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Analysis of root causes of major hazard precursors (hydrocarbon leaks) in the Norwegian offshore petroleum industry

Jan Erik Vinnem [a,*], Jon Andreas Hestad [b], Jan Terje Kvaløy [c], Jon Espen Skogdalen [d]

[a] Preventor AS/University of Stavanger, Rennebergstien 30, 4021 Stavanger, Norway
[b] Safetec Nordic AS, Bergen, Norway
[c] Department of Mathematics and Natural Sciences, University of Stavanger, Norway
[d] Department of Industrial Economics, Risk Management and Planning, University of Stavanger, Norway

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ABSTRACT

The offshore petroleum industry in Norway reports major hazard precursors to the authorities, and data are available for the period 1996 through 2009. Barrier data have been reported since 2002, as have data from an extensive questionnaire survey covering working environment, organizational culture and perceived risk among all employees on offshore installations. Several attempts have been made to analyse different data sources in order to discover relations that may cast some light on possible root causes of major hazard precursors. These previous attempts were inconclusive. The study presented in this paper is the most extensive study performed so far. The data were analysed using linear regression. The conclusion is that there are significant correlations between number of leaks and safety climate indicators. The discussion points to possible root causes of major accidents.

1. Introduction

1.1. Background and context

The Norwegian offshore petroleum industry has been free from major accidents for almost 25 years, the last major accident (ignited gas blowout) having occurred in October 1985. This is a significant achievement. In the preceding ten years, five major accidents occurred despite a much lower activity level.

'Major accident' in the offshore industry is often understood to be an accident sequence that is out of control and that has the potential to cause five fatalities or more. This may be for instance gas leaks where ignition has occurred or, in the case of structural failure, where at least local structural failure has occurred. This interpretation is in accordance with HSE's definition [1].

Unignited leaks or structural impact without structural failure are not accidents but precursors. In these situations there are still functional barrier systems intended to prevent harm to people, the environment and/or equipment.

A root cause is the most fundamental cause of an accident or incident that can be reasonably identified and that management must control.

This definition will be used for this review. It contains three key elements [2]:

- *Basic cause*: Specific reasons as to why an incident occurred that enable recommendations to be made which will prevent recurrence of the events leading up to the incident.
- *Reasonably identified*: Incident investigation must be completed in a reasonable time frame. Root cause analysis, to be effective, must help investigators to get the most out of the time allotted for investigation.
- *Control to fix*: General cause classifications such as 'operator error' should be avoided. Such causes are not specific enough to allow those in charge to rectify the situation.

The offshore petroleum industry in Norway has reported major hazard precursors to the authorities for a decade. The first data collection exercise at the beginning of 2001 covered the period 1996 through 2000. The work now covers the period 1996 through 2009 and is known as "Trends in risk level", or RNNP, see www.ptil.no/rnnp. The relevant major hazards for personnel on the installation are addressed in QRA studies, and these were one of the main sources for identification of indicators. Table 1 shows an overview of the categories of major hazard precursors (called 'DFUs') included in RNNP.

Barrier data have been reported since 2002, as have data from an extensive questionnaire survey covering working environment,

* Corresponding author. Tel.: +47 51487880.
E-mail address: jev@preventor.no (J.E. Vinnem).

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Table 1
Overview of major hazard precursor categories ('DFUs').

DFU no.	Description	Average no./yr 2003–08
1	Non-ignited hydrocarbon leaks	16.7
2	Ignited hydrocarbon leaks	0
3	Well kicks/loss of well control	16.2
4	Fire/explosion in other areas, flammable liquids	2.5
5	Vessel on collision course	33.0
6	Drifting object	0.8
7	Collision with field-related vessel/installation/shuttle tanker	0.7
8	Structural damage to platform/stability/anchoring/positioning failure	7.8
9	Leaking from subsea production systems/pipelines/risers/flowlines/loading buoys/loading hoses	2.8
10	Damage to subsea production equipment/pipeline systems/diving equipment caused by fishing gear	2.2

organizational culture and perceived risk among all employees on offshore installations.

Some attempts (see refs. in Sections 1.3 and 1.4) have been made to analyse various data sources in the search for relationships that may cast some light on possible root causes of major hazard precursors in the Norwegian offshore petroleum industry. These previous attempts were sometimes inconclusive, in the sense that no significant correlations could be identified.

The most recent attempt covered precursor data, barrier data, serious injury data, questionnaire survey data (biannually) and noise exposure data in relation to occupational health. This is the most extensive study performed so far, which may largely explain why this study succeeded in identifying significant correlations where previous studies had failed to do so. The correlations in themselves may not necessarily point to root causes but some may come to light through subsequent discussion of these correlations.

The first part of the paper briefly reviews some of the previous studies. Next follows a brief review of the data sources and the statistical analysis that has been performed. A summary of the results is presented and a thorough discussion of the implications of the results is reported, with particular emphasis on implications with respect to root causes.

1.2. Purpose of the study

This paper presents a study carried out as part of ongoing research aimed at identifying important risk-influencing factors for major hazard risk in the Norwegian petroleum industry, with the active cooperation of the Petroleum Safety Authority.

The purpose of the study was to search for potential factors that would help to explain the large differences between installations, even within the same company, with respect to the frequency of hydrocarbon leaks with a rate above 0.1 kg/s[1]. Possible root causes were also sought. Finally, indicators that may be used for major hazard risk associated with hydrocarbon leaks were explored.

1.3. Safety culture, safety climate and questionnaire in RNNP

There are many definitions of culture in anthropology. One definition of culture would be the common set of ideas, values, attitudes and norms that characterize a group of people. Culture used in this sense of the word is an aspect of all sides of society and thus influences how we approach safety, technology, politics, economics, etc., and last but not least, how we act and think in our everyday lives. In other words, culture is an aspect that has an influence on most things, perhaps everything that we do. Safety culture is an integrated part of the organizational culture [3]. The research related to safety as part of an organizational culture is relatively new, but there is a large volume of articles discussing safety culture in general, such as [4–8]. Schein [9] uses the term organizational culture as, "observed behavioral regularities when people interact (language, customs and traditions, rituals), group norms, espoused values, formal philosophy, rules of the game, climate, embedded skills, habits of thinking/mental models/linguistic paradigms, shared meanings and 'root' metaphors or integrating symbols", which shows the complexity of meanings of a culture. James Reason emphasized the organizational cultural role in safety management. According to Reason [10] the organizational culture most closely captures its essence that is shared values (what is important) and beliefs (how things work) that interact with a company's people, organizational structures and control systems to produce behavioral norms (the way we do things around here). Maybe the most widely accepted definition of safety culture comes from the nuclear power industry: "*The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organizations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures*" [11]. Safety culture has acquired a significant place in literature and there is an agreement that safety culture is a proactive stance towards safety [12].

The RNNP seeks to measure the safety climate of individuals working offshore at a given time. The scores are aggregated at organisation level to provide indicators of the organisation's current safety climate. Safety climate can be described as the employees' perceptions, attitudes and beliefs about risk and safety. These perceptions are often measured by questionnaires and provide us with a "snap shot" of the current state of safety. However, we consider safety culture to be a more complex and enduring phenomenon than safety climate, reflecting fundamental values, norms, assumptions and expectations which to some extent reside in societal culture.

Hence it follows that safety culture should be examined and complemented by qualitative methods and other measures, e.g. interviews, observations/audits and fieldwork [17]. Safety climate is defined either as a sub-component of safety culture [13] or as a reflection of the actual safety culture by others [14].

Can culture be measured? Anthropologists and psychologists tend to disagree on this question. Many psychologists appear to believe that it is possible to measure culture—or at least to measure the safety climate (see Safety Science, volume 34, 2000) [15]. We share the belief of an earlier study where the core objective was to examine the psychometric qualities of the questionnaire related to the RNNP [17]. Their basis was that safety climate is a reflection of an underlying safety culture of a work group, plant or organisation. How close this reflection is to the actual safety culture will depend on the quality of the instrument used to measure it.

The RNNP work has been published in several articles, such as [16–19]. The topic of [19] is the detail of the major hazard indicators. All (of) the studies [16–18] are based on questionnaire data but not focused on major hazards. Further analysis of major hazard related data has been performed in several instances, but few of these studies have been published.

[1] The lower limit of 0.1 kg/s flowrate is used because leaks below this value are not considered to be capable of leading to major accidents.