Hydrogen sulphide mapping study for existing facilities

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Abstract

This study was carried out because of concern about the hydrogen sulphide (H_2S) concentration level in one of the oil fields and its impact on the operation and maintenance teams at the sites. The H_2S level rose with the level varying across different wells but the HSE impact was not known. The objective of the study was to determine H_2S risk classifications for the off-plot and on-plot facilities based on the design for sour service specification and on physical effects modelling.

UniSIM Design R390 software was used to provide process modelling under the operating conditions and it was also deployed in the study to find out: Fluid compositions for different water cut and H_2S concentrations, the mass flow rate for the multi-phase streams and gas streams (kg/h).

The Shell FRED 6.0 model was used to find out the flow rate of the flashed flow in Kg/s. The fraction of the dispersed gas was calculated by dividing the two values of mass flow rate of the multiphase and flashed gas. The flow rate of flashed gas was calculated by multiplying the fraction of the flashed gas by the mass flow rate of the multiphase. Having the composition of the flashed gas from UniSIM model and the calculated flow rate, Shell FRED was used to calculate the H_2S dispersion contour.

The outcome of the study was a simple monograph to be used by the operation and maintenance team at the site to classify the off-plot facilities. The on-plot facilities were colour coded to determine the H_2S risk in the plant. The classifications determined the minimum requirements for personal protection.
Keywords: H_2S, hydrogen sulphide, classifications.

WIT Transactions on Information and Communication Technologies, Vol 47,
www.witpress.com, ISSN 1743-3517 (on-line)
doi:10.2495/RISK140181

1 Introduction

Petroleum Development Oman (PDO) is the leading hydrocarbon exploration and production company in the Sultanate of Oman. It produces more than 70% of the crude oil in the country and almost all of its natural gas supply.

This study was carried out due to concerns about the H_2S concentration level and its impact to the operation and maintenance team at one of PDO sites. Levels of H_2S that were detected varied from 10 ppmv to 20,000 ppmv in the gas phase. The objective of the study was to develop for operation and maintenance workers a classification for the off-plot multi-phase streams of the individual flow lines from each well, as well as the combined streams from multiple wells going to the production and gathering stations. In addition, classifications for on-plot gathering/production stations were developed. Due to limitation of paper size, a classifications of one field, is mentioned in the paper.

1.1 Facilities description

There are about 330 wells currently operating in the classified field. Of these, about 155 have been tested for H_2S content. If test results are extrapolated for the entire cluster, about 53% of wells in the field had H_2S contents of less than 50 ppm, and 32% of wells had more than 500 ppm. The rest of the wells were between 50–500 ppm.

2 Toxic impact of H2S

H_2S is an extremely dangerous substance and can cause fatalities if not managed properly. H_2S is a colourless, flammable and highly toxic gas with a strong rotten egg odour and in high concentrations it can lead to permanent health effects or even death.

Exposure can also result in irritation to the eyes and respiratory system; apnea (stop or pause in breathing), coma, convulsions; conjunctivitis, eye pain, lacrimation (discharge of tears), photophobia (abnormal visual intolerance to light), corneal vesiculation (blistering); dizziness, headache, lassitude (weakness, exhaustion), irritability, insomnia and gastrointestinal disturbance [2].

3 Methodology

3.1 Base data and H2S sample measurement

The H_2S concentration measurements from the field wells were provided by the chemistry department in Petroleum Development Oman (PDO) which is the base for the study.

Table 1 shows the methodology that was used to measure the H_2S concentration at the sites.

Table 1: H_2S field testing methodology.

Testing Phase	Reported Unit	Method
Gas Phase (above crude)	Ppm	ASTM D5705
Liquid Phase	Mg/l	Garret Gas Train (GGT)/Pecop 2012

3.2 Off plot H2S modelling

UniSIM Design R390 was the software used as a tool to simulate process modelling under the operating conditions to find out:

- Fluid compositions for different water cut and H_2S concentrations;
- Mass flow rate for the multi-phase streams and gas streams (kg/h).

There are two variances in the UniSIM model, the H_2S concentration in the vapour fraction and the water cut. From the UniSIM model, the multi-phase flow rate composition and the mass flow rate Kg/h were obtained. The UniSIM file diagram is shown in Figure 1.

Using the process condition from UniSIM, Shell FRED 6.0 software was used to find out the flow rate of the flashed gas in kg/s. The fraction of the dispersed gas was calculated by dividing the two values of mass flow rate of the multi-phase and flashed gas. The flow rate of flashed gas was calculated by multiplying the fraction of the flashed gas by the mass flow rate of the multiphase. Having the composition of the flashed gas from UniSIM model and the calculated flow rate, Shell FRED was used to calculate H_2S dispersion. Figure 2 illustrates the methodology used and then a number of concentrations of interest for H_2S were investigated, as shown in Table 2.

Table 2: H_2S concentrations of interest.

H2S concentration of interest	Reason behind the concentration
5 ppm	8-hours time time-weighted average limit
10 ppm	Short time exposure limit and the typical value at which hydrogen sulphide gas detectors are set
100 ppm	Persons who are exposed with no breathing protection have approximately 30 minutes in which to make good their escape without long-term consequences
300 ppm	Onset of significant health effects for 30 minutes

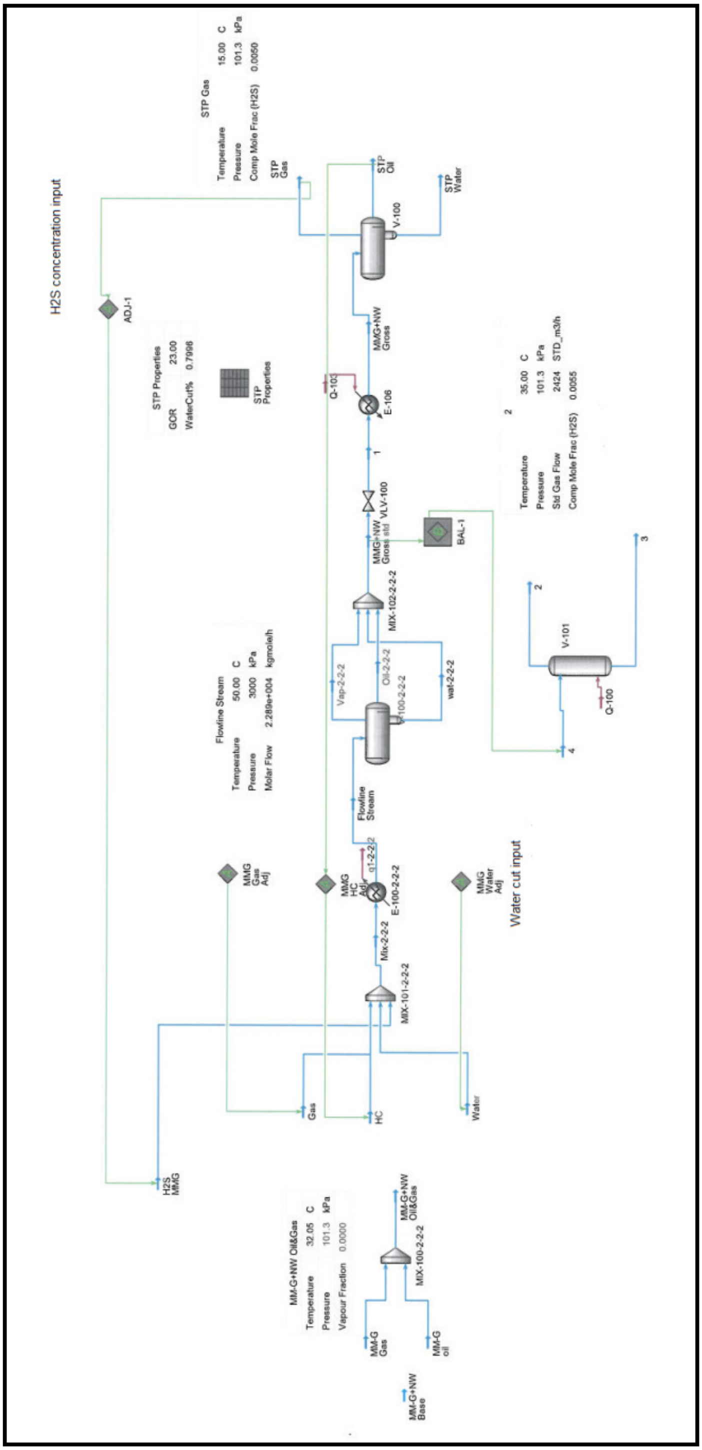

Figure 1: UniSIM model diagram.

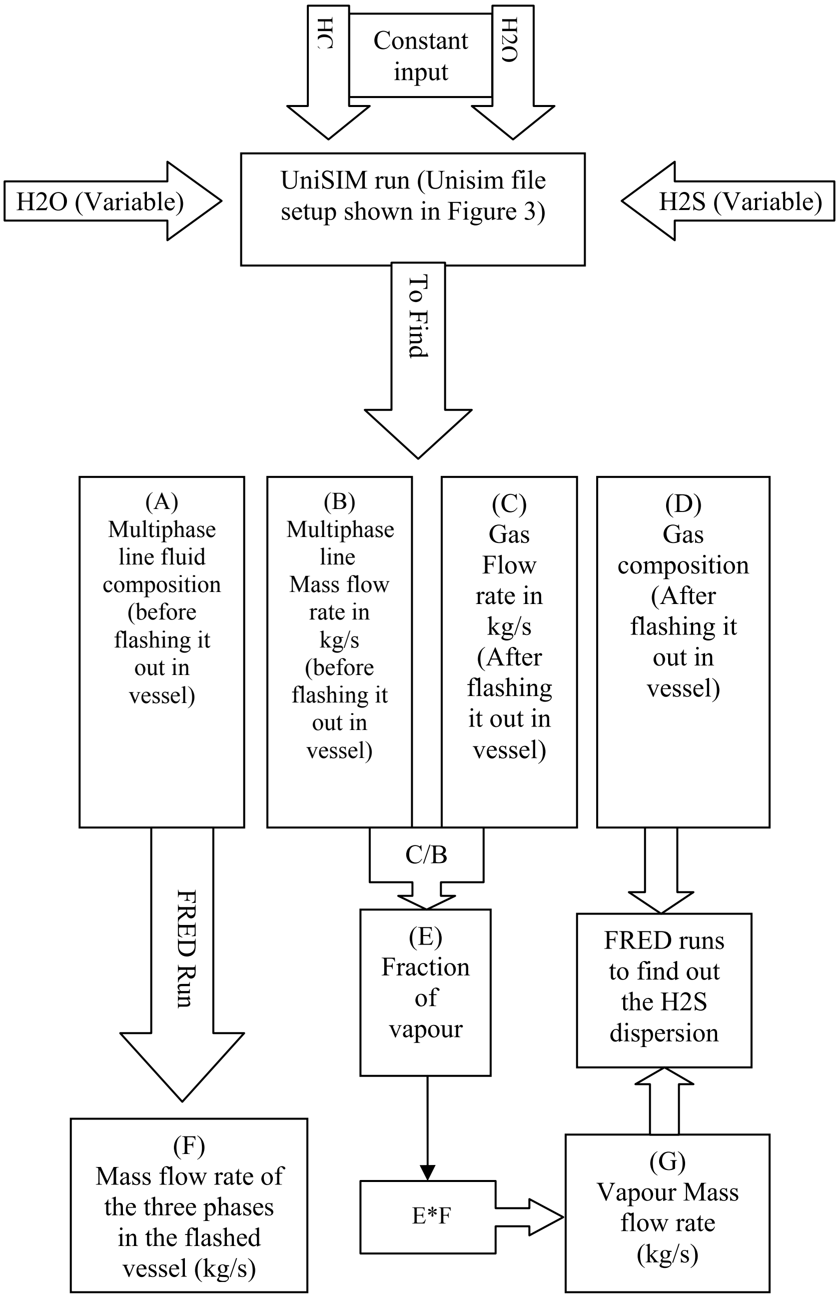

Figure 2: Dispersion modeling process summary.

3.3 On-plot H2S modelling

The location of the points to model was selected according to the H_2S content and the process conditions where it was expected the highest risk of H_2S in the processing steps would occur. The selected points can be seen in section 5.2.

For the multi-phase streams (the inlet to Production Stations & Gathering Stations), the method described in section 3.2 was used. For the gas streams, the gas compositions taken from the UniSIM model were modelled in Shell FRED to find out the H_2S dispersion contour. The assumptions are mentioned in section 4.2.

3.4 Basis for H_2S classifications

PDO specifications, design for sour service, SP-1190, version 3, define the classifications of the multi-phase process streams as stated below:

- The classification of multi-phase process streams shall be based on physical effects modelling, completed in accordance with PDO specification SP-1258. Multi-phase process streams shall be classified as very toxic, when physical effects modelling demonstrates that a medium-sized release through a 22 mm diameter hole results in greater than the onset of significant health effects level of concern for H_2S (300 ppm) in air concentration at a distance of 2 m from the point of release, assuming very stable weather conditions;
- A facility or wellhead shall be classified as low risk sour if it does not include any very toxic process streams, but does include one or more gaseous process streams, where H_2S is present at concentrations > 0.005% vol. (50 ppm);
- A facility or wellhead shall be classified as high risk sour if it includes one or more very toxic process streams.

4 Uncertainty and assumptions

4.1 Uncertainty

- The UniSim model was used to find out the composition and flow rate of the multi-phase and vapour. The method relies on the accuracy of the UniSim model;
- Assuming the fluid is homogenous, which means the fluid is well mixed and does not flow in two/three phases;
- The package used for this assessment was Shell FRED 6.0. This package is mandated as a standard screening tool for dispersion analysis and the recommended guidance is that other more detailed software should be considered if the results obtained by FRED do not enable firm conclusions to be reached. FRED allows dispersion

analysis to be carried out on a variety of releases by allowing the user to input the specific stream data. In the case of investigation of components of streams (such as the hydrogen sulphide in this case) the analysis is carried out by assuming that the dispersing plume remains largely homogenous such that a constant ratio exists at all points between the actual stream concentration and the concentration of the component of interest.

4.2 Assumptions

Shell FRED software inputs assumptions:

- Leak hole diameter: 0.022 m
- Weather temperature: 35^{o}C
- Wind speed: 1.5 m/s
- Weather condition F (Very Stable)
- Discharge coefficient (liquid): 0.6
- Discharge coefficient (gas): 0.8
- Surface roughness: 0.1
- Sampling time: 10 min average
- Stack height: 5 meter
- Homogenous flow rate of the multi-phase flow
- Release direction is assumed to be in the same direction as the wind.

5 Off-plot H2S risk classifications

The off-plot H_2S dispersion contour is summarised in Table 3. The basis for the classifications is described in section 3.4. The process conditions used for the below dispersions are:

- H2S range: 0–20000 ppm
- Water cut: 0–99
- GOR: 9 sm^3/m^3
- Pressure: 15 Bar

The classifications of the field are summarised in Figure 3:

- Those off-plot facilities (e.g. flow line, manifold and wellhead) that have an H_2S concentration of more than or equal to 5500 ppm in the gas phase, and the water cut is less than 40%, will be classified as high risk sour facility;
- The off-plot facilities (e.g. flow line, manifold and wellhead) that have an H_2S concentration of less than 5500 ppm H_2S in the gas phase will be classified as low risk sour facilities, regardless of the water cut;
- The above classifications are valid for a GOR less than or equal to 100 sm^3/m^3 (see section 5.1).

Table 3: H_2S dispersion contour for the field.

H_2S ppm	Water concen-tration %	H_2S fraction in Flashed gas	Vapour Flow rate kg/s	Pressure (bar)	10 ppm contour (m)	100 ppm contour (m)	300 ppm contour (m)	Classification (H_2S risk)
5000	5	0.005	0.24	32	41	5	1	Low
5500	5	0.0055	0.2	32	42	5	2	High
6000	5	0.006	0.2	32	45	5	2	High
5500	35	0.0055	0.18	32	44	5	2	High
5500	40	0.0055	0.17	32	34	5	1	Low
6000	40	0.006	0.17	32	36	5	2	High
7000	40	0.007	0.17	32	41	6	2	High
20000	40	0.02	0.17	32	153	14	5	High
5500	45	0.0055	0.09	32	29	4	1	Low
6000	45	0.006	0.11	32	34	5	2	High
6000	80	0.006	0.05	32	25	5	2	High
5500	80	0.0055	0.05	32	22	4	1	Low
7000	80	0.007	0.05	32	25	5	2	High
7000	90	0.007	0.03	32	31	5	2	High
6000	90	0.006	0.03	32	27	5	2	High
6000	95	0.006	0.01	32	22	4	2	High
6000	99	0.006	0.002	32	11	3	2	High

H_2S concentration in ppm

Water cut	< 5500	≥ 5500
≥ 0	Low Risk Sour	High Risk Sour
≥ 40	Low Risk Sour	Low Risk Sour

Figure 3: The field off-plot classifications.

5.1 Gas oil ratio sensitivity

To see the effect of the Gas Oil Ratio (GOR) in H_2S dispersion, a sensitivity study was done and the result is shown in Figure 4 and Figure 5.

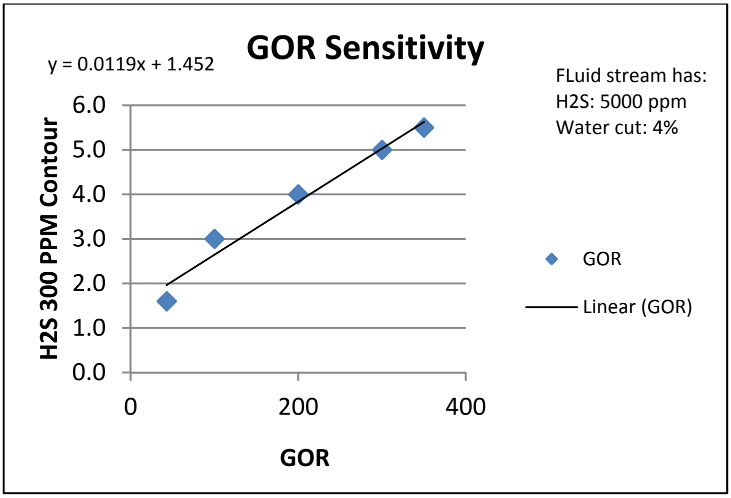

Figure 4: GOR sensitivity for a water cut of 4%.

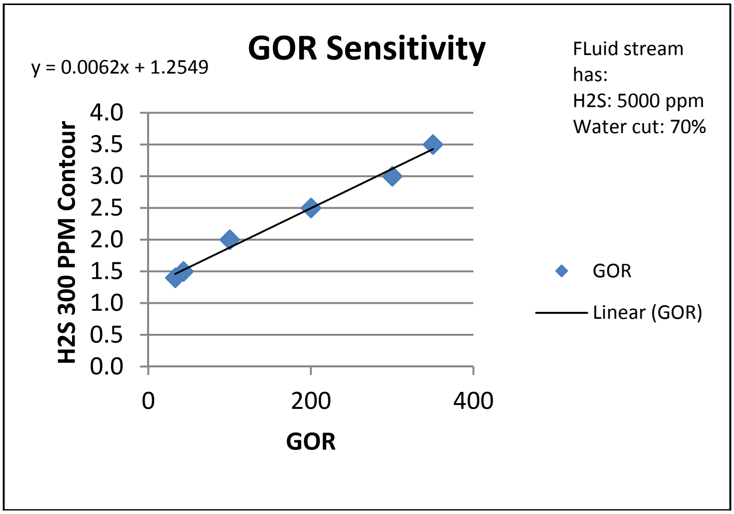

Figure 5: GOR sensitivity for water cut 70%.

Two charts were plotted to see the relationship between GOR and H_2S dispersion as follows:

- Figure 4 represents the GOR sensitivity at a water cut of 4%, an H_2S concentration of 5000 ppm and an H_2S dispersion contour result in more than two metres at a GOR of 50;
  Figure 5 represents the GOR sensitivity at a water cut of 70%, an H_2S concentration of 5000 ppm and the H_2S dispersion contour result in more than two metres at a GOR of 100.

We can conclude from this sensitivity study that:

- For the water cut of $\geq$ 70%, the result of the study is not applicable if the fluid stream has GOR more than 100;
- For the water cut of 0–70%, the result of the study is not applicable if the fluid stream has a GOR of more than 50.

5.2 On plot H2S risk classifications

The classifications of the Production Station are summarized in Figure 6 below:

- One of the inlet is classified as high risk sour facility;
- The line transfer gas out from T-7105 to AP flare is classified as High Risk Sour facility;
- The rest of the station other than what stated above, is classified as low risk sour facility.

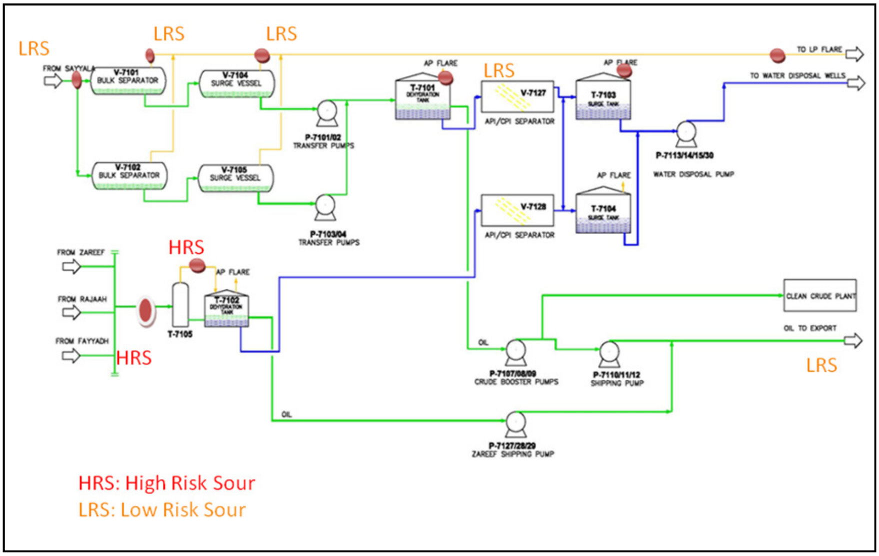

Figure 6: H2S risk classifications for the field Production Station.

5.3 Conclusion

H_2S Risk classifications for the off-plot can be determined by using a simple monograph after knowing the water content and the H_2S concentration in the off-plot stream (Figure 3). The classifications for the on-plot have been determined by marking the plot plan. The classifications specify the minimum requirement for equipment isolations and personnel entry into sour areas as per the company procedure for high risk or low risk sour facilities.

References

[1] Design for Sour Service Specification, Petroleum Development Oman L.L.C, Version 3, 2011.
[2] NIOSH (2005), NIOSH Pocket Guide to Chemical Hazards, DHHS (NIOSH) Publication No. 2005-149, U.S. Government Printing Office.