CONSEQUENCES OF POTENTIAL ACCIDENTS IN HEAVY WATER PLANTS

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ABSTRACT

Heavy water plants achieve the primary isotopic concentration by H_2O-H_2S chemical exchange. In these plants are stored large quantities of hydrogen sulphide (high toxic, corrosive, flammable and explosive) maintained in process at relative high temperatures and pressures. It is required an assessment of risks associated with the potential accidents. The paper presents adopted model for quantitative consequences assessment in heavy water plants. Following five basic steps are used to identify the risks involved in plants operation: hazard identification, accident sequences development, H_2S emissions calculus, dispersion analyses and consequences determination. A brief description of each step and some information from risk assessment for our heavy water pilot plant are provided. Accident magnitude, atmospheric conditions and population density in studied area were accounted for consequences calculus.

Key words: heavy water plant, isotope separation, accident assessment

At industrial scale, the chemical water-hydrogen sulphide exchange is the widest method for water isotopic concentration. Storage large quantities of hydrogen sulphide (high toxic, corrosive, flammable and explosive gas), maintained in process at relative high temperatures and pressures, require risks assessment. The main steps of the methodology are: hazards identification, accident sequences development, H_2S emissions calculus, dispersion analysis and consequences determination /1/. The H_2S quantity released in atmosphere may be biggest or lowest than H_2S hold-up of damaged equipment. This depends on connections with other equipment, security systems and failure position in the system.

Identification of initiating events with potential risks is the goal of hazard studies. Selection of initiating events, judged to be significant, are dependent of H_2S quantity released, risk criteria being H_2S toxicity. All initiating events types, resulted from the HAZOP study, were grouped together so that the event with most dangerous consequences to be studied further.

Accident sequences were developed by using event tree method. From event tree analysis results various mitigating actions for each accident sequence.

Consequences of each accident sequence were estimated on the bases of operating experience, industry data, and physical and mathematical methods.

The releasing can proceed from a fracture, hole or a catastrophic failure of the enclosure, a valve failure or a safety system failure. There are three main emission types: gas, liquid or two-phase mixture. Depending on the connections of enclosure with other equipment and the failure position in system, the H_2S quantity evacuated to atmosphere is variable. For gas discharge the process is similar to the laminar flow through a convergent nozzle. Weight flow rate of liquefied gas, released by fractures with equivalent diameter lowest than a tenth from vessel diameter or one of its dimensions, is computed using Bernoulli's equation. It is considering that the fluid remains in liquid state till pass through the fracture. If the liquid gas is discharged through a fracture with the equivalent diameter equal or bigger than a tenth from the length of pipe, a critical two-phase flow is yield. It is assumed that the two phases constitute a stable homogeneous mixture. The emission time is determined by using the mass balance equation in unsteady state, recalculating the system pressure at each iteration and assuming a constant temperature during the release. Emissions analysis are presented for primary isotopic concentrations of water in pilot plant from Rm. Valcea, those block diagram is illustrated in Figure. 1.

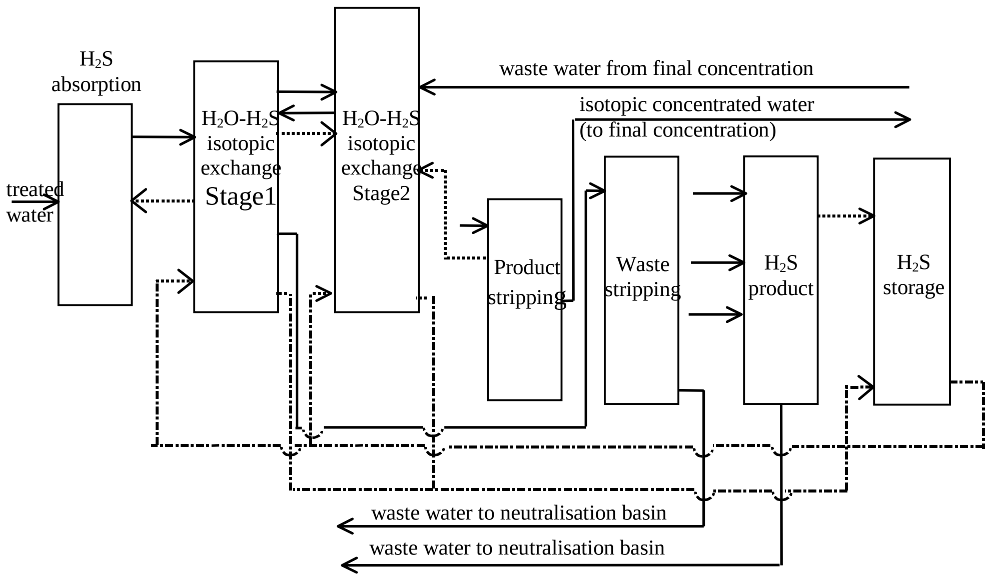

Figure 1. Pilot plant block diagram

Several potential accident types associated with H_2S releasing were studied: column, vessel, manhole catastrophic damaged, gas pipe fracture, small fracture of equipment wall. Natural phenomenon, explosions or corrosion could create these damages. The following accident states are also considered in calculus of the H_2S gas emissions for the isolated enclosures by the interblocking system: isotopic exchange column damage (catastrophic), manhole damage, pipe gas fracture and wall's small fracture in the column's gas space. For these accidents the initial jets parameter were computed. In case of "column failure" event a momentary emission occurs. At “manhole failure” event the emission time is about few seconds and to “small fracture” event the time of H_2S discharge is among 45-290 minute. Releases of saturated water with H_2S through fracture, with 0.1 m diameter, located to columns' bottom are simulated. The time of discharge is among 23 and 54 seconds, depending on water hold-up of column.

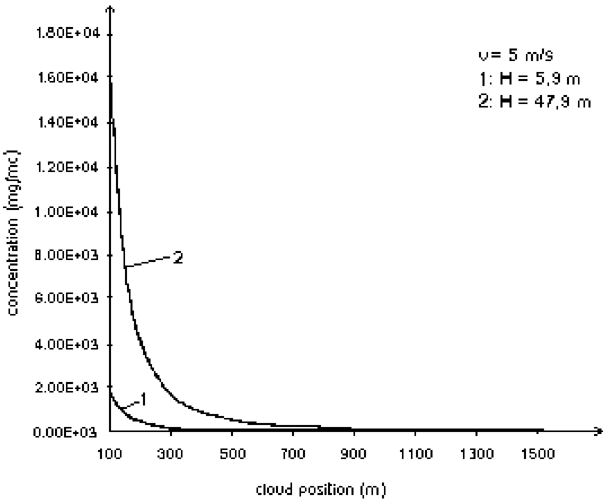

Figure 2. Mean concentration vs. cloud position to wind direction (dual temperature process plant)

Considering Gauss and “dense gas” models, a computer program was developed to predict the dispersion of H_2S /2/. For three accidents the H_2S concentration inner and outer the cloud, at different distances to the source, was computed. To illustrate the application of the “dense gas” model, two accident sequences will be presented: S1 – gas pipe fracture in cold isotopic exchange column area, isolated by interbloking system and S2 - pipe gas fracture in H_2S storage section, with locally discharge of entire H_2S quantity, due to failure of manual isolating valve. For S1 it is assumed that the parameters of overall quantity of released humid gas are identically with those of the damaged column. From calculus results an emission time about 45-50 minutes for a discharge by fracture with equivalent diameter about 0.025 m. For S2 it is assumed that H_2S is dry and is at 46.6°C and 9.9 atm. The emission time for gas discharge by a fracture with equivalent diameter about 0.025 m is 451.2 minutes. The gas cloud travels in the wind direction, both for S1 and S2. The computation results for the two accident sequences are illustrated in Figure 2, 3.
Gauss model of dispersion analysis was performed for following accident sequence “wall fracture at isotopic exchange cold column”. It was taking into account that a humid gas is released to atmosphere. Two cases are analysed: H_2S released at an effective height about to 5.9 m and H_2S released at an effective height about to 47.9 m. The assumed atmospheric conditions were: wind velocity, u = 5.5 m/s, and neutral (D) atmospheric stability class. The variation of H_2S concentration at the ground level, beyond and in the cloud axis, both to H = 5.9 m and H = 47.9 m, is presented in Fig. 4, 5.

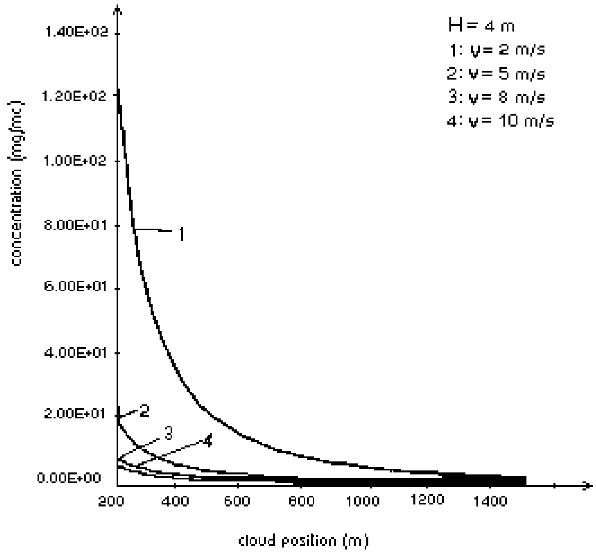

Figure 3. Cloud concentration vs. cloud position, at different wind velocities (H_2S storage)

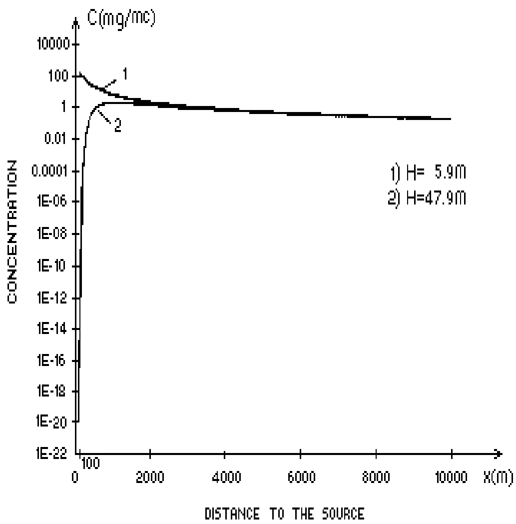

Fig. 4. H_2S concentration at ground level (y = 0, z = 0) vs. distance to the source

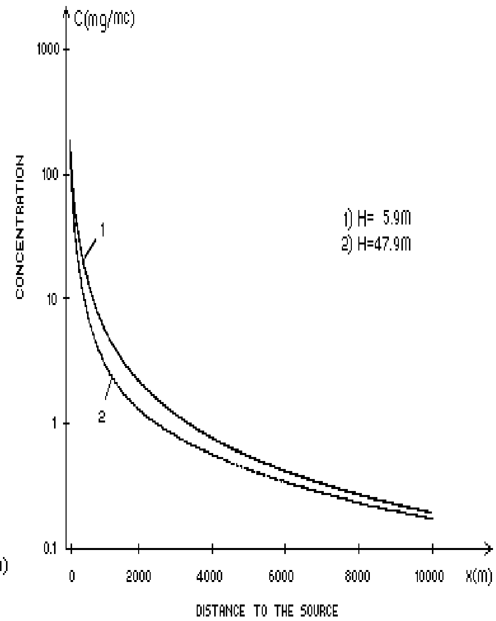

Fig. 5. H_2S concentration at the cloud central axis (y = 0, z = 0) vs. distance to the source

The consequences of exposure to H_2S are provided for accident sequences S1 and S2, described previously. The emission point level is about 5.9 m to the ground, in both cases. The concentrations are computed at initials flow rate (about 1.51 kg/s to S1 and 0.73 kg/s to S2) for a wind velocity to about 5.5 m/s and a neutral atmospheric stability class. The consequences were provided by using the "probit" relation (dose-response relation) for H_2S and probit value-death rate percentage dependence /3/ . The results are presented in Table I.

Table I.

Accident sequence	Distance in the wind direction from the release point	H_2S concentration	Probit value	Death rate percentage
	m	ppm		%
gas pipe fracture in cold isotopic exchange column area	100	761	8,43	100
	200	383	5,48	68
	300	212	2,94	2
gas pipe fracture in the H_2S storage section	100	368	12,34	100
	200	186	9,44	100
	300	103	6,70	95,5
	400	66	4,96	48,5
	500	46	3,43	5,5

The paper presents some results from consequences evaluation for potential accidents in our heavy water pilot plant. It was used the methodology presented in speciality literature, involving three steps: emission, dispersion and consequences calculus.

References:

M. Mazzini - Course on Risk Assessment in Industrial Activities, 1995

I. Ciucci - The dispersion of Neutral and Dense gases in the Atmosphere, 1995

S. B. Gibson - Risk Criteria in Hazard Analysis, Chemical Engineering Progress, February 1976