PETROLEUMSTILSYNET

Investigation report

Report	
Report title Personal injuries from H_2S exposure at Sture on 12 October 2016	Activity number 001903018

Security grading		
☑ Public	☐ Restricted	☐ Strictly confidential
☐ Not publicly available	☐ Confidential	

Summary

A work accident at the Sture terminal near Bergen in Hordaland county was reported to the control room at 16.05 on Wednesday 12 October 2016. The incident occurred in connection with work on an H_2S reactor in the oily water treatment plant, which had suffered operating problems. Sludge had accumulated and was to be removed by blowing in compressed air at its base. Compressed air had been admitted, and the operators ascended to the top of the 14-metre-high reactor to check that everything was in order. An apprentice and two work-experience pupils accompanied them up, so that a total of five people were on top of the reactor. H_2S must have escaped through the top-mounted ventilation valve, and the people who came up were exposed in various degrees to the toxic gas. Four eventually managed to get down by themselves, while the fifth was so affected by the gas that he needed help. Emergency measures were implemented and those who participated in the response – risking their own life and health at times – helped to reduce the consequences of the incident. Øygarden fire brigade was mobilised to the site and managed, with help from Sture personnel, to lower the injured person. One of the injured was flown to Haukeland University Hospital by helicopter. The other four who had been exposed were transported to the hospital by ambulance.

The investigation has identified a number of regulatory breaches, including inadequate management of activities, resources, processes and expertise. It has also found deficiencies in the shift roster and shift changeover, as well as inadequacies in the leadership and execution of emergency response assignments.

Involved	
Main group T-Land-based plants	Approved by/date Kjell Arild Anfinsen/10 February 2017
Members of the investigation team Sissel Bukkholm, Espen Landro, Bryn Aril Kalberg	Investigation leader Arne J Thorsen

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1 Summary

A work accident at the Sture terminal near Bergen in Hordaland county was reported to the control room at 16.05 on Wednesday 12 October 2016. The incident occurred in connection with work on an H_2S reactor in the oily water treatment plant, which had suffered operating problems. Sludge had accumulated and was to be removed by blowing in compressed air at its base. Compressed air had been admitted, and the operators ascended the 14-metre-high reactor to check that everything was in order. An apprentice and two work-experience pupils accompanied them up. The last man collapsed when he reached the top. This incident was reported to the control room. First aid was initiated. The apprentice and one of the work-experience pupils descended. One operator felt ill and began to descend. Some distance down the steps, he passed out and fell onto the landing. The other operator passed out and lay on the top. After a time, he recovered consciousness and continued to give first aid to the pupil. A smoke-diving team and the on-scene commander arrived. The smoke divers ascended. A crane truck was obtained to lower the injured person. Øygarden fire brigade arrived and managed, together with personnel from Sture, to lower the injured person to the ground. One of the injured was flown to Haukeland University Hospital by helicopter. The other four who had been exposed were transported to the hospital by ambulance.

The following non-conformities were identified:

- inadequate management of activities, resources, processes and expertise
- inadequate staffing and expertise when the shift started
- inadequate transfer of information at the shift changeover
- inadequate leadership of the emergency response
- inadequate training in the use of emergency equipment
- absence of a plan for rescuing personnel from a height
- radio communication did not work

and the following improvement point:

- lack of an unambiguous name for the plant.

2 Introduction

Background

The Petroleum Safety Authority Norway (PSA) was notified at 16.45 on Wednesday 12 October 2016 of a work accident at the Sture terminal in Hordaland. It was reported that five people had been sent to Haukeland University Hospital after exposure to hydrogen sulphide (H_2S) gas. This exposure occurred during work on an oily water treatment facility in the terminal area, and the five were on top of an H_2S reactor when the incident occurred. In addition, Øygarden fire brigade reported than one of its personnel who had attended the scene was sent to Haukeland for a check-up after having felt unwell.

The police conducted a site investigation on the same day the incident occurred.

Statoil conducted its own investigation of the incident.

The PSA decided on 13 October 2016 to investigate the incident.

Investigation team

The PSA's investigation team comprised the following:

Arne J Thorsen	process integrity, investigation leader
Espen Landro	process integrity
Sissel Bukkholm	working environment
Bryn Aril Kalberg	logistics and emergency preparedness

Approach

The team travelled to Sture on 13 October 2016 for initial information-gathering and an inspection of the incident site. A brief meeting was also held that day with the police at Straume.

Conversations with personnel concerned and specialists were conducted in three meetings at Sture and one at Forus plus a video conference. Documentation was also reviewed.

Mandate for the investigation

1. Clarify the incident's scope and course of events
    a. clarify and assess safety and emergency preparedness aspects
    b. identify assessments made ahead of the incident.
2. Describe the actual and potential consequences.
3. Assess direct and underlying causes, with the emphasis on human, technological, operational and organisational aspects
    a. observed nonconformities from requirements, methods and procedures
    b. improvement points.
4. Discuss and describe possible uncertainties/unclear aspects.
5. Identify possible breaches of the regulations, recommend further follow-up and propose the use of instruments.
6. Assess the player's own post-incident investigation.
7. Prepare a report and a covering letter in accordance with the template.

3 The incident

3.1 Brief description of the H_2S reactor

The treatment plant is intended to clean oily water from the terminal before it is discharged to the sea. Accumulated in a rock cavern before being pumped to the plant, this consists primarily of produced water from the field and surface water from the plant site on land.

H_2S gas is formed in the cavern by sulphate-reducing bacteria in the oil. This process occurs when oily water lies immobile in the cavern for a long period without the presence of air.

Water in the cavern is pumped to the reactor for removal of H_2S gas before continuing through the treatment plant.

The H_2S reactor is a 14-metre-high concrete cylinder with a diameter of five metres. Water is pumped in over the top and conducted to the bottom of the reactor, which is filled with packing material in the form of pots to create the largest possible contact surface between water and bacteria. The water rises through the reactor while bacteria convert the H_2S to sulphate. After treatment, the water overflows into the collection chamber at the top of the reactor before flowing on to the next stage in the treatment plant.

A recirculation pump takes water from the collection chamber and feeds it back to the reactor in order to ensure adequate water circulation.

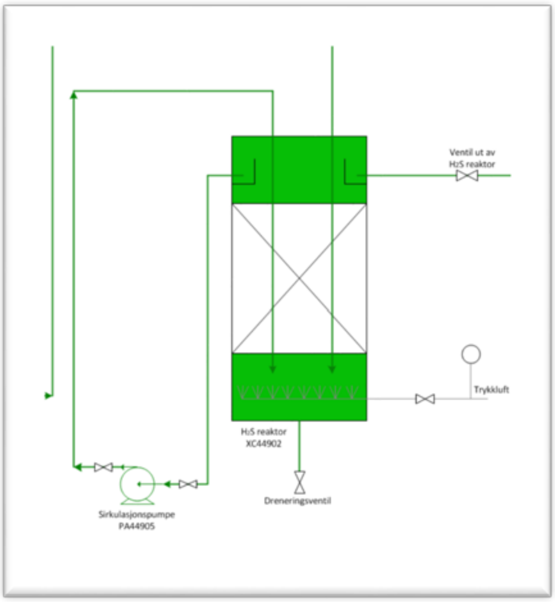

Fig 1. Diagram (source: Statoil)

Fig 2. H_2S reactor (source: police)

A compressed air supply is connected to the bottom of the reactor in order to “blow out” the latter when the sludge build-up has become too large. To do this, compressed air is admitted to the reactor, bubbles up through the water and dislodges sludge which overflows into the collection chamber and passes on into the treatment plant. This is the job which was to be done during the afternoon shift of 12 October 2016.

The H_2S reactor and treatment plant are not in continuous use. They are activated when the water level in the cavern is high enough and shut down when it is sufficiently low again.

It was decided in 2011 to demolish the original reactor, built in 1994. Ready in 2012, the new and modified unit operates on the same principles as its predecessor. Changes were made to the inlet arrangement at the base, and the reactor was lined with an artificial-fibre material.

3.2 Course of events

Monday 10 October – morning shift
A laboratory assistant who was on an inspection tour of the plant noticed that water was flowing from the top of the H_2S reactor and reported this to the control room. The reactor was shut down and two operators ascended it to check whether the system held a lot of sludge. One operator wore a respirator, the other did not. The plant was restarted during Monday.

Wednesday 12 October – morning shift
The reactor was shut down early on Wednesday morning. Two operators on the morning shift climbed the tank to check that the grating on top was in place. Pots had earlier been observed at the treatment plant intake. The operators had personal protective equipment (PPE) with them, such as filter mask, nitrile gloves and chemical suits. After obtaining gas detector readings above the limit value for H_2S, which is 10 ppm, they descended again and suited up with breathing air before inspecting the reactor top. A gas detector placed by the inspection hatch gave a maximum reading – in other words, over 100 ppm H_2S – and a personal gas

meter showed 27 ppm at chest height. Results of the inspection were communicated internally in the shift to other operators and the shift supervisor. However, no entry was made in the shift log. Nor were the H_2S levels communicated to the arriving shift at changeover.

Wednesday 12 October – afternoon shift
It was almost a dead calm. The shift began with overlap/takeover from the previous shift at 13.45. The shift is meant to comprise six operators and a supervisor. The regular shift supervisor was off, and had been replaced on a temporary basis by a coordinator from another shift. At this time, the acting supervisor was also on call for production issues. Pursuant to Statoil's governing documents, one person is not supposed to do both jobs simultaneously. It was therefore agreed that the coordinator from the morning shift would continue to serve as shift supervisor until the coordinator meeting was over. Another coordinator from the meeting would then take over the duty role while the rostered shift supervisor took on that job for the rest of the shift. These changes of roles were not clearly communicated to the others on the shift. Furthermore, two operators were absent. There was an apprentice on the shift as well as two pupils on work experience. When the shift began, it comprised one acting supervisor, one coordinator, two control room operators, operator1, operator2, an apprentice and two work-experience pupils. Operator2 had long experience from Kollsnes, but was on his third day at Sture and therefore had little experience with this plant.

A coordinator meeting is held roughly every fifth week, normally in the service building. Such a meeting took place on Wednesday afternoon, but it was moved to the emergency response room in the control-room building because of low staffing on the shift.

When the shift began, the day's jobs were agreed between the coordinator and the rest of the team. No vessels were berthed. and not much was to be done out in the plant. Blowing out the H_2S reactor with compressed air was one of these assignments. Operator1 had not done this job before and was briefed by the coordinator on how it should be carried out. After dinner, the operator took the apprentice and the two work-experience pupils with him to do the job. Operator2 arrived immediately afterwards. Operator1 first opened the ball valve to the air, and operator2 opened the control valve. The two operators then ascended the reactor to check that the grating was in place. The apprentice and the two work-experience pupils were told to wait below. This was not understood, and the three followed the operators onto the reactor. The operators noticed a strong smell of H_2S when they reached the reactor top. The second work-experience pupil lost consciousness a few seconds after arriving as the last man on top. Operator1 reported to the control room by walkie-talkie at around 16.05.

3.3 Responding to the incident

It is difficult to establish an exact timeline for the incident. The various responses were initiated without the exact time being noted. The PSA team has accordingly opted to describe the response with the provision of only a few timings. It does not feel that this is of crucial significance for understanding the incident.

The control room operator immediately informed the coordinator meeting of the incident. The emergency services (medical communication centre, police and fire brigade) were notified. At the same time, the control room operators did not think it necessary to sound the plant (evacuation) alarm or shut down production.

The shift coordinator, who was attending the coordinator meeting, ran immediately to the fire station in his role as on-scene commander.

The acting shift supervisor took on the role of commander for the second-line emergency response and performed it until the arrival of the duty commander for the second line.

At the same time, two of the other coordinators went to the fire station and suited up to serve in the response team (smoke divers). They fetched breathing air equipment from store. Smoke diver1 took an additional breathing machine/hose with him because he knew from experience that this could be required. The on-scene commander took with him a first-aid bag which included an oxygen cylinder. The coordinator car and another vehicle failed to start. The on-scene commander therefore chose the "shift supervisor" car, which contained a stretcher. The fire engine, with extra breathing air equipment, remained in the fire station.

The on-scene commander drove with the two smoke divers to the H_2S reactor.

The remaining coordinators assembled in the break room/TV lounge by the control room to await further instructions.

At the H_2S reactor, the incident had developed. Work-experience pupil1 and the apprentice had descended quickly. Operator2 pulled work-experience pupil2 away from the vent channel and over the edge. Operator2 had a walkie-talkie, but it was not working. He called down to the apprentice to shut off the compressed air.

Operator1 felt ill and began to descend. He passed out on the steps and fell to the landing. He eventually descended to the ground.

Operator2 also felt ill and believed he must have lost consciousness for a few minutes. He came to lying across work-experience pupil2. After failing to establish contact with the latter, operator2 began performing artificial respiration.

The apprentice had shut off blowing out with compressed air.

The smoke-diving team had reached the H_2S reactor and prepared to ascend and help the two on top. Smoke diver1 discovered that the breathing machine/hose did not match, and used replacements he had taken from store. The two smoke divers took the first-aid bag with them and ascended the H_2S reactor.

The on-scene commander sent the apprentice back to the fire station to fetch a stretcher which was more suitable for bringing injured people down from the H_2S reactor.

When the smoke divers reached the top of the H_2S reactor, the position was that operator2 was trying to keep the head of work-experience pupil2, who was lying prone, over the edge while simultaneously trying to keep his own head there.

The smoke divers sent operator2 down and took over responsibility for work-experience pupil2. They gave him oxygen and he came to, panicked and had to be restrained.

After a relatively short time, smoke diver2 was alerted that his air supply was running low and he descended. He was sent back to the fire station to fetch the fire engine which had additional air cylinders. At the same time, the control room was informed by walkie-talkie that more response personnel were needed.

Smoke diver1 was on top with work-experience pupil2. After a time, his air supply began to run low. He found a rope on top of the reactor and tied up work-experience pupil2 so that he could not fall off the edge, ran out of air and descended. He reported that somebody had to ascend and that a crane was needed to lower the injured person.

Operator2 took an oxygen cylinder and climbed up to work-experience pupil2.

Two new coordinators were ready and suited up as smoke divers, and seated themselves in the fire engine with smoke diver2. Smoke diver3 had a compressed air cylinder equipped with an additional breathing mask (buddy mask).

Smoke diver1 took a new air cylinder, but had problems putting it on. The carrying straps for the cylinder failed to work as intended.

The Bergen fire brigade confirmed at 16.14 that a lift was on its way, due to arrive at 17.15.

Smoke diver4 was asked by the on-scene commander to look after the apprentice and work-experience pupil1. These three drove back to the control room/TV lounge.

The on-scene commander had gone with operator1 to fetch a crane truck.

Smoke diver3 checked his equipment and ascended. Work-experience pupil2 was conscious, panicky, waved his arms around and pulled the mask from operator2. The latter received smoke diver3's buddy mask.

The on-scene commander got a crane truck in position and tried to operate the crane. He was neither licensed for nor experienced with driving a crane. He gave up the attempt and left it to operator1, who was both licensed for and experienced with crane operation but who had been unconscious not long before and fallen down the stairs. The on-scene commander stood behind operator1 and watched as he operated the crane. Operator1 succeeded in lifting a stretcher so that it was hanging at the top of the reactor.

The Øygarden fire brigade reached the H_2S reactor at 16.25.

Smoke diver1 tried to ascend even though the straps in the compressed air cylinder were not functioning properly, but was stopped by the fire brigade.

Smoke diver3 succeeded in getting the stretcher over the railing around the top of the H_2S reactor. The Øygarden fire brigade smoke divers reached the reactor top. Operator2 was to descend, but had problems removing the buddy mask. He tore this off and descended. The buddy mask was left dangling from smoke diver3 and leaked air.

The stretcher which was lifted up lacked straps for fastening patients. The Øygarden fire brigade smoke divers worked with smoke diver3 to position and secure work-experience pupil2 on the stretcher.

The police arrived at the main gate at 16.33.

The ambulance helicopter landed at 16.35 alongside the treatment plant/H_2S reactor. Clearance for this had been secured by the acting second-line commander/shift supervisor.

Operator1 had succeeded at 16.48 in lowering work-experience pupil2 to the ground.

The latter was flown by ambulance helicopter to Haukeland University Hospital. The four others directly involved in the incident (operators 1 and 2, the apprentice and work-experience pupil1) were driven to the hospital by ambulance. One of the fire brigade smoke divers was also sent to hospital for a check-up.

The second line decided that management and health personnel should go to Haukeland to provide support for both relatives and plant personnel. A contact number was also established for relatives by using the Statoil call centre. This functioned from around 19.00.

The duty second-line commander arrived at the emergency response centre at 17.05.

The second line called in extra personnel and established a new shift to take over operation of Sture. A debriefing was organised for the afternoon shift members not sent to Haukeland and others involved in the incident

3.4 Dispersal of the gas

In connection with its investigation, Statoil has prepared a gas dispersal analysis as a tool for understanding both the course of events and the risk potential. A simulation of this kind is a simplification of reality, and its results are affected by uncertainties.

Statoil has run three different simulations to recreate various phases of the incident. One is the shut-down H_2S reactor running with the reflux pump only and without compressed-air blowing (scenario 3), which is the condition before the blowing operation. The second is blowing compressed air at a rate of about 0.18 m^3/s with the assumed H_2S concentration (scenario 1) to simulate the operation from the start of air inflow until the tank is air-filled. Finally, blowing air at a rate of 0.18 m^3/s with a somewhat lower H_2S concentration (scenario 2) to simulate the blowing operation after it has been under way for a time.

The simulation shows that personnel on the tank top during blowing could have been exposed to concentrations up to almost 1 000 ppm. Based on calculations and medical consequences, Statoil's investigation report estimates that the five people on top of the tank were exposed to concentrations of 400-2 000 ppm H_2S.

The gas dispersal analysis considers three sources of uncertainty in the analysis. These are the gas composition, the quantity of air supplied and the use of Cartesian coordinates in connection with the simulation. Various measurements before and after the incident support the simulations. Measurements made on top of the reactor earlier on the Wednesday accord well with scenario 3, and ground-level measurements alongside the reactor during the incident fit well with scenario 1 and later with scenario 2.

4 Potential of the incident

Actual consequences

Five people were hospitalised, with four discharged after one day and one after three days.

No material damage or harm to the environment was registered.

Potential consequences
H_2S is a highly toxic gas. The dispersal analysis carried out shows that the personnel were exposed to potentially fatal concentrations. Under slightly different circumstances, one or more of the exposed personnel could therefore have died.

It is known from medical literature, including occupational health guidelines, that H_2S exposure can also give rise to latent injuries. A high level of acute exposure may damage the nervous system. The gas can cause damage to lungs, give rise to respiratory symptoms among asthmatics, and affect people with cardio-vascular conditions. It is too early to say anything certain about possible latent injuries from the Sture incident.

In the team's view, it is unlikely that the incident could have caused material damage or harm to the environment.

5 Observations

Observations by the PSA fall generally into two categories.

- Nonconformities: observations where it believes that regulations have been breached.
- Improvement points: observations where deficiencies are seen, but insufficient information is available to establish a breach of the regulations.

5.1 Nonconformities

5.1.1 Inadequate management of activities, resources, processes and expertise

Nonconformity
Activities, resources, processes and expertise were not managed in such a way that the work could be done in a safe manner. Knowledge of risk at Sture was lacking or was not applied in an appropriate manner.

Grounds
H_2S is a highly toxic gas. Nevertheless, no measures were taken at Sture which adequately reduced the probability that it might give rise to hazards or accidents.

A working environment health risk assessment (WEHRA) for the treatment plant was carried out in 2013-14. This treated H_2S primarily as an odour problem. Measures still remained to be implemented at the time of the incident.

Signs in the area stated that the control room should be contacted concerning H_2S, but this was not able to determine the concentration in the area. No H_2S detectors were permanently installed in the treatment plant. The stairs up to the top of the H_2S reactor had no barrier.

Documentation about the treatment plant was not reviewed ahead of blowing out the reactor. No description of the relevant job appeared in the system and operational documents.

No risk assessment was conducted for the job of blowing out the reactor, whether in the form of a safe job analysis, a pre-job conversation, a "management and compliance" review, buddy check or the like – even though the plant operators on the shift had not done this job before.

Routines for information-sharing between the shifts were inadequate. Nothing was said about the high H_2S values measured on top of the reactor that day, either in the shift log nor verbally during handover to the relevant shift. As a general observation, people were reportedly not always scrupulous about making entries in the shift log. See section 5.1.3.

It appears that requirements for using PPE are unclear and compliance with these inadequate. A number of comments indicate that management and workers differ in their understanding of when and what PPE should be used. The use of portable gas meters when in the area was also largely up to the individual operator. Interviewees reported that personnel worked on receiving pigs – which involves a danger of exposure to hydrocarbons and mercury – without wearing necessary respiratory protection. People also failed to use PPE when working on/by the ammonia plant, despite the risk of exposure to this substance.

The afternoon shift was understaffed on the incident day. Instead of three plant operators, the shift had only one operator with expertise on and experience from the plant. In addition to his ordinary plant work, he was also responsible for four people under training. See section 5.1.2. On the basis of information received by the investigation team, no overall assessment appears to have been made of whether it was prudent to begin the shift with such low staffing.

Requirements
Sections 4, 5 and 6 of the management regulations on risk reduction, barriers, and management of health, safety and the environment respectively.

5.1.2 Inadequate staffing and expertise when the shift started

Nonconformity
Adequate staffing and expertise had not been secured when the afternoon shift started on Wednesday 12 October 2016.

Grounds
The shift is responsible for operating Sture. It must have the necessary expertise and capacity at all times to execute these activities while simultaneously being able to handle hazards and accidents.

To perform these duties, Statoil has established a staffing norm for shifts at Sture. This comprises the shift supervisor, a coordinator, two control room operators and three plant operators. In addition come the laboratory assistant and a gate security guard. Interviewees commented that departure from this norm was possible after more detailed assessments.

The afternoon shift on 12 October 2016 started with an acting shift supervisor who was normally the coordinator on a different shift, a coordinator, two control room operators, one plant operator, one plant operator under training on his third day at Sture, an apprentice and two work-experience pupils. The laboratory assistant and gate guard were also at work.

This means in practice that, instead of three plant operators, the shift had only one plant operator with experience from Sture. In addition to his ordinary operator duties, he was also responsible for people under training (an operator new to Sture, an apprentice and two work-experience pupils).

It is the investigation team’s understanding that no overall assessment was made of whether it was prudent to begin the shift with such low staffing.

Requirements
Section 14 of the management regulations on manning and competence
Sections 50 and 65 of the technical and operational regulations on competence and the emergency preparedness organisation respectively. See the guidelines. See sections 6, 10 and 17 of the industrial safety regulations on organisation and qualifications respectively

5.1.3 Inadequate transfer of information at the shift changeover

Nonconformity
The necessary transfer of information was not ensured between the departing and arriving shifts concerning the status of safety systems and ongoing work or other details significant for HSE.

Grounds
Two operators ascended the H_2S reactor during the morning shift on 1 October 2016 to investigate that the grating was secure. They had PPE and gas detectors. One detector showed more than 100 ppm of H_2S, while the other measured 27 ppm H_2S. This information was not entered in the shift log or communicated in another way to the afternoon shift.

Interviewees conformed that the shift log is the key tool for transferring information at shift changeovers. However, it emerged from the interviews that keeping the log is treated casually, and that its use for experience transfer varies and is also to some extent arbitrary.

Requirement
Section 54 of the technical and operational regulations on transfer of information at shift and crew changes

5.1.4 Inadequate leadership of the emergency response

Nonconformity
The emergency response organisation was not led in a coordinated manner.

Grounds
In addition to being a hazard and an accident, the incident was a stressful event in that the shift's own personnel were directly involved.

Those who participated in dealing with the incident contributed to reducing its consequences. The response personnel took action which threatened their own life and health at times.

However, actions by individuals comes across as uncoordinated and poorly managed. Nobody assumed the role of smoke-diver commander. The response gives the impression of individuals taking the initiative on their own account and doing things partly on the basis of impulse and their own assessments. The disposition of available smoke-diver capacity by the coordinators in the coordinator meeting comes across as arbitrary.

Examples include:

- operator2 took an oxygen cylinder and ascended again to help work-experience pupil2 soon after the same operator had lain unconscious on top of the H_2S reactor, recovered and got himself down
- smoke diver1 ascended with a compressed air cylinder incorrectly attached to his back

- which two coordinators were first chosen to join the response/smoke-diving team appeared arbitrary
- which two coordinators were the next to be picked, and when, appeared arbitrary.
- available smoke-diving expertise was not used.

Requirements
Section six of the management regulations on management of health, safety and the environment
Section 65 of the technical and operational regulations on the emergency preparedness organisation. See the guidelines. See sections 10 and 17 of the industrial safety regulations on qualifications

5.1.5 Inadequate training in the use of emergency equipment

Nonconformity
Training and exercises have been inadequate for ensuring that response personnel are able at all times to deal effectively with complex hazards, accidents and stresses.

Grounds
A number of examples emerged during the interviews that emergency equipment failed to function or that response personnel could not get it to work properly. Examples include:

- the strap for the compressed air cylinder did not work
- wrong breathing machine/hose
- problems with removing the buddy mask
- stretcher lacked straps for securing the patient
- stretcher lacked straps for lifting
- cars failed to start.

It emerged from the interviews that these problems were primarily attributable to the fact that response personnel have not trained enough on the use of the equipment to be familiar with its use in complex hazard, accident and stress conditions.

However, these problems could to some extent also reflect inadequate inspection and maintenance of the equipment.

Requirements
Sections 52, 65 and 67 of the technical and operational regulations on practice and exercises, the emergency preparedness organisation, and handling hazard and accident situations respectively

5.1.6 Absence of a plan for rescuing personnel from a height

Nonconformity
No plan had been established at Sture for rescuing people swiftly from an injury site above ground level.

Grounds
It emerged from the interviews that rescuing personnel from an injury site above ground level was not described in the emergency response plan for Sture.

This lack of a plan was manifested during the incident response by the improvised use of a crane truck. The crane was not certified for lifting people. Furthermore, the stretchers brought to the injury site were not prepared for securing and lowering an injured person.

It emerged during the interviews that the need to rescue personnel from injury sites above ground level has also arisen in earlier incidents.

The investigation team has not checked whether a plan for rapid rescue of personnel from injury sites above ground level has been established at Kollsnes, but notes that relevant equipment was not sent from there.

A lift was despatched from the Bergen fire brigade. This would have taken at least one hour and 15 minutes to reach Sture after the alert. Some time would also have been required for rigging and lifting before the injured person could be brought down to a safe area.

Requirement
Section 67 of the technical and operational regulations on handling hazard and accident situations

5.1.7 Radio communication did not work

Nonconformity
Walkie-talkies which do not always work are in use at Sture.

Grounds
It emerged during the interviews that operator2 was equipped with a walkie-talkie which did not work. Other cases where walkie-talkies had failed to function were also mentioned.

Requirement
Section 22 of the technical and operational regulations on communication systems and equipment

5.2 Improvement points

5.2.1 Lack of an unambiguous name for the plant

Improvement point
When notifying incidents at Sture, and for that matter at Kollsnes as well, the use of the StureKollsnes plant name can leave it unclear where the incident is actually located.

Grounds
The official name of the two Sture and Kollsnes plants is StureKollsnes.

It emerged during the interviews that those notified and called in to the second-line response understood the incident to be at StureKollsnes. That ambiguity had no practical consequences in this case. It quickly became clear that the incident was at Sture.

Requirement
Section 67 of the technical and operational regulations on handling hazard and accident situations

6 Discussion of uncertainties

The following uncertainties are discussed.

Degree of exposure
Establishing the exact concentration of H_2S which personnel on the tank were exposed to is impossible. The exposure also varied between individuals. The last man up was the first to pass out, but he could have been more exposed because people moving about on the top had set the gas in motion and possibly caused it to flow down along the stairs. Statoil's investigation report has estimated 400-2 000 ppm H_2S on top of the reactor. The investigation team has not produced its own estimate and has utilised Statoil's assessment. It takes the view that personnel have unquestionably been exposed to harmful quantities of H_2S.

Timeline
Considerable chaos prevailed during the incident, and exactly what happened when is somewhat unclear. Descriptions by the response personnel also differed fairly substantially. The investigation team does not consider this to be unnatural, or to be important for understanding the course of events.

7 Statoil's investigation report

Statoil's investigation report has looked at the most important causes. It describes the underlying and direct causes of the incident and assesses the actual and potential consequences. It also describes the management of the emergency response.

Statoil's investigation report reflects the same course of events and level of seriousness as the PSA report.

8 Appendices

A: The following documents have been used in the investigation
- Note, gas dispersal analysis, Synergi 1487964
- Shift reports 9-11 October 2016 part 1 of 2
- Shift reports 11-13 October 2016 part 2 of 2
- Central control room log incident five pages 12 October 2016
- System 44 – treatment of oily water – operational section
- System 44 – treatment of oily water – system section
- WEHRA R38 Treatment plant
- Event log and alarm list 11-12 October 2016
- Investigation report A 2016-14 MMP L2-final
- Organogram

B: Abbreviations

H_2S	hydrogen sulphide
HSE	health, safety and the environment
PPE	personal protective equipment
ppm	parts per million
WEHRA	working environment health risk assessment

C: Overview of personnel listed