0-Accidents in Offshore Oil and Gas Production - the Quantitative part

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0-ACCIDENTS IN OFFSHORE OIL AND GAS PRODUCTION – THE QUANTITATIVE PART

COLLABORATION PROJECT: DANISH OPERATORS & CENTRE OF MARITIME HEALTH AND SAFETY, ESBJERG

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Editorial committee: Fabienne Knudsen, Hanna B. Rasmussen, Jørgen Riis Jepsen and Vibeke Stegelmann

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0-ACCIDENTS IN THE OFFSHORE OIL AND GAS PRODUCTION – THE QUANTITATIVE PART

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List of abbreviations

ADI ............... Alternative duties injuries
CDC ............... Center for Disease Control and Prevention in the USA
DEA ............... Danish Energy Agency
DPA ............... Danish Data Protection Agency
LTA ............... Lost time accident
LTI ............... Lost time injuries
LWDC ............ Lost word day case
MARS ........... Major Greece injury reporting system
MOG ............ Maersk Oil and Gas
MTI ............. Medical treatment injuries
MTC ............. Medical treatment cases
NOMESCO ... The Nordic Medico-statistical Committee
OGP ............. International Association of Oil & Gas Producers
RWC ............. Restricted work cases
RWDC .......... Restricted work day cases
STF ............. Slips, trips and falls
TRI ............. Total reportable injuries
Summary

According to data from the national authorities and operators, the injury incidence rates of lost time accidents in Danish oil and gas operators have declined significantly over the recent decades. There have been significant annual variations, but the trend points towards a zero-injury level, and this is probably due to the safety programmes applied by the industry. An analysis of the data and methods used by the authorities in five countries shows comparable trends, but incomparable risk levels. This incomparability is due mainly to different criteria applied for inclusion of injuries and to different populations that may or may not include onshore workers.

The International Association of Oil & Gas Producers (OGP) runs an international surveillance system that, however, also gives insufficient information on the methods in the OGP annual reports. We identified a number of potential threats to the comparability in between countries: There is insufficient information with regard to whether the company worker populations always include both offshore and onshore workers; there is a potential for differential information bias due to non-reporting from around 50% of the companies; there is a potential of underreporting. In addition, in spite of a unanimous OGP definition of lost time accident, there is no confirmatory evidence that all the companies use the same injury inclusion criterion. These concerns complicate the comparability of injury incidence rates. In conclusion: Due to the lack of methodical information and shortcomings, neither the national authorities' data, nor the OGP data can be regarded as valid tools for international risk comparisons. They are, however, applicable for trend analyses.

The challenge is to clarify the methodological questions to amend any shortcomings. The potentials in the international safety collaboration and surveillance system can then be activated for prevention.
Report conclusions

Overall, there is a decreasing trend in the incidence rates of the reported LTA-1-day (lost time accident) over the last three decades in the Danish offshore industry. Similar trends for the specific injury rates are also seen in the four other countries studied (Australia, Norway, Great Britain, United States).

There has been a downward trend of the Danish incidence rates of the LTA-1-day reports for 2003-2007. In this period, there is an upward trend in the incidence rates of the injuries that are reported and recognised for compensation, and a slight increase in the LTA reported injuries with more than five weeks lost time. The injury prevention programmes are still being improved.

In Denmark, before 1989, the offshore LTA-1-day injury incidence rates were much higher than onshore but from 1986-1989 the incidence rates decreased sharply. Since then, the incidence rates of LTA-1-day offshore have been lower than onshore with a slightly decreasing overall trend from 1990-2007, a significant increase from 2001-2003 and a decreasing trend thereafter.

The downward trend of the Danish incidence rates from 1986-2007 indicates that the safety programmes have been implemented with good effect. The rapid decrease of the incidence rates in the years 1987-1989 can be mainly explained as the result of intensive safety programmes.

The increased rate for the LTA-1-day injuries during 2002-3 is unexplained. The new and wider definition of compensable injury definition in Denmark in 2004 may partly explain the increase of the compensated injuries.

Slips, trips and falls (STF) injuries constitute a major part, up to 60%, of the LTA-1-day injuries and still, in 2007, constitute a significant proportion of the cases. A large number of STF injuries would probably be preventable by targeting the intervention to specific types of injuries for and also by international sharing of best practices.

The offshore injury incidence rates in other countries cannot be compared directly with the Danish data due to use of different methods for registration of the injuries and various delimitation of the workers populations. The use in the UK of the number of persons as the denominator, instead of working hours, hampers a comparison with countries that uses working hours as the denominator.

The worldwide incidence rates from the OGP also suffer from unresolved issues concerning the included risk population onshore and offshore, the inclusion of subcontractors and the lack of data from half of the member companies. There is a potential of underreporting, and in spite of a unanimous definition of lost time accident, there is no confirmatory evidence whether all the companies apply an identical injury inclusion criterion. Due to the mentioned methodical problems based on the available data, there is no evidence that any country has a better safety than others.
Report proposals

A causal analysis of the decline of Danish injury rates during the 1980’s has not been performed and would be useful for learning. The sharp decline of the injury rates in Norway since 2000 would also be worth analysing.

The increase of the Danish incidence rates during 2001-2003 remains unexplained. One hypothesis may be that a high number of new and less-experienced employees have been recruited, but such an influence has not been confirmed. An analysis of the multiple causal factors in detail would be relevant.

The injuries related to STF in Denmark should be paid more attention for prevention. A collaborative effort by the international OGP in terms of causal analysis and sharing the best practices for prevention of specific types of injuries such as STF is proposed.

The linking of national and company safety databases to the employees’ record database would be a valuable tool for prioritising the safety and health interventions. The information should include the employees’ main work area, type of platform, experience in the job, safety training courses, job description, number of working hours, etc. This would allow for a more precise epidemiological monitoring of LTA incidence rates in specific departments and to monitor the employees’ training and experience status more effectively than by simply registering the injured persons. At the same time, the occurrence of work-related diseases like low back problems could be included and contribute to prioritising health and safety interventions. Such databases could be used for further research by linking the personal identification numbers with data from health registers.

A valid international surveillance of injury incidences demands clear definitions of injury, clear criteria for separating the offshore sector from the onshore sector, and securing supply of data from all companies. The degree of underreporting is unknown for any country. This should be analysed in order to obtain valid comparisons in between countries, companies and other industries. The international OGP data are especially hampered by underreporting due to lack of data from about half of the oil- and gas producing companies.

The incidence rates can be further analysed by using data from hospital emergency departments and from insurance companies, including incidence rates for permanent disabilities. These data would be regarded as less biased in terms of underreporting than the LTA-1-day data.

The graphics used in the annual reports from the companies, the national authorities and the OGP should provide sufficient information for the graphics to be understood without reading the text. Further, by analysing the trends over several decades, the impact of the implemented safety measurements can better be identified and used for learning.

Part B concludes, that no scientific publication has dealt with analysis and solving of the methodological problems permitting, in particular a valid comparison of the international injury incidence rates.
Report part A: Analysis of existing data

Introduction

This report deals with occupational injury rates only. No process and safety incidents are covered at all. In this context it emphasised that a study of serious near miss incidents and process safety constitutes an important part of the learning in relation to overall safety. The Lost Time Injuries (LTI) statistics only give a partial picture of the developments. However, since they are the only figures published in somewhat comparable format they are used in an attempt to make assessment of LTI frequencies across countries with offshore industries with which we can compare ourselves.

The Alexander Kielland platform disaster, The Piper Alpha incident, and the more recent Texas Refinery and Gulf spill incidents are in the minds of the industry and emphasises the high safety attention required. Further, there is much information available on safety and health issues from the offshore oil and gas industry and from the national authorities. In contrast to other industries with a high risk of injury and catastrophes, there are only a few peer-reviewed publications on the quantitative side of the risk prevention in the offshore industry while many publications have applied other methods.

Aims

The overall aim of this project is, based on existing information, to compare the injury rates in offshore oil and gas producing countries and to estimate the effect of safety implementations.

More specifically, the aim of the project is to compare the Danish accident levels with the levels of other North Sea and similar countries involved in offshore drilling and oil production to find out whether lessons can be learned from identified differences. Benchmarking means should be developed for comparative valid analysis across the offshore oil industry and the results should be oriented towards immediate application by the companies and authorities.

The project is divided into two parts: A) An analysis of the existing data on injury incidence rates, and B) A study of peer-reviewed epidemiological studies on injury incidence rates.
Methods

The objective is defined as: “to map the available statistical data in order to find out where to concentrate the fieldwork.” There are, however, significant problems by comparing the injury incidence rates among different countries. The inclusion criteria of the injury cases may differ from each other so that the results are incomparable. The objective was then re-defined as: Based on the existing data to perform an epidemiological study of occupational injuries in the Danish offshore industry, to compare the offshore industry with the on-shore trades and with the offshore industry in comparable countries.

Epidemiology is the study of the relations of the health risk factors and the health-related states and health events, and to use this knowledge for health promotion and risk prevention. When existing injury incidence rates cannot be compared in between the countries, they can be used to compare the trends and to assess the possible effects of implemented safety programmes.

This provides a possibility for identifying bias that causes invalid comparisons and to reveal the solutions for comparison.

Some basic definitions of relevance include:

- An occupational injury has been defined as a sudden and unexpected harmful event arising due to an accident at work. Both “accident” and “injury” are used synonymously for the same type of event. Identical criteria for inclusion of the injury cases are required for valid comparison of incidence rates from different countries. The specific criteria for inclusion of injuries from the different countries are presented later.

- Incapacity for work occurs when due to an occupational injury, the victim is unable to perform the normal duties of work in the normal job. A work-related injury involving an employee that is unable to perform the full range of normal work activity is often registered as a “Restricted Work Case” (RWC).

Underreporting of injury cases

It is well known that the level of underreporting of occupational injuries differs significantly in between various industrial trades and also of the seriousness of the injury and other conditions. Various degrees of underreporting among the compared study populations can distort the results significantly. By analysing and comparing rates over many years, the degree of underreporting is subject to changes, which may also bias the results. It is relevant to regularly monitor the degree of underreporting, in order to estimate the magnitude of a potential bias. The use of several sources of injury data information allows for improving the data quality. The degree of underreporting is supposed to be highest for minor injuries and lowest for the most serious cases, but even for fatal injuries, there is no guarantee that all cases are reported to the authorities. Supplemental data from insurance can provide valuable additional information. In order to obtain the least biased comparable results among different countries it is recommended to use the most serious injuries for comparison of the incidence rates. Another type of bias that may be suspected in the OGP data due to lack of data from about half of the oil- and gas producing companies. Report-
ing that in some countries is limited to “good companies” can give serious bias when comparing with countries where all companies report. A request concerning the estimated size of these two types of underreporting to the OGP main office in London was not responded.

**The study population**

The study population is the source population from which the injury cases come. Only cases arriving from the defined study population (cohort) should be member of the study population. Study populations can be dynamic or fixed. The offshore working populations are dynamic populations, and the population in risk is mostly defined by the total annual number of work hours that all members of the population have contributed together. The number of work hours is normally counted as the number of days each person has been on the platform multiplied with 13 hours per day until the end of the year 1999 and 12 hours since the beginning of the year 2000.

All the cases, as defined, arising from the population during the observation time, are candidates to be included as injury cases.

The study population is defined and used as “denominator” for calculation of the incidence rates. Detailed information on the study populations used as “denominator”, the inclusion criteria of the injury cases, the methods used for calculation of the incidence rates and ratios are required for assessment of the validity of the comparison in between various populations. Bias can arise when some countries include onshore data and data from the subcontractors are included, while the denominator in others is limited to cover offshore data. A request concerning the OGP data on this issue was not answered.

**The incidence rates**

This is a measurement of the number of injuries per one specified unit of time in the population (example per 1 million working hours). The incidence rate is calculated as, e.g. the number of new cases divided by the total number of work hours in one year (multiplied with 1 million).

Detailed information on how the incidence rates are calculated is needed to assess whether the incidence rates can be validly compared. The short form “incidence” is used often instead of “incidence rate”. The national authorities and the industry use different terms with identical meaning like “injury frequency rate” instead of “incidence rate”. The cumulative incidence rate expresses the percentage of persons that sustained an injury event during 1 year or another defined period.

**The prevalence rates**

The prevalence rate is defined as the number of existing cases in a population with a certain health condition, divided by the number of subjects belonging to the population. The application of the prevalence rates and the incidence rates in injury epidemiology can be illustrated by applying the use of the rates to the basic structure in the Haddon’s Matrix:
As per definition injuries occur as sudden events, they are measured by use of the incidence rates. Certain chronic conditions, such as incapacity for work or daily activities after an injury, and exposure to some specific risk factors, are measured by the use of prevalence rates.

### The relative risks

A quantitative comparison of the risk of injury in two or more groups is done by calculation of the relative risk as the ratio of two comparable incidence rates. The relative risk is calculated by dividing the incidence rate in one group with the incidence rate in the comparison group. The two incidence rates must be based on identical numerators and denominators to be valid, and therefore knowledge about definitions of the cases (numerator) and the hours of work (denominator) is required to assess whether or not the relative risk is a valid estimate. Knowledge on the estimated degree of underreporting in the compared populations is also required for the assessment of validity of the relative risks.

Biased relative risk estimation in the oil- and gas industry can especially arise from three types of errors:

1) An incomparability of the injury inclusion criteria;
2) An incomparability of the denominators, with regard to inclusion of only offshore data or additionally onshore and subcontractors' data;
3) An underreporting from individual companies and on the national level, due to the lack of coming from a proportion of companies.
The study populations

The study populations included here are employees on oil and gas production and drilling platforms in Denmark, Norway, United Kingdom, Australia and USA. The data from the oil and gas production is limited to offshore production and does not include onshore oil and gas production workplaces except for the USA, where the injury and population data from oil and gas production also includes onshore workplaces. The Danish offshore data are compared with the corresponding data for all economical active persons working in land-based trades in Denmark.

Danish offshore oil- and gas production

Denmark has produced hydrocarbons since 1972, when the production commenced from the Dan field. Since 1997, Denmark has been more than self-sufficient in energy from the production of oil and gas in the North Sea. Since the Danish Energy Agency (DEA) was established in 1976, the Authority has dealt with matters relating to oil and gas activities in Danish territory including supervision of the activities concerning safety and working environmental issues on platforms and drilling rigs.

The oil- and gas production installations on the Danish continental shelf in the North Sea, as well as drilling rigs and miscellaneous vessels associated with oil and gas production, provide jobs for up to 3,000 people. The employees have a multitude of different skills and include blacksmiths, electricians, geologists, engineers, painters, scaffolders, catering staff, medics, management, supervisors and operators etc.

The production installations consist of about 50 platforms, some of which are interconnected by bridges. The working hours are not registered separately for the different job categories, so the specific incidence rates cannot be calculated. The daily working hours offshore are calculated as 13 hours per day until Dec. 31st 1999 and 12 hours since then. On wellhead platforms, the normal work pattern is two weeks of work offshore (with 14 work days) followed by three weeks off ashore. Drilling rig work schedules vary, and may involve working offshore for up to three weeks followed by three weeks off. The work schedule on board vessels follows the usual maritime practice.

The Danish population data

The population used for calculation of the injury incidences includes all persons working on the platforms for shorter or longer periods and do not include persons working onshore. The population is defined by the annual total sum of working hours since 1986 divided into mobile (drilling) and fixed (productions) platforms. Each employee contributes to the total annual sum of hours by the number of work days on the platforms multiplied by 13 hours per day till the end of 1999 and from the beginning of 2000 by 12 hours.
Sources of information of the Danish offshore population data

Since 1986, the DEA has published its annual report “Oil and Gas Production in Denmark”. This report indicates the number of working hours on the fixed and the mobile platforms as well as the notified work related injuries. All reports were collected and the data on the number of hours worked, the number of reported injuries and the injury incidence rates per 1 million working hours were extracted for each year. The data were entered in Excel datasheets and the graphs are produced from the datasheets.

The Danish Operators are legally obliged to notify injuries and report hours worked on the oil and gas production platforms to the DEA. Information about the working hours is based on the Vantage or a similar system. The Vantage system counts the number of workdays on the platforms and multiplies with 13 hours to get the number of working hours (12 hours after 2000). The Vantage System also registers the helicopter embarkations in the airports.

The Statistics Denmark gives the number of employees, working on the platforms. For 1997-2007 (16-65 years of age) the number of employees increases from 1230 in 1997 to 2796 in 2007 (http://www.statistikbanken.dk/RAS9). Information from the Danish Operators about the total number of working hours is available for 1984-2007. The operators are not obliged to inform about the number of persons working on the platforms. However, these data are not required for this study as the working hours are used to describe the study populations.

The Danish Operators

Data that include persons working on the platforms and exclude workers onshore were supplied by Maersk Oil and Gas (MOG), Hess Denmark, South Arne, and Dong Energy. For MOG, the population is defined by the annual sum of working hours for 1984-2007, and presented separated for mobile and fixed platforms. The number of person-days on the platforms is registered by MOG’s own system, which is comparable to the Vantage system. All persons being transported to and from the platforms by the helicopters are registered at the airport. The number of working hours is calculated by multiplication of the person days at the platforms by 13 hours (12 hours from 2000). The number of million working hours was given for Hess Denmark, “South Arne” for the years 2000-2007 and for Dong Energy for the years 2003-2007. Data includes fixed and mobile units for MOG but only fixed platforms for Hess Denmark and Dong Energy.

The Danish comparison population on shore

Statistics Denmark gives the number of economical actives (employers and employees) in all trades (16-65 years of age) (http://www.statistikbanken.dk/RAS9). Statistics Denmark also provides information about the total number of working hours from 1990.

The Norwegian population data

The offshore working population in the Norwegian oil and gas industry is defined by the annual total sum of working hours since 1990, separated for mobile (drilling) and fixed (production) platforms. Each employee contributes to the total annual sum by his or her total number of working hours whether only for a few months or the whole year.
The information for 1990-2007 is obtained by personal contact to “Petroleumstilsynet” in Stavanger, Norway (http://www.ptil.no/forside/category10.html). The Norwegian offshore operators are legally obliged to report the total number of working hours every 3 months to the authorities. They are also obliged to describe the method used for calculation of the total hours and to inform about the average number of persons employed on the platforms. The data include oil and gas production work offshore.

**The British population data**

The number of offshore workers for 1995-2007 from the UK is given in the report Offshore Injury, Ill Health and Incident Statistics 2007/2008 HSE December 2008: (http://www.hse.gov.uk/offshore). The annual population data up to and including 2003/04 is taken from the Inland Revenue (Tax system). For 2007/8, the estimated offshore population (based on total number of working hours divided by 2000 hours per worker year) and the number of hours derives from the industry’s Vantage personnel tracking system. The British Health and Safety Executive (HSE), is a non-departmental public body of the United Kingdom responsible for regulation and enforcement of workplace health, safety and welfare, and for research into occupational risks in England, Wales and Scotland.

**The Australian population data**

Information about the number of working hours for 2002-2006 is available in a graph in the report from the “Australian Petroleum Production & Exploration Association Limited” (APPEA) about health, safety, Environment and Social performance 2005-6. In 2002 there were 60 million working hours, and this number increased to 100 million in 2006. APPEA was responsible for the injury data from the oil and gas industry until 2005 (http://www.appea.com.au). The APPEA data covers both onshore platforms and onshore processing data.

Since January 2005, The National Offshore Petroleum Safety Authority (NOPSA) has been the legal regulator in Australia (http://www.nopsa.gov.au/board.asp) dealing solely with offshore safety. The data used in this context only comes from APPEA.

**The US population data**

Information about the number of working hours is available for 1994-2007 on BLS homepages (http://www.bls.gov/iif/oshsum.htm) given in 1000’s. The number of working hours used to define the denominator for the BLS industry incidence rates are reported by survey respondents (personal information).

The BLS data include onshore exploitation and onshore processing data. The number of working hours is recalculated to 100 “full time workers” presuming that each person work 40 hours a week during 50 weeks a year. Then 100 full time workers or 200,000 work hours multiplied by 5 is equivalent to 1 million working hours. Thus, the data is comparable with similar data from other countries that use working hours in the denominator. The population data is not used here, instead the given incidence rates for the specific injury inclusion criteria are used.

Table 1 gives an overview of the population data available for the incidence rates calculations.
The International Association of Oil & Gas Producers

The OGP annual was used for collecting data and information about methods. The OGP 2005 data Report No. 379 May 2006 (www.ogp.org.uk), Appendix G, shows the size of the database in thousands of hours worked, reported for each contributing country. For Denmark, there are large differences between the hours reported to the Danish Authority and to OGP: In 2006 there is 9.4 million working hours “in the upstream petroleum sector in regions and countries” reported to the OGP. This number should be compared to 4.9 million working hours reported for the offshore industry to the DEA. Similar differences are seen for Norway. There is no explanation given for these differences, and no information whether the data cover both onshore platforms and onshore processing data and subcontractors. A request for this information from the OGP main office in London was not answered.

Table 1: The population data used in five countries and OGP for injury incidence rate calculations

<table>
<thead>
<tr>
<th>Country</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>The annual total numbers of working hours are given in millions for offshore 1984-2007 (DEA and MOG). Data on the working hours in millions for onshore were available from 1990 for Hess Denmark and for 2003-2007 for DONG.</td>
</tr>
<tr>
<td>Norway</td>
<td>The annual total numbers of working hours for offshore 1990-2007.</td>
</tr>
<tr>
<td>UK</td>
<td>The HSE gives the annual average number of persons working offshore 1995-2007. No information on working hours was provided from the HSE.</td>
</tr>
<tr>
<td>Australia</td>
<td>The annual total working hours for offshore and onshore processing activities were given in a graph for 2002-5. No other information about the population data was provided.</td>
</tr>
<tr>
<td>USA</td>
<td>The annual numbers of total working hours are given for 1994-2007 for oil-and gas extraction industry including both offshore and onshore processing activities.</td>
</tr>
<tr>
<td>OGP</td>
<td>The annual number of working hours in thousands (“in the upstream petroleum sector”) for each contributing country is provided in the annual reports.</td>
</tr>
</tbody>
</table>
Injury inclusion criteria

The Danish Energy Agency offshore sector
Injuries must be notified to the DEA if the injury causes at least 1 day of lost time after the day when the injury happened. Also injuries that are supposed to give permanent incapacity or indemnity for costs of treatment etc must be reported to the Danish National Board of Industrial Injuries. Occupational injuries that happen onshore in the oil and gas industry should be reported to the Danish Working Environment Authority. The DEA annual reports “Oil and Gas Production in Denmark” for 1984-2007 provides information on the number of reported LTA > 1 day injuries, fatal injuries and “serious injuries”. There is no definition of “serious injuries”.

The Danish Operators

Maersk Oil and Gas
Data about the number of LTA-1-day from MOG are given in the reports for 1984-2007. The MOG uses six internal different injury/incident registration criteria:

Lost Time Injury
A fatality or lost workday case. The number of LTIs is the sum of fatalities and lost workday cases.

This criterion is used for the reporting to the DEA and to the OGP.

Lost workday case (LWDC)
Any work related injury other than a fatal injury, which results in a person being unfit for work on any day after the day of occurrence of the occupational injury. “Any day” includes rest days, weekend days, leave days, public holidays, or days after ceasing employment.

Incapacity for work is required for categorising an incident as a Lost Time Injury. Thus, it does not matter whether the injured person is actually working the day after the incident at the latest, as long as capacity for work has been demonstrated or the medical adviser has declared the person fit for work, restricted or full time. If capacity for work cannot be demonstrated the day after the incident due to, e.g. prolonged examinations, the result of these examinations will decide whether the injury is a lost work day case or not.

Restricted Work day Case (RWDC)
Any work-related injury other than a fatality or a lost workday case, which results in a person being unfit for full performance on the regular job on any day after the occupational injury.

Work performed might be:

- An assignment to a temporary job
- Part-time work at the regular job
- Continuation full-time in the regular job but not performing all the usual duties of the job
- If the person is not able to carry out meaningful work due to the incident, then the incident is recorded as a lost workday case (LWDC)
Medical Treatment Case (MTC)
Cases that are not severe enough to be reported as fatalities or lost workday cases or restricted workday cases but are more severe than requiring simple first aid treatment, and/or which requires repeated first aid treatment over several days. It is a condition that the injured person can work without restrictions within own job area one day after the injury was suffered.

First Aid Case (FAC)
Cases insufficiently serious to be reported as medical treatment or more serious cases, but nevertheless require minor first aid treatment, e.g. dressing on a minor cut, removal of a splinter from a finger. First aid cases are not recordable incidents.

When repeated medical treatment over several days is required, the injury is registered as a Medical Treatment Case if the incident happened during working hours.

Off Duty Injury:
A sudden, unexpected and injurious incident outside working hours and during offshore stay. Off duty injuries are recorded in the OMS database but are not included in the calculation of the accident frequency.

Hess Denmark
Data for the “South Arne” production field about LTI are defined as being “not able to work the following day” and Medical Treatment Cases (MTC), i.e. a work-related injury or illness that would prevent the injured person from working on the day following the injury, whether or not he or she is actually scheduled to work the following shift. If the medical professional declares that the individual is unfit to return to work on the day following the injury, then the case is classified as a DAFWC (Days Away From Work Case) even if the following day is not a scheduled work day”. The exact numbers of LTI and the numbers of working hours and also the calculated incidence rates 2000-2007 are given.

The US-OSHA guidelines for the recording of work related incidents are used with inclusion criteria on different levels of severity with specific definitions. Besides the LTI definition, the following conditions are defined: Near Miss, First Aid Case, Recordable Injury/Illness Case (Medical Treatment), Restricted Work Case, High Potential (HiPo) Incident, Major Incident (MIA), Recordable Fatality and Road Accidents. For the calculations and comparisons the LTI per 1 million work hours are applied. Due to the small numbers of cases per year, the averages over all the years, for which data are available, are used for comparisons.

DONG Energy
Data on the number of LTA-1-Day as defined: not able to work the following day after the injury, on the fixed installations. The Siri Platform plus two additional satellite platforms had no personnel working. DONG took over as operator of the Siri area in the autumn of 2002, so the data cover the period 2003-2007. (Danish Energy Agency Offshore Sector Guidelines Executive Order 644 of 25 June 2008).
Concerning the mobile installations there are only data for 2007-8, which, however, were not available to be included in this analysis.

**The Danish National Board of Industrial Injuries (Arbejdsskadestyrelsen)**

Occupational injuries should legally be reported to the National Board of Industrial Injury in case of fatal injuries and injuries with suspected disablement, loss of work capacity, more than 5 weeks loss of work time or a need for coverage of treatment costs. The Board keeps a register of all cases with applied specific definitions and codes based on the national industrial coding system. Information about the injury cases reported for compensation was obtained by personal contact to the Danish Board of Industrial Injuries relating to the codes 111000 and 112000 for extraction of crude oil and gas and related services (“udvinding af råolie og naturgas” + “serviceydelser”).

**Emergency ward treated injuries (Sydvestjysk Sygehus, Esbjerg) register**

Information on medically treated injuries from all industries registered by the Nomesco coding system at the emergency ward on Sydvestjysk Sygehus is available from the National Institute of Public Health, [http://www.si-folkesundhed.dk/Statistik/Ulykkesstatistik/Tabeller.aspx](http://www.si-folkesundhed.dk/Statistik/Ulykkesstatistik/Tabeller.aspx).

The data code used for the offshore injuries is “Extraction of crude petroleum, natural gas, etc”. There is an increasing trend in 2000-2007 of the incidence rates of these injuries. It is, however, unknown whether the data are coded correctly and whether they include injuries occurring at the oilrigs situated in the harbour of Esbjerg. Results and discussion of the data from the Emergency ward is presented in APPENDIX 1.

**Danish Working Environment Authority onshore legal injury reporting criteria**

The criteria for legal notification of onshore injuries are identical to those applying for the offshore platforms (LTA > 1 day). The notifications are sent to the Danish Working Environment Authority. Injuries that are supposed to give permanent incapacity or to be compensated for the costs of treatment etc. must be reported to the Danish Board of Industrial Injury. The annual injury statistics are available on the Internet for both the LTA > 1 day and include cases notified and recognised for compensation.

**Norwegian offshore injury inclusion criteria**

All reportable injuries should be reported to the Norwegian Energy Authority, “Petroleumstilsynet” in Stavanger. Information on the number of reported injuries for 1990-2007 was provided by personal contact to Petroleumstilsynet ([http://www.ptil.no/forside/category10.html](http://www.ptil.no/forside/category10.html)).

Notified injuries are classified according to medical criteria by two main categories (below) including fatal injuries, with cases with lost working time (LTA) in both categories. The reports include only injuries that happen offshore. It is informed that “Petroleumstilsynet” does not focus on” LTA
due to constraints with getting valid data. Besides the fatal injuries, there are two reportable injury categories.

Norwegian offshore Injury categories

**Injury category 1:** Fatal and serious injuries with the following criteria:
- a) Head injury with concussion, loss of consciousness or other serious consequences
- b) Loss of consciousness due to occupational exposures
- c) Bone fractures, exclusive finger and toe fractures
- d) Injuries to inner organs
- e) Complete or partial amputation of body parts
- f) Intoxications with risk of permanent health damages (like H₂S-intoxications)
- g) Skin injuries like burns, frost injuries or chemical burns of 3rd degree, or partial burn injury in the face, hands, or feet, or all damages that cover more than five percent of the body surface
- h) Hypothermia
- i) Permanent or long time incapacity for work

**Injury category 2:** All compulsorily notified injuries in category 2 include those with medical treatment given by physician or nurse (First aid cases are not included, even if provided by a physician).

UK offshore injury inclusion criteria


Further information was obtained through personal correspondences with the HSE info line.

**Reportable major injuries:**
- a) Fractures, other than fingers, thumbs and toes;
- b) Amputation; Dislocation of the shoulder, hip, knee or spine;
- c) Loss of sight (temporary or permanent);
- d) Chemical or hot metal burn to the eye or any penetrating injury to the eye;
- e) Injury resulting from an electric shock or electrical burn leading to unconsciousness, or requiring resuscitation or admittance to hospital for more than 24 hours;
- f) Any other injury: leading to hypothermia, heat-induced illness or unconsciousness; or requiring resuscitation; or requiring admittance to hospital for more than 24 hours;
- g) Unconsciousness caused by asphyxia or exposure to a harmful substance or a biological agent;
- h) Acute illness requiring medical treatment, or loss of consciousness arising from absorption of any substance by inhalation, ingestion or through the skin;
i) Acute illness requiring medical treatment where there is reason to believe that this resulted from exposure to a biological agent or its toxins or infected material

Reportable over-three-day injuries
An over-3-day injury is one which is not "major" but results in the injured person being away from work OR unable to do the full range of the normal duties for more than three days.

The Australian offshore injury inclusion criteria
“Australian Petroleum Production & Exploration Association Limited” (APPEA) was responsible for the injury data registry in the offshore industry until 2005 (http://www.appea.com.au). Since January 1st 2005, the “National Offshore Petroleum Safety Authority” (NOPSA) has been the legal regulator in Australia (http://www.nopsa.gov.au/board.asp). The data presented in this context are based on the APPEA reports: Health Safety and Social Performance Report 2003 and 2005-6 and APPEA Annual report 2001. The APPEA injury criteria are categorised as: Fatalities, total reportable injuries (TRI), LTI, medical treatment injuries (MTI), and alternative duties injuries (ADI).

The LTI are defined as those resulting in a permanent disability and/or time lost of one complete shift or day or more as described in the medical certificate.

MTI are those for which treatment is required, whether in a hospital or with a first aid kit.

ADI are those injuries after which a worker is unable to continue for a period of time in his or her normal activities, and so is assigned other work until full recovery.

There is no information about the specific number of reported injuries in the categories. However, the incidence rates for LTI > 1 day were provided for the 1993-2003 per 1 million working hours (see 2.5 next section). The data cover onshore platforms as well as onshore processing data.

The US oil- and gas extraction injury inclusion criteria
The USA Bureau of Labor Statistics uses three types of inclusion criteria: 1) cases with days away from work, 2) cases with job transfer, and 3) other recordable cases. The criteria: “Cases with days away from work” is used here. This is not identical definition as the Danish inclusion criteria (LTA > 1 day) but the nearest comparable indicator that is available: (http://www.bls.gov/iif/oshsum.htm).

The OGP injury inclusion criteria
The OGP Safety performance indicators - 2005 data Report No. 379 May 2006 (www.ogp.org.uk) define the indicators used for international comparison: Number of fatalities, fatal accident rate, lost time injury frequency and total recordable incident rate. The annual reports inform that the injuries with at least one day off work are included.
Table 2: Overview of the main injury inclusion criteria used:

<table>
<thead>
<tr>
<th>Country</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>The DEA: LTA-1-day&lt;br&gt;MOG: LTA-1-day (6 internal registration criteria in all)&lt;br&gt;HESS: LTI and Medical Treatment Cases and RWC Dong Energy: LTA-1-Day&lt;br&gt;Onshore: LTA-1 day (+ Restricted Work day Cases included from 2005)</td>
</tr>
<tr>
<td>Norway</td>
<td>Serious injuries (according to a list of inclusion criteria)&lt;br&gt;All reportable injuries (medical treatment, not only first aid)</td>
</tr>
<tr>
<td>UK</td>
<td>Reportable major injuries (according to a list of specific criteria)&lt;br&gt;Reportable are LTA-3-Days</td>
</tr>
<tr>
<td>Australia</td>
<td>The LTI one complete shift/day or more&lt;br&gt;MTI&lt;br&gt;ADI</td>
</tr>
<tr>
<td>USA</td>
<td>Injury cases with days away from work (unspecified number of days)&lt;br&gt;Injury cases with job transfer or restriction&lt;br&gt;Other recordable cases</td>
</tr>
<tr>
<td>OGP</td>
<td>Lost time injuries</td>
</tr>
</tbody>
</table>
The incidence rates reported

Danish Energy Agency: The overall accident frequency offshore

The Annual Reports from the DEA gives the “overall accident frequency” for fixed and mobile platform units, respectively.

Discussion: “Frequency” can be defined as a measure of the number of occurrences of a repeating event per unit time. It can be discussed whether injury events are “repeating events”. In addition, “frequency rate” is not an epidemiological concept, so it would be more convenient instead of using the term “accident frequency” to calculate the injury incidence rate per 1 million working hours.

Incidence rate per 1 million working hours = number injuries / number of working hours in millions

Maersk Oil- and Gas

Annual information on LTA-1-day accident frequency rates per 1 million working hours is given for 1984-2007, separated for mobile and fixed units, and used for comparison.

Hess Denmark

Incidence rates for LTI and Medical Treatment Cases (MTC) are given for 2000-2007, South Arne EHS statistics. The “LTI” is defined as LTI (equivalent to LTA-1-day) per 200,000 working hours (similar to the US standard for BLS incidence rates calculations).

The rates in the graphics provided by the company are per 200,000 working hours. The incidence rates used in this context are calculated per 1 million working hours based on the information on the total hours of work and the number of LTI’s from the company.

DONG Energy Denmark

The Injury Frequency Rate calculated as lost time LTA-1-day 1 million working hours is given for 2003-2007 for fixed units and for 2007-2008 for mobile units, respectively.

Norway

Offshore injuries per 1 million working hours: 1990-2007, split up in “serious” and “all reportable injuries” was given by personal contact to Petroleumstilsynet, Stavanger, Norway.
United Kingdom

Offshore injury incidence rates: Injury incidence rates for 3-days lost time injury, major injury and fatal injury are available per 100,000 workers per year for the period April 1995 - March 2008 (HSE -Report: “Offshore, Injury, Ill Health and Incident Statistics 2007/2008 HID Statistics Report HSR 2008 – 1 Dec 2008). Neither the population data used nor the injury criteria (LTA-3-days) are comparable to the Danish data. However, as the same criteria have been continuous over the years, the trends of the injury incidence rates can be compared.

For comparison, the UK injury incidence rates/100,000 are recalculated to rates/500 persons that corresponds to rates/1,000,000 working hours with a working year of 2000 hours.

Australia


The incidence rates include data from offshore platforms and onshore processing activities.

The incidence rates are presented in a graph. No tables with the precise numbers are available.

USA

Oil- and gas extraction injury incidence rates: The USA Bureau of Labor Statistics tabulates the incidence rates of nonfatal workplace injuries for the specific sectors, (http://www.bls.gov/iif/oshsum.htm). The incidence rates criteria: “Cases with days away from work” is used here. This criterion is not expressed with the exactly same words as the Danish inclusion criteria (LTA > 1 day) but constitutes the most comparable indicator. The industry SIC code for 1995-2002 is code 13 “Oil and gas extraction”. For 2003-2007 the NAICS code 211 “Oil and gas extraction” is used.

The International Association of Oil & Gas Producers oil- and gas extraction

The OGP uses “Lost time injury frequency” which is defined as the number of lost time injuries (fatalities and lost workday cases) incidents per 1 million working hours. The “hours worked” for offshore workers are calculated on a 12 hour workday.
Table 3: Terminology used for “injury incidence rates”

<table>
<thead>
<tr>
<th>Country</th>
<th>Agency</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>DEA</td>
<td>“Overall accident frequency / 1 million working hours”</td>
</tr>
<tr>
<td></td>
<td>MOG</td>
<td>“LTA-1-day accident frequency rates / 1 million working hours”</td>
</tr>
<tr>
<td></td>
<td>HESS</td>
<td>“Lost time Injury / 1 million working hours worked”</td>
</tr>
<tr>
<td></td>
<td>Dong</td>
<td>“Injury frequency rate / 1 million hours worked”</td>
</tr>
<tr>
<td>Norway</td>
<td></td>
<td>“Injuries / 1 million working hours”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Injury rates / 100,000 workers” (per year)</td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td>“Lost time injury frequency rates / 1 million working hours”</td>
</tr>
<tr>
<td>USA</td>
<td></td>
<td>“Incidence rates of non-fatal occupational injuries / 200,000 working hours”</td>
</tr>
<tr>
<td>OGT</td>
<td></td>
<td>“Frequency rate of lost time injuries /1 million working hours”</td>
</tr>
</tbody>
</table>

*Trends of the incidence rates related to the safety programmes*

Information on the legal regulations and the implemented safety programmes was obtained from the annual reports from the DEA, 1984-2007.

*Protection of personal information*

This study is notified and recognised by the Danish Data Protection Agency (DPA). The author is responsible that all personal and company data are protected against third parts according to recommendations of the DPA.

*Data analysis and statistics*

The data have been entered and analysed in Excel data files. 95% confidence intervals for incidence rates and for relative risks are calculated by use of Open Source Epidemiologic Statistics for Public Health, Version 2.2.1. www.OpenEpi.com. The relative risks of injury incidence rates are calculated as one incidence rate divided by another incidence rate, for example the incidence rate for offshore compared with the incidence rates onshore:

\[
\text{RELATIVE RISK (offshore/land)} = \frac{\text{INCIDENCE RATE (offshore)}}{\text{INCIDENCE RATE (land)}}
\]
Results

The Danish Offshore Sector 1988-2007

The Danish offshore activities increased significantly over the last decades. Figure 2 shows the development of the annual working hours in millions 1988-2008 on both types of installations as reported to the DEA. The number of persons working offshore in the Danish oil and gas extraction installations is about 3000 in 2007.

Figure 2: DEA. Million work hours on fixed and mobile installations

Figure 3 presents the numbers of millions of working hours on fixed installations (the blue line) and mobile installations (the red line) side by side so that relative numbers of working hours on drilling and installations can be compared. Most years the majority of the working hours have been performed on the fixed installations. The annual numbers of working hours on the mobile

Figure 3: Total working hours in millions on mobile and fixed installations Danish offshore sector
installations only exceed the number of hours on the fixed installations in 2000. The trend lines indicate a higher increase in the fixed (production) installations than the mobile installations.

The total numbers of LTA-1-Day injuries reported from both types of Danish offshore installations are presented in Figure 4. Overall there is a decreased trend in the period. There are large fluctuations over the time with a sharp decrease in 1987-1989 and a marked increase in 2001-2003 followed by a decreasing trend.

![Figure 4. DEA Number of reported accidents on fixed+mobile installations Danish offshore sector](image)

The incidence rates per 1 million working hours in Figure 5 show the same pattern as the number of reports. There is a decreasing trend line over the whole period with fluctuations and the highest increases during 2001-2003 on the fixed installations.

![Figure 5. Incidence rates per 1 million working hours Danish offshore sector](image)
The incidence rates for both fixed and mobile installations with 95% confidence intervals are presented in Figure 6. The largest changes occurred in 1987-88, 1988-89 and in 2001-02 as indicated by the three arrows.
Table 4 present the relative risks of the most significant changes of the incidence rates in the period based on the data from the DEA for offshore installations. The relative risk for 1987-88 is calculated by dividing the incidence rates 1987 with the incidence rates for 1988. The relative risk for 1988-89 is calculated by dividing the incidence rates for 1988 with the rates for 1989. The relative risk for 2001-2002 is calculated by dividing the incidence rate for 2002 by the incidence rate for 2001. The 95% statistical confidence intervals have been calculated by use of the Open-Epi programme. The relative risks for 1987-88, 1988-89 and 2002-2001 are all statistical significant.

Table 4: Relative risk of significant changes of the incidence rates in the period 1986-2007 with 95% confidence intervals and p-values. Data are based on the reported data to the DEA.

<table>
<thead>
<tr>
<th></th>
<th>Relative Risk</th>
<th>95% confidence intervals</th>
<th>P-values (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987-88</td>
<td>0.42</td>
<td>0.28-0.62</td>
<td>0.001</td>
</tr>
<tr>
<td>1988-89</td>
<td>0.41</td>
<td>0.22-0.74</td>
<td>0.003</td>
</tr>
<tr>
<td>2001-02</td>
<td>2.71</td>
<td>1.60-4.60</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Comparison of the incidence rates offshore with all trades on land 1986-2007
The trends of the incidence rates of notified LTA-1-day per 1000 persons, employed in all types of industrial trades on shore 1979-2007 as reported to the Danish Working Environment Authority, are presented in Figure 7. The rates are based on the number of persons at work. There is an overall slightly increasing trend over the three decades.

The trends of the incidence rates for LTA-1-day notifications offshore 1984-2007 show a major decrease in 1987, while there are no major changes 1979-2007 in the onshore trades (Figure 8).
Changes of number of working hours and the incidence trends

The average number of onshore working hours per year has gradually increased as shown in Figure 9.

There has been a slightly decreased trend for the incidence rates in spite of increased working hours as seen in Figure 9, where the person numbers are used in the denominators. In Figure 10, the incidence rates for LTA-1-day onshore are presented with the changed working hours taken into account.
Relative risk for LTA-1-day offshore and all trades onshore

Figure 11 presents the relative risks for LTA-1-day injury incidence rates offshore-onshore where the blue line point out the relative risk= 1.0. The incidence rates are based on the numbers of hours worked onshore and offshore. The overall pattern of the relative risk is decreasing after 1990 with an increase in 2001-2 and a decrease thereafter.
Danish Operators 2000-2007

The trends of the incidence rates from the fixed installations reported from the MOG and the DEA are compared in Figure 12. The trends for 1988-1998 are nearly identical for MOG and DEA. For 1984-1988, there is steeper decrease for the MOG incidence rates compared to the DEA rates. For 2001-2003, the increase in MOG incidences is less than the DEA increase.

![Fig 12. Incidence rates LTA-1-Day per /1 mil work hours for fixed (production)installations (MOG and all reported to DEA) 1982-2007](image)

**The incidence rates for 2000-2007 for the Danish operators**

Data for comparison the incidence rates for fixed installations for 2000-2007 are available for MOG and Hess Denmark while the data from Dong Energy are only available for 2003-2007. The results are presented in Figure 13: The incidence rates for Dong Energy are highest initially and later approaching the same level as the others. The average incidence rate for fixed installations as notified to the DEA for 2000-2007 for all three Danish Operators was 7.2 LTA per 1 mill working hours.
There is an overall downward trend for all operators. The average incidence rates for LTA’s during 2000-2007 are calculated for Hess Denmark and for MOG and for Dong Energy for 2003-2007. The calculated averages are 9.2, 4.4, and 3.6 LTA’s per 1 million working hours for Dong Energy, MOG and Hess Denmark, respectively.

The large variations for the operators Hess Denmark and DONG are expected due to the relatively few number of LTA-1day cases, and the comparison between the companies is unstable due to the small numbers of LTA’s. Hess Denmark had 0 LTA in 2006 and in 2007.
Reports to the Danish Energy Agency 2000-2007

The total incidence rates of the LTA-1-day notified to the DEA, including the LTA > 5 weeks lost time injuries, are compared to the available data from The Board of Industrial Injuries 2000-2007 (Figure 14). The incidence rates for the LTA-1-day injuries decreases after 2003 while the incidence rates of notified and the recognised injuries offshore and the LTA > 5 weeks reported to the DEA increased slightly in the period.

During the first half of the period, the number of working hours increased, followed by a decrease as presented in Figure 15. The increased working hours may explain some of the increased incidences of LTA, conditioned a substantial part of the extra working hours are performed mainly by new and less experienced employees and this aspect needs to be further investigated.
Slips, Trips and Falls

In the annual reports, the DEA has calculated the number of injuries related to slips, trips and falls out of the reported LTA-1-day cases 1998-2007. The injuries related to slips, trips and falls constitute 30-50% of all reported injuries.

The incidence rates, however, have not been calculated before. Due to the large proportion of slips, trips and falls and the high potential for prevention it seems relevant to give more attention to these injuries.

The Incidence rates during 1998-2007 for all injuries and for slips, trips and falls / 1 mill working hours on fixed installations are presented in Figure 16. The incidence rates for the mobile installations are only available for 2003-2007 (Figure 17).
The incidence rates of slips, trips and falls show a decreasing trend parallel to the trend of all types of injuries on mobile and fixed installations (Figure 17). For the mobile installations it seems that slips, trips and falls have been prevented more effectively.
The proportions of slips, trips and falls are presented in Figure 18 and still constitute more than 25% of all types of injuries. There is an important potential for improving prevention, especially on fixed installations.

![Figure 18. Slips, trips and fall related injuries as percentages of all injuries on mobile and fixed platforms 1998-2007 (Data from Danish Energy Agency)](image)

**Trends of the injury incidence rates in five countries 1992-2007**

The trends of the incidence rates 1992-2007 for Denmark, Norway, UK, Australia and US are presented in Figure 19. The injury inclusion criteria are those reported by each country. The denominators used are per 1 million working hours, except for the UK where the incidence rates are given per 100,000 persons employed. In order to obtain visual comparability in the graphs, the denominator data are recalculated and presented as incidence rates are per 500 persons per year. The injury inclusion criteria are “all reportable injuries” for Norway and LTA-3-days for the UK. For the other three countries, the LTA-1-day inclusion criteria are used. In Figure 21 the data from offshore Norway also include the incidence rates for the most serious injuries and for all reportable injuries.

There is a steep decrease of the LTA-1-day incidence rates in Denmark 1987-1989 and a similar decrease of “all reportable injuries” in Norway later in 2000. The incidence LTA-1-day rates in the US do not show the same steep decrease but gradually decreases over the years. Data about the trends are not available for UK and other countries before 1993. Similar data from Holland show the same sudden downwards trend but delayed a couple of years later than for Denmark (please see the literature review).

The trend of the incidence rates of the most serious injuries in Norway and the trend of the incidence rates of the LTA-3-days from the UK run almost parallel with a slight decrease in the period.
Figure 19: Trends of the injury incidence rates in the oil- and gas industry in 5 countries 1984-2007 with specific definitions of the inclusion criteria and denominators.

- UK incidence rates LTA-3-days offshore /500 workers/year
- NORWAY incidence rates offshore all reportable injuries/ 1 mill hours
- USA incidence rates oil- and gas extr LTA-1-day/1 mill hours
- DENMARK incidence rates LTA-1-day offshore /1 mill hours
- AUSTRALIA incidence rates LTA-1-day oil-and gas extract /1 mill hours
Figure 20: Incidence rates of injury rates in the oil- and gas industry in 5 countries 1992-2007 (fixed and mobile installations)

- NORWAY incidence rates offshore all reportable injuries/1 million hours
- NORWAY incidence rates offshore SERIOUS injuries/1 million hours
- USA incidence rates oil- and gas extr LTA-1-day/1 million hours
- DENMARK incidence rates LTA-1-day offshore /1 million hours
- AUSTRALIA incidence rates LTA-1-day oil-and gas extract /1 million hours
- UK incidence rates LTA-3-days offshore /500 workers/year

The trend of the overall decrease of the incidence rates based on the total LTA-1-day notified to the DEA 1986-2007 is statistical significant with a p-value <0.001 (Figure 21).

The trends for the period 1979-2007 for LTA-1-day incidence rates offshore compared with the trends for the onshore industries are shown in figure 22. The trend for the onshore LTA-1-day incidence rates fluctuates slightly, and without any large changes in trend such as the steep fall in the offshore incidence rates during 1986-1989.

The large decrease of the LTA-1-day incidences in the late 1980s was followed by a slight overall decrease of the incidence rates 1990-2007 as seen in Figure 23.
The overall changes of the incidence rates 1986-2007 and the main safety programme implementations in the period are shown in Figure 25. The first set of legislation for offshore Oil and gas installations (Hav-anlægslov) was implemented in 1981. The specific set of legislation for the DEA from 1986 implemented the regulation of the offshore working environment. In 1987, MOG implemented an extensive training and information campaign for prevention of all unsafe acts for all employees in the offshore industry. The marked reduction of the incidence rates started before the British Piper Alpha platform explosion on July 6, 1988 with 167 lives lost.

Figure 23. Overall trend of incidence rates LTA > 1 day fixed+mobile inst/1 mill work hours 1990-2007
The significant increase of LTA-1-day incidence rates 2001–2002 has been commented in the DEA annual report for 2002 and the operators were asked for their possible explanations. There is also an increase in dangerous occurrences, such as gas leaks, and all these incidents were supposed to be caused mainly by disregard of safety procedures, which again was related to many new and relatively inexperienced employees.

The annual number of working hours increased gradually with small variations in the years 1988-2007.

In general, the variations of the average number of working hours do not follow the variations of the incidence rates. There may, however, be a relation between the increased incidence rates in 2002 and the increased number of working hours, which is presented later (Figures 25 and 26).
Figure 25. Working hours and incidence rates on mobile installations 1988-2007

Figure 26. Incidence rates for LTA-1-day reports to DEA and work hours in millions for all Danish fixed offshore installations
Discussion

The Danish offshore injury rates compared with the onshore industries

Comparison of the offshore LTA-1-day incidence rates based on working hours in the denominator with that of all trades on land 1986-2007 by use of the same injury inclusion criteria has demonstrated a lower relative risk offshore 1990-2007 for all the years. The relative risk is nearly about 0.5 during most of the 1990s.

However, due to differences of the compared populations this result may to some degree be somewhat biased. The onshore population includes nearly one million persons some of which may have an occupation with a low LTA-1-day injury risk. The offshore employees have a multitude of different skills and include blacksmiths, electricians, engineers, painters, scaffolders, catering staff, management, supervisors and operators, so that the workforce on average is more a group of manual workers out of which, e.g. those engaged in metal work, due to the character of their work would be likely to carry an increased risk of injury. A better group for comparison would be from land-based manufacturing, building and construction and service industries, which would reduce the risk difference.

It is also of importance to note that the underreporting onshore is estimated to be about fifty percent. Offshore it may well be smaller due to a high level of safety culture. On the other hand, notification demands at least one day of lost time and it may be subject to interpretation whether an accident cases lost time if the worker is not evacuated but can perform other tasks offshore in spite of the injury. Another important aspect is that the numbers of working hours onshore are changing over the years. Consequently, in future comparisons adjusted working hours should be used in the denominators both for onshore and for offshore to avoid the bias due to incomparability of the populations.

If the potential differences with regard to underreporting and if the populations are comparable, the injury risk level offshore is expected to be much lower than the average on shore.

Trends of the injury rates 2000-2007

The incidence rates for the LTA-1-day injuries for the Danish Operators have been decreasing 2003-2007. During the same period, however, the incidence rates of notified and recognized injuries offshore to the National Board of Industrial Injuries and the LTA > 5 weeks reported to the DEA increased slightly. There is no explanation of this increase for the more serious injuries. However, the contrast may indicate underreporting of milder cases. This could be analysed further by using register data for the offshore population and use of personal identification numbers to compare with the data in the injury compensation registers.

The number of working hours increased in part of the period that has been studied and this was followed by a decrease, as presented in Figure 17. The increased incidences of LTA-1-day, especially in 2002-2003 may be due to the employment of many new and less experienced employees.

The legally applied criterion for occupational accidents that may be accepted by the Danish National Board of Industrial Injuries was changed in January 2004 so that it became broader than
previously. The current legislation requires notification for “An injury caused by an occupational event or exposure, that happens suddenly or within five days”. In contrast to the old definition, the current definition includes lifting injuries and injuries caused by an exposure of a few days duration, e.g. bursitis of the knees due to a specific work task involving climbing within five days of exposure. This could be some of the explanation for the increased rate of the injury compensation cases.

Slips, trips and falls

The trend of the incidence rates of LTA-1-day related to STF on fixed installations 1998-2007 presented in Figure 16 runs almost parallel with the overall trends of the incidence rates for all types of accidents, though the increased incidence rates for all types of injuries are steeper than for STF’s during 2001-2003.

The incidence rates for the LTA-1-day related to STF on mobile installations during 2003-2007 and the incidence rates for all types of injuries for 1998-2007 presented in Figure 17 again show almost parallel trends of the incidence rates during 2003-2007, and are nearly as parallel as the trends of the fixed installations. The proportion of STF of all injuries is presented in Figure 18 for 1998-2002 for fixed installations and for both types of installations for 2003-2007. The STF proportion of all injuries constituted 60% in 2005 but was reduced for 2006-2007 for both platform types. There is no information about any specific prevention programme aiming to reduce slips, trips and falls, but this would still be of relevance.

The incidence rates in five countries 1992-2007

The comparison of trends for offshore incidence rates during 1992-2007 in the five countries, which is presented in Figure 20, is constrained and form three causes: Firstly, the use of different injury inclusion criteria. Secondly, the use of different denominators; especially the UK uses as the only country the number of persons at work while the other countries use the number of millions of hours worked in the denominator. Thirdly, that USA, and Australia until 2005, both include onshore work in the oil and gas extraction industry. A comparison with the Danish offshore incidence rates is only possible with the Australian figures and only after 2005. However, as the injury incidence rates have been calculated by use of the same criteria during the years, the trends of the injury incidence rates can be compared. The improvement is supposed to be effects of the implemented injury prevention programmes.

Incidence rate trends as possible effect of the prevention programmes

The incidence rates for LTA-1-Day for Maersk Oil fixed platforms/1 million working hours (Figure 12 - 13) are almost identical with the DEA data 1988-1998. The more steeply reduced MOG incidence rates compared to the DEA rates for 1986-1989 and for 2001-2003 are probably an effect of prevention programmes.

Hess Denmark has very low incidence rates for LTI from South Arne for 2000-2007 but due to the small numbers of LTI’s, the statistical intervals are wide and more time is needed for regarding the good results as stable. The injury rates from MOG are similar to the average for Hess Denmark.
The higher number of incidents gives more stable rates and the decreasing trend indicates the stability of preventive efforts in MOG.

The overall reduction of the incidence rates during 1986-2007 may be explained by effective safety programmes (Figure 25) during the period. In contrast, there is no decline after implementation of the first law for offshore Oil and gas installations implemented in 1981 and so probably no direct effect. However, the specific regulations for the offshore working environment implemented by the DEA from 1986 and especially after the extensive training and information campaign for all employees of MOG in 1987 aiming for prevention of unsafe actions for all employees have caused significantly reduced incidence rates. This decrease occurred prior to the Piper Alpha platform explosion 1988 so it could not be attributed to an increased risk attention after the disaster. According to the DEA annual report for 1989, the continued reduction of the LTA incidences is mainly due to the MOG targeted information and training programmes.

The annual DEA reports during 1990-2007 continuously inform on the new implemented or planned safety programme and regulations. Following the gas explosion in 2001 on the Gorm Field with 2 seriously injured persons and about 1 billion DKK loss of oil production, there was no immediate further reduction of the incidence rates.

The significantly increased LTA-1-day incidence rates during 2001–2002 are commented in the DEA annual report for 2002 and the operators have been asked for possible explanations. There has been an increase in dangerous incidents, such as gas leaks, all of which were supposed to be caused mainly by disregard of safety procedures, which again were related to many new and inexperienced employees. This, however, remains to be documented.
Part B: Systematic review of epidemiological studies

Abstract:
A literature search for epidemiological analyses on accidents occurring in the offshore oil and gas industry yielded only two peer-reviewed studies that included data after 2000, one from the USA and the other from the Netherlands. The fatal injury incidence rates in the USA oil and gas industry increased since 1992 and are now about seven times higher than in other industries ashore. In the Dutch study, the incidence rates of lost time accidents > 1 day for contractors in the Dutch offshore industry was reduced – especially in 1992 – and is still decreasing. A significantly decreased incidence rate, particularly for the Exxon Company, some years previously was attributed to be a consequence of a comprehensive preventive programme inspired by the Exxon Valdez disaster.

There is a large amount of safety literature available internationally. As different methods are used in the offshore quantitative safety literature, the injury incidence rates cannot be compared. However, the trend analyses can be compared to assess the effect of the implemented safety programmes, which was also done in part A of the project. Studies on musculoskeletal disorders show that the prevalence of complaints and disorders is comparable to that in the general population. The causes of the disorders are multiple, including psychosocial factors.

Introduction
Publications with injury incidence rates from the oil and gas offshore production have been searched to compare data from the Danish Operators with similar data at an international level.

Only peer-reviewed publications including injury incidence rates from 2000 and later were searched. (The “injury” term is used for “accident”). The database PubMed was searched by using combinations of the following words: injuries, epidemiology, incidence, accident, offshore, petroleum, petroleum drilling workers, and oil and gas industry. Only very few articles were found.

To rule out errors in the search, other searches were done by use of the words: “incidence and injury” which gave 85425 references; “incidence and occupational injury” gave 3009 references and “Injury and incidence and agriculture” gave 367 references, all pointing to confirm that there really are so few epidemiological studies on injuries in the offshore oil and gas industry. “Google” searching was additionally applied and potentially relevant journals for specific search were found in the Electronic Library at the University of Southern Denmark.

Fifteen relevant peer-reviewed journals, all indexed in PubMed, were found and searched directly from their homepages one by one by using the words “offshore and injury”, but without revealing further results. However, as the number of peer-reviewed studies are nearly zero, there is quite a lot of non-peer-reviewed information about safety in the oil and gas offshore sector, for example in the British Health and Safety Executive (www.hse.gov.uk/) and the Society of Petroleum Engineers (www.spe.org/). Specific information about the reported injuries is available on the Internet from the national responsible authorities.
**Results**

Only two studies were found that included incidence rates. Two other relevant studies are based on case series without incidence rates.

The first of the incidence rate studies is an analysis of the fatal injuries in the USA oil and gas production, based on data from 1988-1990 and from 2003-2004 (1). The oil and gas extraction in the USA employed approximately 380,000 workers on approximately 1,300 drilling rigs in 2006. The main result of the study is that the number of fatalities among oil and gas extraction workers increased from 85 fatalities in 2003 to 98 in 2004. The Center for Disease Control and Prevention in the USA (CDC) analysed the data and found an annual fatality rate of 30.5 per 100,000 workers (404 fatalities) during 2003-2006, approximately 7 times higher than the rate for all workers (4.0 per 100,000 workers). Nearly half of the fatalities are attributed to highway motor-vehicle crashes or being struck by machinery or equipment.

The CDC analysed previously the 1988 to 1990 incident reports from the International Association of Drilling Contractors (2). This association is an industry-wide international trade association representing 95% of the world's oil and gas drilling companies. The overall non-fatal incidence rate in 1988 to 1990 was 1.2/100 full-time equivalents and the overall fatal incidence rate was 7.5/100,000 full-time equivalents.

The second study is in Dutch (14). Based on the information in the figures, the incidence rates of all reportable injuries decreased sharply 1992 to 1993. This is mainly due to a reduction in the incidence rates of the contractors that operates supplementary to the main operator (Exxon Mobile Company). The incidence rates of the Exxon Company are much lower at the time when the contractors' rates decreased. There is no information whether a similar decrease may have happened in the Exxon Company (Please see the discussion).

**Studies without incidence rates**

Some years ago Statoil Exploration & Production Norway introduced a new system for categorisation and follow-up of undesirable incidents, including personal injuries. There were 24,400 registered undesirable incidents in the Norwegian division of Statoil for 2002. However, there is no information about the number of workers and about the number of injuries of the total number of undesirable incidents, and the incidence rates cannot be calculated (3).

A study of non-fatal injuries from Greece was based on data from the major injury-reporting system (MARS) and covers 6 years from 1997 to 2003 (4). The figures cover the entire Greek Petrochemical Industry together with the Cyprus Refinery and range from extraction sites and offshore facilities to refineries, production and storage sites in Central and Northern Greece and on the island of Cyprus. The MARS is an injury information network, consisting of local databases in each Member State of the European Union and a central analysis system at the European Commission's Joint Research Centre in Ispra in North Italy. This system does not allow for calculation of epidemiological incidences rates. It is criticised that the information currently available at a European level is not sufficient to come to reliable conclusions regarding the frequency of such events (5). A rough estimate can, however, be calculated based on the total number of personnel working in
this sector that reaches 5000 people from which more than 3000 are employees of the production and storage sites. There were 1024 major injuries during the 6 years and the rough estimate is 57 injuries reported per 100,000 workers. Due to lack of information about the injury inclusion criteria and lack of information of the number of hours worked, no comparisons can be made to the Danish Operators.

**Work-related musculoskeletal disorders**

Acute cases with low back pain are often included in the injury statistics. Other musculoskeletal disorders that are developed gradually are normally not included in the injury statistics. But as the prevention of these disorders is highly important in the offshore health and safety system, studies of these disorders were included in this review. The literature search was done by using the words: prevalence, offshore, oil and gas, prevalence, cumulative trauma disorders, low back pain and musculoskeletal disorders. Only three relevant studies were found.

Offshore workers from a Chinese oil company were invited to complete a self-administered questionnaire providing information on socio-demographic characteristics, occupational stressors, social support, coping style, health related behaviour, past injuries and musculoskeletal pain (6).

The prevalence of musculoskeletal pain over the previous 12 months varied between 7.5% for elbow pain and 32% for low back pain; 56% workers had at least one complaint. Significant associations were found between various psychosocial factors and musculoskeletal pain in different body regions after adjusting for potential confounding factors. Occupational stressors, in particular stress from safety, physical environment, and ergonomics were important predictors of musculoskeletal pain, as was coping by eating behaviour.

The prevalence of musculoskeletal disorders (MSD) was assessed in a cross-sectional study in 2000 among employees in the UK oil and gas industry, predominantly on offshore installations (7). Assessed by the Nordic Musculoskeletal Questionnaire (N=321), 80% of the sample reported that they had experienced some form of MSD in the past 12 months; 37% reported that they had experienced one or more problems over the past seven days. Low back problems were most frequently reported, 51% of the sample had experienced such problems in the past 12 months, and 17% during the past week. The prevalence rate of neck, shoulders and/or upper back MSD was also 17%. Mental health, workload, physical environment stressors, and body mass index predicted musculoskeletal disorders with a different relative importance across different body areas.

A Norwegian review of epidemiological studies on health conditions among offshore petroleum workers included a few peer-reviewed publications and none with data illustrating incidences or prevalence after 2000 (8-11). The authors expressed a doubt whether the prevalence of musculoskeletal disorders differs from that among onshore workers. They propose that the main risk factors are physical stressors and a fast pace of work. Among catering personnel, these disorders are important causes of loss of the required health certificate and a need for further study in this area is stressed. Better knowledge of the causes of loss of the health certificate may contribute to preventing early retirement.
The work-related diseases from Norway’s offshore petroleum industry notified by the physicians to the Petroleum Safety Authority were analysed (12). For the period from 1992 to 2003, there were 6725 cases of work-related diseases out of which 3131 were musculoskeletal disorders (47%). The other large disease groups were hearing loss (25%) and skin diseases (15%). Among the musculoskeletal disorders, upper limb disorders accounted for 53%, back disorders for 20% and lower limb disorders for 16%, of which knee disorders dominated (12% of all cases).

The dominant occupational categories were maintenance work (40%) and catering (21%). Frequently reported types of exposure were high physical workload, repetitive work and walking on hard surfaces/climbing stairs and ladders. A total of 1709 cases of occupational hearing loss were reported with variable incidence of reported hearing loss, from 1 per 1000 in 1992 to 9 per 1000 in 2002, demonstrating that hearing loss is an important health challenge (13).

Discussion

The fatal injury incidence rate in 2003-2006 was seven times higher in the USA oil and gas productions than for all workers in the USA. Approximately 25% of U.S. oil and natural gas production comes from offshore areas and half of the fatal injury is traffic injuries. The fatal injury incidence rate during 2003-2006 of 30.5 per 100,000 workers is much higher than the incidence rate of 7.5 per 7.5/100,000 full-time equivalents for 1988 to 1990. The results might be biased due to different calculation of full-time equivalent (workers) in the two data collection periods. Another possible source of bias is that the data from 1988 to 1990 was collected from nearly all drilling contractors, while the data for 2003-2006 is only for the USA. As the USA data comes from both onshore and offshore production, the data cannot be compared with other countries with oil and gas production being predominantly done offshore.

The second epidemiological study is only in Dutch language but some results can be understood from the illustrative graphs. The injury incidence rates of all reportable injuries decreased dramatically from year 1992 to 1993 among the contractors. This level among the contractors had been kept on a level of about 40 injuries per 1 million working hours and decreased to about 10 per 1 million working hours. The dramatic decrease in the rates did not occur in the Exxon Mobile sector, because in this company had already reduced the incidence to a lower level with less than 10 injuries per 1 million working hours in 1987-1989.

The company informed that the risk prevention success is due to the “Operations Integrity Management System” (OIMS), which is a comprehensive and effective safety programme that is integrated in all aspects of the company activities. Therefore it might be wise to learn from the programme.

The study of musculoskeletal disorders among Chinese offshore petroleum workers and also the British study (7) show that these disorders are indeed common and causally related to many different risk factors, including psycho-social factors (6-7). The authors of the Norwegian review of musculoskeletal diseases expressed a doubt whether the prevalence of musculoskeletal disorders differs from that among onshore workers and the same was expressed in the British study (8).
notified work-related diseases among Norwegian offshore workers are the results of long time exposures and do not represent the actual working conditions (12-13).

Besides the few scientific publications, there are some reports that can be used for documentation of health and safety promotion. However, there may be problems with their quality compared to peer-reviewed publications. The methods are not always sufficiently described. The definitions of the injury inclusion criteria or the study populations are absent or unclear. Even where the research quality is good, it may be difficult to get copies of the reports. Another problem arises with reports written in languages other than English. These problems hinder a wide international use of the results and collaboration between the companies and nations.

Conclusions

There is no comparative international studies, but two studies with national incidence data after 2000 and only a few studies with data before 2000 exist. One of the studies, the US study from 2008, analyses the fatal injuries in the US oil and gas production, based on data from 1988-1990 and from 2003-2004. The result is that fatal injuries in the oil and gas production in the USA are seven times higher than for all workers in the USA and the rate increased significantly from 1990 to 2004. However, the data from the USA include both onshore and offshore accidents (and more than half of the accidents happened in the traffic), so these data cannot be compared with other countries. The safety system in the Exxon Mobil Company has obviously been very effective and their hired contractors are more slowly adapting to similar risk prevention systems. The Exxon Company declares that their risk prevention success is due to the “Operations Integrity Management System.” This is a comprehensive safety programme that is integrated in all aspects of the company’s activities. Due to the success of the programme, it might be wise to learn from the programme. Studies of musculoskeletal disorders show that the prevalence of complaints and disorders are on the same levels as in the general population. The causes of the disorders are multiple factors including psycho-social factors.

Recommendations

There is a need for more epidemiological studies of offshore injuries and of work-related diseases to identify the specific areas that need attention. There is a need for epidemiological assistance for staff involved in the offshore injury prevention programmes.
References


Appendix 1

Data from the Emergency department treated injuries for staff in offshore/oil rigs

The medical treated injuries at the emergency ward on Sydvestjysk Sygehus from all industries are registered by use of the Nomesco coding system and the results are available from the National Institute of Public Health, http://www.si-folkesundhed.dk/Statistik/Ulykkesstatistik/Tabeller.aspx.

The National Institute of Public Health (NIPH) maintains the Injury Register based on data collected at emergency departments in four Danish hospitals. One of these hospitals is the Sydvestjysk Sygehus, in Esbjerg, Denmark, which is located near the helicopter transport base to the offshore platforms. The injury coding systems at the hospitals use the Nordic Accident classification system worked out by the Nordic Medico-Statistical Committee (NOMESCO). The data code used for the offshore injuries is “Extraction of crude petroleum, natural gas, etc”.

During the period 2000-2007, the incidence rates of the emergency department treated injuries registered in the NOMESCO system as injuries “Extraction of crude petroleum, natural gas, etc” increased as presented in Figure 1.

![Figure 1. “Extraction of crude petroleum, natural gas, etc” injury incidences of emergency dpt in Esbjerg treated / 1 mill work hours](image)

Oilrigs in the harbour of Esbjerg

During the period 2000-2007 there is an increasing activity of oilrigs repair in the harbour of Esbjerg. Many of the occupational injuries that happen during repair of the oilrigs in the harbour will most probably get medical assistance at the local emergency ward at Sydvestjysk Sygehus Esbjerg. The actual NOMESCO injury classification does not include a specific code for place and work activity that is relevant for oilrig repair work in the harbour. Therefore some of the injuries that occurred during oil rig repair in the harbour may be registered by error as “Extraction of crude petroleum, natural gas, etc” offshore platform injuries, e.g. eye injuries that are most likely to result from grinding and welding during oil rig repair. This potential misclassification hinders
preventive use of the system. There is a lack of coding option for occupational eye injuries and of repair work of offshore installations in the harbour.

The validity of the used Nomescoc accident classification system has recently been studied with the conclusion that the prospective coding system proved problematic, both with regard to correctness and completeness (Ugeskr Læger 2007;169(45): 3856-3861).

The accuracy of the coding system, especially for the possibility to code the place and type of work more specific, remains to be investigated. This can be done by analysing a sample of injury reports from the emergency ward in Esbjerg reported in the Nomescoc system.

The increase in the emergency treated injuries may be due an increase in the injuries from the oilrig in the harbour and not from the offshore sector. The oilrig repair work in the harbour of Esbjerg increased in 2000-2007. The NOMESCO injury register system does not have a specific code for occupational injuries from repair work of oil rigs in the harbour. Injuries from the oil rigs may therefore be coded wrongly as if they were from the offshore oil and gas extraction platforms. If the injuries from oilrigs in the harbour are included in the offshore sector and the working hours are only calculated from offshore, then the incidence rates will increase by error.

**Conclusions**

Since 2003, an increased number of emergency injuries registered at the emergency ward, Sydvestjysk Sygehus in Esbjerg have been coded as offshore injuries. This increase is probably erroneous and may be due to coding as offshore injuries of injury cases occurring at the oilrigs in the harbour. The increase of “offshore” injuries registered at the emergency ward should not be viewed as offshore injuries before this has been analysed in details.