CDWQ Guidelines. Formation waters in Nova Scotia, typically, can not meet these requirements without prior treatment before discharge.

The following is a list of commercially available treatment technologies currently being used by the Industry. This list does not represent a hierarchy of options; it is expected that the generators of the waste will choose the treatment option which is best suited to the characteristics of the formation waters they are dealing with and within what is economically achievable for the project. The Industry is also not limited to the technologies listed in this document. As technology advances and more is learned about the potential environmental effects of formation waters, it can be expected that new technologies will emerge and standards will change.

1. Ion Exchange
Ion exchange is conventionally used to describe the purification, separation and decontamination of aqueous and other ion-containing solutions with use of solid ion exchangers. Commercial ion exchange is used in many locations for formation water treatment. The technology is capable of treating water of varying quality which makes it one of the more flexible treatment options.
The finished water quality is high enough it can be used for irrigation, livestock or watering in some jurisdictions. A waste brine is also produced which, depending on the chemistry, must be disposed of at an Approved Facility. Waste brine storage requires an Approval from Nova Scotia Environment.
Ion exchange has proven to be economically viable under appropriate conditions.
There are currently no existing independent commercial ion exchange facilities in Nova Scotia.

2. Reverse Osmosis
Reverse Osmosis is a separation process that uses pressure in excess of osmotic pressure to force a solvent through a membrane that retains the solute on one side and

allows the purified solvent to pass to the other side. The process is used most often for desalination but is also effective in removal of all particles larger than one angstrom.
Pretreatment is required as membranes can not be backwashed because of the design which allows water to flow through in only one direction.
The finished water quality will meet FWAL Guidelines. Waste brine is typically piped to a storage pond for further evaporation and eventual disposal at an approved facility. The brine storage requires formal approval from Nova Scotia Environment.
This process has been effectively utilized worldwide for various types of water and wastewater treatment. This process is energy consumptive due to the high pressures required to force the solvent through the membrane. There are currently no independent commercial reverse osmosis facilities in Nova Scotia.

3. Freeze - Thaw Evaporation

Freeze-thaw evaporation may be utilized when the ambient air temperature is below 0°C. The contaminated water is sprayed or dripped onto a freezing pad to create an ice pile. During sub-freezing conditions runoff from the ice pile will have elevated concentrations of chemical constituents compared to the original wastewater. he result is a higher concentrated solute which will be required to be stored for later disposal of at an approved facility. Once temperatures increase to allow for thaw conditions, the melt water can be suitable for beneficial uses such as irrigation. The brine solute storage requires formal approval from Nova Scotia Environment.
Climatic conditions in Nova Scotia may not be suitable for this type of treatment process.There are also implications for soil contamination associated with this method of treatment.While this may be feasible in jurisdictions with large land areas that are isolated from population bases, conditions in Nova Scotia may not be conducive to this practice.

4. Chemical Oxidation + RO

Chemical oxidation destroys organic contaminants which are either dissolved in water or present in free phase. Chemical oxidants are introduced to the wastewater to react with such organic compounds as amines, phenols, chlorophenols, cyanides, halogenerated aliphatic compounds, mercaptans. Chemical oxidation can be combined with other treatment technologies to maximize clean-up results. An example is combined application of chemical oxidation and reverse osmosis treatment technologies in Wyoming for formation waters.Treated water quality is high. A waste brine is also produced which, depending on the chemistry, must be disposed of at an Approved Facility. Waste brine storage requires an approval from Nova Scotia Environment.
Efficiency of the process is reduced with reduced water quality. Capital and operating costs are typically high. There are currently no independent commercial Chemical oxidation/reverse osmosis facilities in Nova Scotia.

5. Constructed Wetlands

Constructed wetlands are artificially constructed wastewater treatment systems which utilize wetland vegetation to promote natural chemical and biological processes to achieve effective treatment of wastewater. There are two principle categories of constructed wetland systems: free water surface and subsurface flow. Constructed wetland systems are very effective in removing nutrients such as nitrogen and phosphorous. Depending on the vegetation incorporated, wetlands can also remove organic or inorganic contaminants given sufficient retention time.
Efficiencies of the process have been shown to be in the 95 percent range. Efficiencies are highly dependent the characteristics of the wastewater and the type vegetation which is utilized.

Constructed wetland technology is considered a new technology with respect to formation water treatment. However, this technology has been successfully employed for treatment of coal mine discharge waters which have similar chemistry to that of formation waters.
Use of an existing natural wetland or a wetland which has been created as part of a compensation plan is strictly prohibited.

6. Deep Well Injection at Dedicated Onshore Sites

Disposal of wastes through injection down wells into pores, fissures and caverns in underground strata has been a favored strategy in many areas, particularly Western Canada and the Western U.S. These disposal sites often take advantage of exploratory wells that did not find commercial quantities of natural gas or oil and therefore represent a non-performing asset to the drilling company or have been evacuated of the oil or gas resource. Using the site for waste disposal therefore allows some cost recovery.

The technical rationale for using deep well disposal is that the materials are deposited in impermeable strata which is hydraulically isolated from potable aquifers and surface waters. In addition, since the particular fluids used in drilling were considered safe enough to use during the original construction of the well, it should be reasonable to assume that more of these materials placed permanently would not pose additional risk.

The arguments against this form of disposal are also persuasive. Injection is a form of dumping since no treatment has occurred or is likely to occur at depth. This results in an area that is permanently impacted and withdrawn from potential beneficial use. There is also additional risk if the underlying geology is not perfectly understood, since leakage may occur and monitoring is difficult and expensive to install.

Since Nova Scotia does not have an extensive history of land-based petroleum exploration and therefore does not have preexisting wells or land areas that are impacted by drilling fluids, it does not appear reasonable at this time to establish deep well injection as a disposal option for formation waters. There are currently no approved deep well injection facilities in Nova Scotia.

Note*: Many jurisdictions are now reviewing environmental impacts of existing onshore deep well injection sites with the stated goal of phasing out these operations.*

Dated this 16th Day of April , 2008

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