

Learning from Experience: Using an Unsupervised Learning Real-Time Mud Contamination Monitoring Simulator in Umm Er Radhuma and Tayarat Hydrogen Sulfide Formations

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Abstract

Drilling boreholes through Umm Er Radhuma and Tayarat Formations southern Iraq has been a challenge due to Hydrogen Sulfide (H_2S). In this era of increased concern for personal safety and environmental factors, the industry needs additional tools and methods for handling this deadly and corrosive gas. In this paper, formations field data are used to validate the simulator which monitors H_2S and automatically helps the engineer adjust mud pH to neutralize free H_2S .

This paper describes a real-time monitoring mud contamination simulator which consists of a PC interface kit and MATLAB graphic user interface. The kit is provided with H_2S indicator. The presented approach is based on the Umm Er Radhuma, and Tayarat Formations mud-logger field records in a way mimic the real-time processing sensors data.

Based on real field data for five wells with historical hydrogen sulfide influx problem, two criteria are used to set the simulator alert levels: the Health Safety Environment (HSE) policy and the results of unsupervised learning for category clustering using Fuzzy Adaptive Resonance Theory (ART). This simulator invests different alert levels to enable proactive decision support.

The system demonstrates a reliable response to H_2S intrusion while drilling. It significantly improves a drilling operator's ability to monitor the influx of H_2S and to quickly and safely initiate appropriate treatment.

Introduction

Safely drilling boreholes through hydrogen sulfide bearing formations poses a critical challenge for the oil and gas industry [1, 2]. Furthermore, in addition to the acute rig-site safety issues with H_2S , this gas also has a long-term detrimental effect as it is a major environmental pollutant from oil and gas production and processing [3]. Thus, a precise identification of the

presence of H_2S levels in a drilling fluid stream will improve the process quality in terms of personnel safety and lessened environmental impacts [4]. Therefore, innovative methodologies and automated tools are desired [5]. This integrated approach uses three systems: historical real-time drilling data with hydrogen sulfide influx to create an H_2S problematic event, Fuzzy ART which is attractive because of its speed, scalability, incremental learning, and amenability to parallel implementation [6], and a real-time monitoring simulator mimicking H_2S intrusion.

The presented approach required precise interpretation for the H_2S chemical-physical phenomena. Recalling the historical oilfield data (for the hydrogen sulfide formation) adopted from MATLAB helped to create a new retrievable H_2S profile. To create an event triggering system, Fuzzy ART clustering allowed vector quantization of different alert levels for each variable. Furthermore, the H_2S monitoring simulator is used to mimic the real field data, which is part of the project of the lab-scale real-time mud pH and electric conductivity monitoring system while drilling in hydrogen sulfide formations [7]. When an H_2S influx occurs, the diagnosis of it is an effective strategy to avoid the harmful effects on health and the environment [8]. Hydrogen sulfide contamination is expensive, dangerously toxic to humans and animals, and extremely corrosive to most metals as it can cause cracking of drill pipe and tubular goods, and destruction of testing tools and wire lines [9]. Diagnosis is especially important in wells with a hydrogen sulfide bearing zone, in which the diagnosis is not obvious and problems will therefore take time to resolve. In this paper, the presented integrated approach can be evaluated and transformed into useful symptoms for an automatic diagnosis.

Umm Er Radhuma and Tayarat Formations Overview

The Umm Er Radhuma and Tayarat Formations are more homogenous formation in a limited aquifer of southern Iraq. They represent pale grey dolomitic marl, anhydrite and argillaceous dolomite with anhydrite nodules, argillaceous dolomite, dolomitic limestone, coarsely crystalline dolomite, and rare phosphatic grains. The thickness of both formations is around 500 m, ranging from the top 1000 m true vertical depth to the bottom of the formation at 1500 m [10, 11]. Sulphurous water may flow into the wellbore while drilling Umm Er Radhuma and Tayarat Formations.

Methodology

In this study, an integrated approach that consists of three systems is presented to create an H₂S real-time monitoring system as shown in Figure 1.

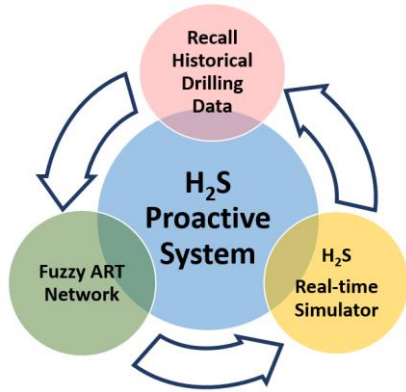


Figure 1. H₂S Proactive System.

Recall Historical Drilling Data

As it is an ever-present factor during drilling it deserves and requires special concern. Especially today's increased concern for personal safety and environmental factors, the industry needs additional tools and methods for handling this deadly and corrosive gas. Issues such as H₂S intrusion create a significant source of human, environmental, and drilling related problems associated "red money" [12]. As a consequence, a key element in the safe and successful well construction process is the detailed monitoring of H₂S [13].

The real-time monitoring concept is based on recognizing variations in expected behavior of rig sensor responses and keep tracking their rate of change (deviation from the accepted level) using hybrid algorithms [14]. This approach links analytic, statistic and knowledge based concepts, together with the rig H₂S sensors on rig floor, shale shaker, and the H₂S unit, mud electric conductivity sensor, and the pH manual readings, as shown in Figure 2. With a real data for wells with H₂S intrusion at a high degree of operational detail, generated using Fuzzy ART automated operations recognition, as it will be discussed later in this work. It is possible to identify the number of clusters which represent different H₂S alert levels.

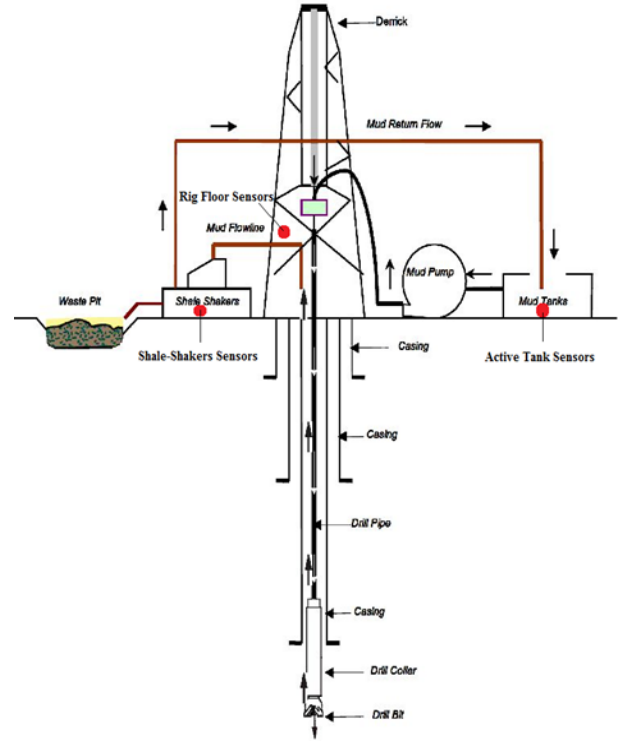


Figure 2. System overview (Adapted from [15]).

Fuzzy Adaptive Resonance Theory Network

Adaptive Resonance Theory (ART) is an unsupervised learning method that eliminates the "stability-plasticity dilemma". ART is capable of learning arbitrary data in both a stable and self-organizing manner [16]. ART1 [17] deals with binary data, whereas Fuzzy ART deals with arbitrary data. Henceforth, we will be referring to Fuzzy ART [16]. Before the training, the data pass through a preprocessing step during which they are scaled to fit into the range of [0,1] and complement-coded, as shown in Figure 3 [18]. The weight vectors w_j are initialized to be all 1. Let x be an input sample. When choosing a category, the competition in layer F2 is calculated, defined as:

$$T_j = \frac{|x \wedge y|}{\alpha + |w_j|} \quad (1)$$

where \wedge is the fuzzy AND operator defined by:

$$(x \wedge y)_i = \min(x_i, y_i) \quad (2)$$

and $\alpha > 0$ is the choice parameter. From the winner-take-all competition,

$$T_j = \max\{T_j | \forall j\} \quad (3)$$

The winning neuron J becomes activated and is fed back to layer F1 for the vigilance test. If

$$\rho \leq \frac{|x \wedge w_j|}{|x|}, \quad 0 \leq \rho \leq 1 \text{ is the vigilance parameter} \quad (4)$$

resonance occurs. Then, in layer F2, the input x is categorized to J and the network is trained by the following learning rule,

$$w_j(new) = \beta (x \wedge w_j(old)) + (1 - \beta)w_j(old), \quad (5)$$

where β ($0 < \beta \leq 1$) is the learning rate. If neuron J does not meet the match criterion, it will be reset and excluded while the search for another matching template continues. If no neuron matches, a new, unallocated neuron will be created as a new category for the input pattern.

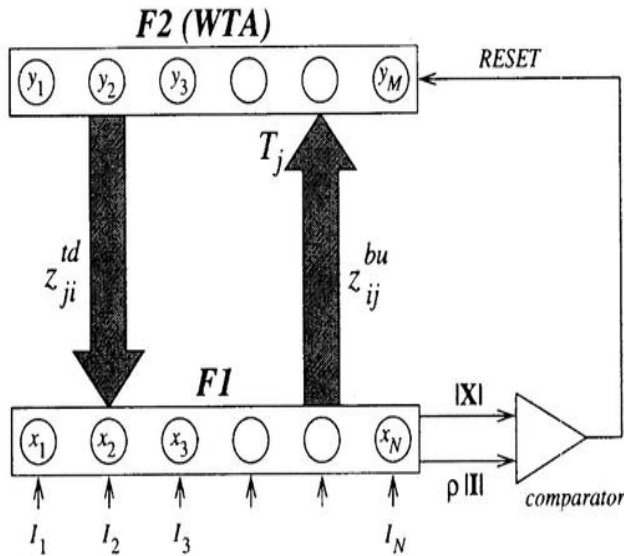


Figure 3. Topological structure of the Fuzzy-ART architecture.

Real-Time H₂S Simulator

From concentrations of 1 ppm, H₂S is detectable by the human nose (rotten eggs odor). 5 ppm is considered as the maximum continuous working exposure limit (8 hours a day or 40 hours per week). 10 ppm is considered as the short time exposure limit (maximum of 4 exposures a day of less than 15 minutes each) and the concentration above which respiratory protection is required [7, 8]. Therefore, by using HSE policy, the drilling service companies set two levels of alerts, 5 ppm for Light alarm, and 10 ppm for Sound alert when the drilling crew should be evacuated.

In this work, the real-time mud contamination monitoring system shown in Figure 4 consists of a PC interface kit with a MATLAB graphic user interface. This system detects that sudden change in H₂S and triggers an alarm. To do so, the kit is provided with three LEDs (green, yellow, and red) represent the different alert levels.

Results and Discussion

The H₂S concentration measurements for five drilled wells in Umm Er Radhuma and Tyarat in the southern of Iraq are used in this study. The setup of the alert levels for the developed H₂S simulator are adopted from both drilling oprator HSE policy and the Fuzzy ART network ranges.

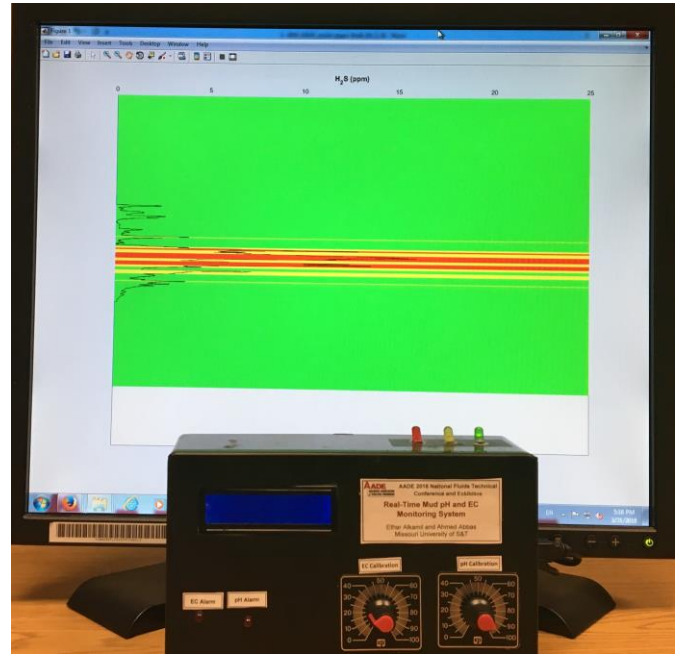


Figure 4. H₂S Monitoring Simulator.

For the dilling service companies, the simulator three LEDs (green, yellow, and red) are set based on the H₂S concentrations (0, 5, and 10) ppm respectively, as shown in Table 1. Using Fuzzy ART, the simulator’s three LEDs (green, yellow, and red) are set based on the accumulated knowledge from the network training of H₂S concentration for the five wells real data used in this study, as shown in Table 1. The smallest value between the weights of each Fuzzy ART category is used to define the alert levels.

Table 1. Simulator Alert Levels

Data Base		Green Light	Yellow Light	Red Light
Drilling Operator		0	5	10
Fuzzy ART Network	Well A	0	2.68	7.83
	Wells A,B	0	2.79	8.66
	Wells A,B,C	0	2.79	8.46
	Wells A,B,C,D	0	2.75	8.46
	Wells A,B,C,D, E	0	2.74	8.46

As shown in Table 1, the randomized well data is processed sequentially, i.e., well-by-well. Furthermore, for each well, it is first ordered using Visual Assessment of cluster Tendency [19]

before being presented to the network, since this pre-processing was shown to improve Fuzzy ART performance [20]. The vigilance parameter is then optimized to find the optimum for three clusters (by observing the number of clusters versus vigilance values) which are represented by the simulator LEDs (green, yellow, and red), as shown in Figure 5. The same procedure is used for all processed wells in this work, as shown in Table 2.

One feature of the presented real-time H₂S monitoring simulator in Figure 6-A is that it displays different colors of alerts (depends on the HSE policy), as shown in Table 1. Before the H₂S influx, the green LED is ON. After hydrogen sulfide intrusion with a concentration up to 5 ppm, thus producing deviation from the acceptable measurement, the yellow LED alarm light is triggered. It remains ON until a significant concentrations (more than 5 ppm) the red LED alarm light is triggered. However, Figure 6-B demonstrates the different colors of alerts based on the results of using Fuzzy ART to train the network based on the five wells used in this study. As long as the H₂S event data are fed to the Fuzzy ART network, the alert level will be updated adaptively, as shown in Table 1.

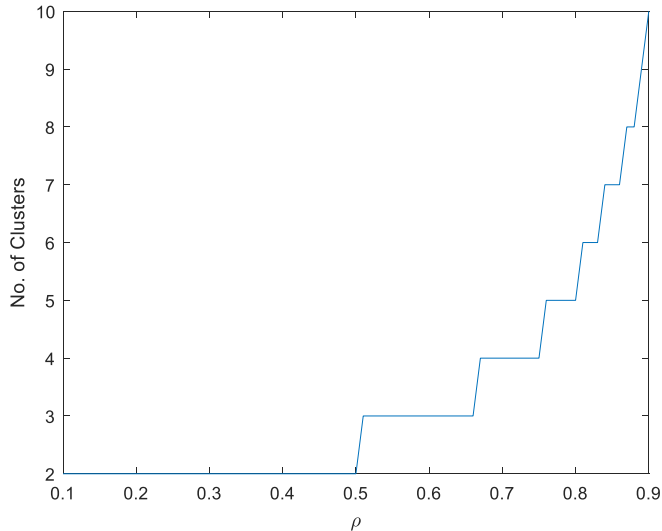
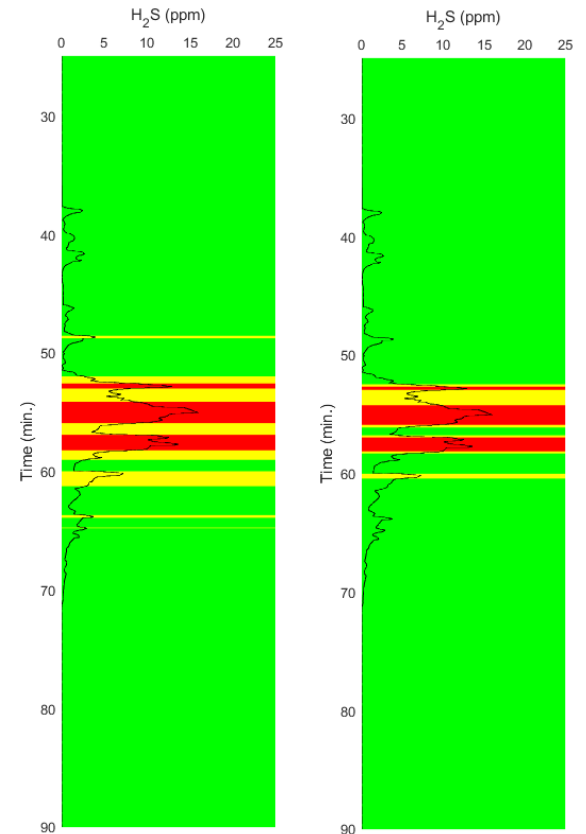


Figure 5. Well B Fuzzy ART Output.

Table 2. Description of the used data.

Data Set	ρ	Number of Data Points
Well A	0.8	310
Well B	0.6	890
Well C	0.5	625
Well D	0.5	711
Well E	0.5	576



(A)

(B)

Figure 6. H₂S Log Interpretation Alert Levels Setting, (A) Field Operators, (B) Trained Simulator using Fuzzy ART.

Conclusions

The presence of H₂S in hydrogen sulfide bearing formations introduces significant risks due to its extreme toxicity and its corrosive effects on drilling rig equipment. To ensure protection of drilling operation personnel, a real-time H₂S monitoring system is developed including three different levels of alerts based on Fuzzy ART for five wells in Umm Er Radhuma and Tayarat Formations southern Iraq. The presented H₂S simulator alert levels are dedicated colored LED's and buzzer to be more visible and hearable to the drill crew who aren't looking at the screen.

It is important to mention that the HSE policy ranges for H₂S alert level are the same in most oilfields with different H₂S hazard level of the hydrogen sulfide formations. Meanwhile, the Fuzzy Adaptive Resonance Theory (ART) approach is used to set the alert levels based on the network training. Therefore, each oilfield can have a different alert level set based on the historical drilling data with H₂S intrusion problem.

Finally, this project demonstrates a robust adaptive method for reducing risks to drilling personnel in oilfields with H₂S dangers.

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