ERCB

ERCBH2S

A Model for Calculating Emergency Response and Planning Zones for Sour Gas Wells, Pipelines, and Production Facilities

Overview

Energy Resources Conservation Board

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1 Introduction

In December 2000, the Provincial Advisory Committee on Public Safety and Sour Gas published recommendations pertaining to emergency planning, preparedness, and response, some of which called for a review of the ERCB's method of calculating emergency planning zones (EPZ) for sour operations. The ERCB addressed these recommendations and issued a revised edition of *Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry* for sour wells, pipelines, and production facilities, requiring licensees to use the ERCBH2S computer software to calculate EPZs. ERCBH2S calculates site-specific EPZs using thermodynamics, fluid dynamics, atmospheric dispersion modelling, and toxicology. The development of ERCBH2S has been a considerable undertaking with stakeholder input from a range of backgrounds, disciplines, and areas of expertise.

This document is an overview of the ERCB hazard management process and a high-level summary of ERCBH2S. It also aims to assist the reader in developing a greater understanding of how the ERCB manages its emergency planning principles and implements them through ERCBH2S. Other documents pertaining to ERCBH2S are:

Directive 071, Emergency Preparedness and Response Requirements for the Petroleum Industry	This directive provides the requirements for the industrial operator. It covers not only sour operations, but any activity where a hazard exists with the potential to cause a risk to the public.
Overview (This document)	Written for industrial operators and public with a particular interest in ERCBH2S. It provides an overview of the ERCB hazard management process and presents a high level summary of the key components of the ERCBH2S software.
Volume 1 Technical Reference Document Version 1.20	Written for the technical specialist and to document the complex science within ERCBH2S. It provides the science required to calculate the EPZ and the basis for selecting the components used to make the calculations within ERCBH2S.
Volume 2 Emergency Response Planning Endpoint	Written for the technical specialist with a particular interest in toxicology. It presents the data available to choose an EPZ endpoint, toxicological calculations and the EPZ endpoint values. It also documents the extensive stakeholder engagement process undertaken to assist the ERCB its EPZ endpoint selection.
Volume 3 User Guide Version 1.20	Written for the ERCBH2S user, it provides a description on how to install and operate the computer software application with tutorial notes.

2 Difference Between a Hazard and a Risk

The terms hazard and risk are frequently misunderstood and used interchangeably, but are different concepts that should not be confused and require clarification.

A hazard can be described as a chemical, physical, social, economic, or political condition with the potential to cause harm to people, assets, the environment, or other things that we may value (e.g., reputation). For example, walking across a wet floor may cause a person to fall and hurt him or herself. A hazard must be controlled to either reduce potential exposure to the hazard or reduce the effects of exposure to it.

Risk is a measure of the potential to cause harm. It reflects both the likelihood an event will happen and the magnitude of harm associated with the event. If a hazardous event with severe consequences is unlikely to happen, it is considered low risk. Using air travel as an example, the consequences of a plane crash could be disastrous, but because a crash is unlikely to occur on a particular trip the risk of dying in a plan crash is low. Events that are considered high risk not only have severe consequences but are more likely to occur. The risk of harm can be minimized by either reducing the frequency of occurrence (i.e., prevention) or reducing the consequences of hazard (i.e., mitigation).

We routinely encounter hazards and their associated risks and use both common sense and experience to reduce the risk of exposure to those hazards. Governing bodies often work to reduce the public's risk of exposure to hazards. For example, new drugs are required to be carefully tested and scrutinized before being licensed for use by the general population. Industrial activities also have the potential to result in undesirable events with severe consequences, but careful management of hazards can minimize those risks.

In Alberta, natural gas, some of which may contain H_2S, is a very important resource that the ERCB is obligated to conserve. Revenue from these operations contributes to the provincial and national economy, providing for services such as health care, education, emergency services, infrastructure, and the safe and secure society that we enjoy as Canadians. Although sour gas operations are conducted with the expectation of a probable benefit, they present a risk to the public. It is the ERCB's responsibility to ensure through regulatory means that a licensee conducts its activities in a manner that is safe and responsible enough to minimize that risk.

By considering what could go wrong and making hazard-based decisions, we can determine emergency response planning requirements, such as the public protection and accident reduction and mitigation measures in *Directive 071*. On the other hand, by considering what may be expected to go wrong and making risk-based decisions, help us consider the appropriateness of land-use activities adjacent to hazardous facilities, such as the setback provisions outlined in various ERCB Interim Directives and Informational Letters.

If a risk is present, it often leads to a discussion of its level of tolerability. Tolerability is very difficult to define and a person's experiences and values associated with a given event compound this difficulty. The risks of exposure to a hazard that the public faces may be voluntarily undertaken or imposed by other individuals or organisations. Risks to the public are generally less tolerable if perceived to be involuntary chosen (e.g., exposure to pollutant) rather than voluntary (e.g., dangerous sports or smoking).

Regulators responsible for hazardous industrial activities struggle with these difficulties in determining the risk acceptance criteria[1] a licensee's operation. Although the ERCB has not defined risk acceptability criteria, it bases its estimates of risk on its knowledge and expertise of what hazards and risks are associated with upstream oil and gas facilities. It then uses these risk estimates to judge whether a particular development or activity is in the public interest.

[1] As long as risk is lower than a prescribed limit (i.e., criteria), it is acceptable.

3 Preparing for a Sour Gas Emergency

ERPs ensure a quick, effective response in the rare event of a sour gas release to protect the public and minimize environmental impact. It is carried out by those who would have the best understanding of the situation at the time of the event. Since the introduction of requirements for site-specific ERPs in *Directive 071*, the ERCB has reviewed and frequently enhanced licensee ERP requirements. The current requirements within *Directive 071* apply not only to sour gas operations, but also include corporate ERP requirements to further reduce risk from hazards posing a risk to the public.

The details of emergency planning, preparedness, and response are complex. Resources, equipment, and general land use information need to be gathered and maintained. Roles and responsibilities of responders—from industry, the local authority, and others—must be agreed to and incorporated into everyone's ERP.

In Alberta, ERPs dealing with public safety in the upstream petroleum industry must be developed according to *Directive 071* to clearly identify all roles and responsibilities of all responders and mutual agreement of them. Licensees must include a summary of these roles and responsibilities in its ERP to avoid any confusion or misunderstanding when responding to an incident. This includes the roles and responsibilities of the local authority which are an important part of a licensee's ERP. Under Section 11 of the *Disaster Services Act*, the local authority of a municipality is responsible for the direction and control of the local authority's emergency response. The local authority uses its Municipal Emergency Plan to respond to any emergency, not just those related to the petroleum industry.

During an incident, those involved in a response effort coordinate their efforts to begin close to the incident where significant exposure to sour gas is more likely. The response then fans out as required, depending on the actual conditions and specific circumstances of the event.

The geographical area that surrounds a well, pipeline, or facility and contains hazardous product is the response efforts' emergency protection zone (EPZ). The EPZ requires specific response by a licensee and is an added measure in an ERP. The EPZ for sour gas well, pipeline, or facility is not arbitrarily chosen, but determined through the dispersion modelling and calculations in ERCBH2S using worst-release scenarios with average dispersion conditions for a major release of sour gas.

For a sour gas well, pipeline, or facility, location of surface developments, including residences, within the EPZ is a trigger for the need to develop and submit a site-specific ERP for review and testing against *Directive 071*.

4 Definition and Purpose of ERP and EPZ

During the development of ERCBH2S, it became apparent that the purpose of an ERP and the EPZ was unclear and misinterpreted by ERCB stakeholders and needs clarification.

An ERP is a regularly maintained document containing critical information on the resources, roles, responsibilities, and pre-planned actions for responders in an emergency to unsure a quick, effective response. Both the industrial operator and local authorities have a responsibility to protect people from impact.

An EPZ is a geographical area surrounding a well, pipeline, or production facility containing hazardous product that requires specific emergency planning by the industrial operator. For sour gas operations, the EPZ is initially determined by assessing the sour gas hazard using ERCBH2S. The actual EPZ included in the ERP is adjusted in size and scope to account for special concerns within or near the area. However, the EPZ does not define the full extent of a licensee's response obligations. A licensee, in coordination with local authorities, must also be prepared to respond to areas beyond the defined EPZ if required at the time of the incident.

The goal of emergency planning, preparedness, and response is to reduce the consequences of a hazard. It does not consider the risk, the product of consequence and likelihood, of the industrial activity. The ERCB addresses risk through stringent engineering standards, procedures and training, and regular inspections. The ERCB also applies setbacks to ensures that the land-use (i.e., recreational land-use as opposed to dense residential) is appropriate for the level of risk. As with the concepts of hazard and risk, EPZs and ERPs should not be confused with setbacks since the objectives are very different.

Directive 071 requires the licensee, within its EPZ, to account for site-specific features and the particular circumstances of the local area. As a starting point, the circular EPZ predicted by ERCBH2S assesses the size of the area that could experience high H_2S concentrations in the event of a release, requiring response measures in an operator's ERP. Modifications may be made to the initial EPZ determined in ERCBH2S for various reasons. For example, reasons for creating an EPZ larger than the ERCBH2S prediction vary but typically include the following:

- the proximity of high-density populations close to, but immediately outside, the borders of the ERCBH2S-predicted EPZ;
- inadequate access to emergency escape routes in the ERCBH2S-predicted EPZ or adjacent to its boundary; and
- information gathered during the public involvement process[2].

The objective is to produce reasonable estimates of the primary hazard area, especially in areas where short-term exposure to high concentrations of sour gas could occur, so that an ERP is meaningful and can be executed effectively.

The ERCB's approval process requires compliance with *Directive 071* and an assessment of a licensee's ERP to test a licensee's preparedness and capacity to implement it. If an ERP is found to be ineffective, the ERCB will not approve the application or will suspend existing operations until the licensee can demonstrate that its ERP is appropriate and that it can implement it. This is a very important aspect of the ERCB hazard management system.

[2] See Section 4 of *Directive 071: Emergency Preparedness and Response Requirements for the Petroleum Industry*.

5 Calculating Emergency Planning and Response Zones for H_2S in ERCBH2S

Prior to development of ERCBH2S, the ERCB's requirements for calculating EPZs were based on simplistic dispersion models and a simplified representation of the emergency. Alternative models in use by industry conflicted with the ERCB's estimates. Since many of the calculations used in these alternatives were based upon proprietary air dispersion models, the ERCB was unable to effectively compare, contrast, or evaluate the results of these various approaches to make appropriate decisions on public safety. Both the ERCB and its stakeholders recognized the need for a common method in determining an EPZ to increase public confidence and industry compliance. This new standard needed to be clearly documented and open for scientific scrutiny and future scientific advances.

ERCBH2S was soon developed as the common method for calculating an EPZ for sour gas wells, pipelines, and facilities in Alberta. However, it should be noted that computer models, such as ERCBH2S, only approximate reality and should be used with caution and within the limitations of the model. When used carefully and skilfully, ERCBH2S is an effective tool for undertaking hazard assessment.

The ERCB has carefully selected the numbers, or inputs, used in ERCBH2S calculations to ensure that the resulting EPZ meets emergency planning objectives. Uncertainty and variability in key parameters for calculating an EPZ are accounted for to ensure that the resulting EPZ errs on the side of public safety and an EPZ that may be larger than necessary.

5.1 Modelling Assumptions

A detailed discussion of the modelling assumptions for ERCBH2S is in the first volume of this series. (see *Volume 1: Technical Reference Document, Version 1.20*). Key assumptions are presented here to provide a general understanding of why certain assumptions have been made.

5.1.1 Source Characterization

Sour gas is typically brought to the surface by a well or transported by a pipeline at high pressure. During a sour gas well blowout or a pipeline rupture, pressure drops to atmospheric pressure. The gas cools rapidly as it expands. Liquid droplets (aerosols) can form and, in combination with the cooling, impact how the gas cloud subsequently disperses in the atmosphere.

Depending on the particular gaseous mixture, gas properties, and ambient conditions, the sour gas cloud from a release may be

- dense (heavier than air; drops over time),
- buoyant (lighter than air; rises over time), or
- neutrally buoyant (about the same weight as air; neither rises nor drops but disperses over time).

As the sour gas cloud drifts away from the source, it dilutes and will, at some point, behave as a neutrally buoyant gas, dispersing until it is no longer detectable (i.e., below the odour threshold).

These are just a few of the characteristic behaviours of a sour gas cloud that are accounted for in ERCBH2S calculations of an EPZ for emergency planning and response. Sour gas wells and pipelines operate under very high pressure and result in a dense release. However, in wells and pipelines carrying multiphase product, the sour gas evaporates from the hot fluid and tends to rise. Although ERCBH2S is capable of modelling buoyant plumes, for the purposes of calculating the EPZ, it presumes that releases are dense. This assumption simplifies the overall hazard assessment, but results in an EPZ that may be larger than necessary should some conditions result in the actual release being buoyant.

Modelling Assumption	Implication
Releases are initially dense.	EPZ may be larger than necessary depending on the actual conditions.

5.1.2 Atmospheric Stability

In Alberta, stable conditions that result in poor atmospheric dispersion occur most frequently at night. In winter, these poor dispersion conditions may also occur during the day. However, it is possible that high concentrations at ground level can occur under other atmospheric conditions.

Modelling Assumption	Implication
All the 54 standard regulatory screening atmospheric dispersion conditions can occur. Some dispersion conditions occur more frequently than others.	EPZ may be larger than necessary under favourable dispersion conditions.

Dispersion of an airborne hazard depends on both atmospheric turbulence and wind speed, both of which influence plume shape and distance to a particular pollutant concentration in the atmosphere. ERCBH2S uses a classification scheme for atmospheric turbulence called the Pasquill-Gifford (PG) stability class.[3] This scheme is applicable worldwide and differs from location-to-location only in how often specific weather conditions occur. ERCBH2S searches for the worst dispersion conditions that produce the largest hazard distance by running the standard regulatory screening conditions (54 combinations of stability class and wind speed). ERCBH2S also uses the probability of atmospheric dispersion conditions in Alberta[4] to weight the worst-release hazard distances to produce the dispersion condition averaged hazard distances.

5.1.3 Topography

ERCBSLAB is the gas dispersion model within ERCBH2S. It assumes that airflow remains parallel to the ground and that terrain does not generate turbulence. ERCBH2S does not require site-specific topographical features, such as hills, mountains, or valleys, to be defined. These features generate turbulence and reduce the size of an EPZ. As a conservative assumption, ERCBH2S does not account for increased dispersion due to terrain.

[3] The Pasquill-Gifford stability class and dispersion condition averaged hazard distances are discussed in detail in the document *Volume 1: Technical Reference Document Version 1.20*.
[4] Based on historical data from Alberta Environment.

The effect of terrain on the predicted dispersion is discussed in detail in the first volume of the ERCBH2S series (see *Volume 1: Technical Reference Document Version 1.20*).

Modelling Assumption	Implication
Airflow remains parallel to the ground and terrain does not deflect the wind's direction.	ERCBH2S does not account for increased dispersion due to terrain. EPZ may be larger than necessary.

5.1.4 Concentration Fluctuations

H_2S concentration within a gas cloud, over time, fluctuates above and below the time-averaged value, leading to an uncertainty in its exact H_2S concentration. Typically, fluctuations above the time-averaged concentration are much greater than those below the average. Gas clouds containing H_2S can be very toxic at higher concentrations. The consequences of being exposed to high concentrations of H_2S for even a short period of time can be severe.

Modelling Assumption	Implication
H_2S concentration fluctuates over time. Fluctuations above the time-averaged concentration are much greater than those below the average.	EPZ may be larger than necessary due to large concentration fluctuations above the time-averaged concentration than seen in laboratory experiments

Most dispersion models will only predict a time-averaged concentration (C). Whereas, ERCBH2S accounts for the uncertainty in H_2S concentration over time and an increase in toxicity at higher concentrations due to atmospheric turbulence. These are addressed by adding a power of 3.5 to the concentration ($C^{3.5}$). The calculation of concentration fluctuation is discussed in detail in the first volume in the ERCBH2S series. (see *Volume 1: Technical Reference Document Version 1.20*).

5.1.5 Exposure Time

Effective response planning for emergency situations involving sour gas can reduce or eliminate risk in two principal ways:

1) **Preventing exposure to harmful levels of H_2S** by preparing well-planned procedures to evacuate people to a safe location before a release occurs. Safe locations may be upwind, an appropriate distance perpendicular to the wind, or far enough downwind. This type of action can be effective when prior warning of a release is given, for example, in the early stages of a well control problem during drilling or servicing operations.

2) **Reducing exposure to harmful levels of H_2S** for short-term sour gas releases when evacuation cannot be effectively carried out. For example, for unexpected releases, such as a pipeline rupture or a release from a production facility, or during adverse weather conditions that may prevent evacuation, it is always much safer to be initially indoors with doors and windows closed than it is to be outdoors. Being inside a house or building affords a buffer from potentially harmful outdoor concentration exposures by removing most of the harmful concentration fluctuation spikes. Often, sheltering indoors can be the best first response action for protection from short duration sour gas release events because it takes a longer time for H_2S concentrations indoors to reach dangerous levels.

Modelling Assumption	Implication
Maximum exposure time is three hours.	Reasonable assumptions in balance with meteorology, evacuation, mitigation, and the hazard.

Calculations in ERCBH2S take into account the accumulation of exposure time to toxic levels of H_2S and presume a maximum exposure time of three hours. This three hour maximum exposure time assumes that

- most conditions will not remain constant for more than three hours,[5] and
- a person can remain conscious while exposed to predicted concentrations for up to three hours.

The exposure duration in the ERCBH2S calculation depends on whether the operation is manned or unmanned. In manned operations, actions such as igniting the well or manually closing a valve can be used to terminate the H_2S release. For unmanned situations, exposure times could be longer unless technological solutions, such as remote valve closure, can be employed. The ERCB encourages technological solutions for a more robust hazard management.

5.1.6 Exposure Levels, Toxicological Model, and EPZ Endpoint.

Previously, the ERCB defined an EPZ boundary by a time-averaged concentration level. This did not account for fluctuations in H_2S concentration nor for exposure being a function of concentration and time. Although this method is appropriate for some toxic gases, current H_2S toxicology studies show that the toxicity of H_2S is a function of time and that it is more toxic at higher concentrations and short exposure times than at lower concentrations and long exposure times.

The new ERCB now defines an EPZ boundary by an endpoint. This endpoint represents a toxic-load, a combination of concentration and time that produces a specific human reaction. The endpoint is calculated using a toxicological model, which does not only consider the fluctuating H_2S concentration over time, but also takes into account the exposure time.

The ERCBH2S calculations take this concentration-time toxicity relationship into account, making the EPZ calculation safer and more representative of site-specific conditions. The endpoint does not represent an actual exposure level, but is used only to perform calculations

[5] Based on a review of the persistence of meteorological conditions in Alberta.

to determine the hazard area where pre-planned incident response is required. It is not an exposure level that will be monitored before action is taken.

The selection of the EPZ endpoint is discussed in detail in the second volume of the series on ERCBH2S (see *Volume 2: Emergency Response Planning Endpoint*).

5.1.7 Hazard Management through Mitigation

The ERCBH2S model and many of its input variables are a new standard used to determine EPZs in Alberta. Parameters used to calculate the EPZ have been carefully selected by ERCB's internal and external stakeholders and cannot be changed by the user**.** The ERCB has given cautious consideration to all assumptions made for calculations in ERCBH2S and in particular the

- high fluctuations in H_2S concentration above the mean,
- margin of uncertainty in the toxicological endpoint of an EPZ,
- modelling of dense gas releases, and
- average meteorological dispersion conditions.

In ERCBH2S, the ERCB defines defaults for several inputs that can be changed by the user to reflect site-specific mitigation actions and/or safety systems. For example, the default exposure time for all wells is 180 minutes (3 hours); however, the ERCB will consider lower exposure/release durations to a prescribed minimum, as stipulated in the third volume of this series (see *Volume 3: User Guide, Version 1.20*) if committed and demonstrable actions are taken. The ERCB encourages system optimization and defining appropriate procedural actions as good hazard management practices.

6 Summary

The ERCB's primary concern in requiring licensees to develop an ERP is public safety. The emergency response measures in this ERP aid licensees and other responders in acting promptly during a major sour gas release or prior to a release.

Both the industrial operator and local authorities have a responsibility to coordinate efforts in or beyond the EPZ to protect the public in the event of an incident. ERCBH2S calculates areas in which industry and the local authorities can coordinate roles and responsibilities for quick effective response. Coordination of responsibilities is an important aspect of a successful ERP.

The EPZ is initially determined by assessing the sour gas hazard using ERCBH2S, a complex computer software tool involving thermodynamics, fluid dynamics, dispersion modelling, and H_2S toxicology. Input parameters have been carefully selected to ensure that EPZs are representative of site-specific conditions. The EPZ calculation includes conservative assumptions. This affords a greater distance for initial response than would be needed in practice during a major sour gas release.

The ERCB encourages applicants and licensees to consider system optimization by adopting mitigation actions and safety systems to ensure that the volume of gas released in an emergency situation is as small as possible.