Report on the Health Impacts of Flaring at Mossmorran and Historical Cancer Incidence

Public Health, NHS Fife

October 2019

1. Introduction

This is a summary of work carried out by or for NHS Fife public health department to investigate and assess health-related claims with respect to the Mossmorran plant in Fife. It is intended that this material be made available to any interested members of the public, for their information.

2. Background

Hydrocarbon processing has occurred at Mossmorran on an industrial scale for several decades. For example, ethylene 'cracking' has been carried out there since the 1980s. These operations involve processing streams of hydrocarbon fluids (in this case, usually ethane and other gases) piped from the North Sea via the St Fergus terminal in Aberdeenshire. At times, when these streams overwhelm local storage capacity and processing capability, they are burned off using on-site flares. This may result from either planned maintenance or an unplanned operational interruption. On several occasions over the past twenty years or so, health concerns have been expressed about operation of the Mossmorran industrial site. In particular, claims of locally increased cancer incidence have been made and have been attributed by some to the industrial operations at Mossmorran. Such concerns have been raised after recent conspicuous episodes of flaring there. Most recently, over 900 calls to Scottish Environment Protection Agency (SEPA) were logged during the April May 2019 high level flaring incident.

3. Assessment

The approach to assessing health impact is presented here in three parts: firstly the report provides summaries both of recent public concerns expressed to SEPA as well as the work examining cancer incidence and/or mortality in the surrounding area. This is followed by a search and review of the literature, carried out by Health Protection Scotland (HPS), of the reported evidence of health impacts relating to flaring elsewhere.

1) Public Concerns Voiced to SEPA in Spring 2019

A range of concerns were expressed by members of the public in telephone calls to the SEPA pollution hotline during April 2019 in response to the unplanned high-level flaring at Mossmorran. These included reference to health and other impacts of the flaring incident at that time. An anonymised text-file log of these calls was made available to NHS Fife. This allowed an analysis in terms of the frequency with which use is made of certain key words. As this file is anonymised we do not know any further information about the callers.

The table below presents the number of recorded comments which include at least one reference to the key word listed and does not represent the number of

individuals reporting these concerns. Among the over 900 calls to SEPA recorded, 291 were reported by SEPA as containing expressed health concerns. Where more than fifty mentions have been made, these are highlighted in **bold.** The number of general calls is disguised to avoid prejudicing evidence that could support enforcement action by SEPA.

Table of health-related concerns in reports to SEPA

Category of Concern Reported	**Expressed concern 'key words'**	**Count**
Sensory Perception	**Noise**	174
	Light/Lit up	73
	Smell/Odour	68
	Taste in mouth	19
General Health	Health (general concerns)	36
	Anxiety/Worry/Stress/Distress/Mental Health	34
	Unwell	11
Respiratory	Asthma	41
	Throat	41
	Breathing difficulties/Wheezing	25
	Cough	13
Other Specific Symptoms	**Sleep**	93
	Headache/Sore head	84
	Eyes	45
	Nausea/Sickness	13
	Cancer/Leukaemia	6
Total of all 'health concerns'		291
General concerns only	Mostly about about nuisance and site safety	>609
Total of all calls		>900

The most frequently cited health concerns related to sensory perception (for example disturbing amounts of noise, bright light and black smoke during flaring activity). The next most frequent were in the general health category. Among the concerns expressed were some about respiratory conditions. Finally, some people spoke about other specific symptoms or conditions with sleep disturbance, headaches, eyes, nausea and cancer being mentioned. Note that we do not know whether these conditions were newly experienced, pre-existing, or were anticipated being caused or aggravated in future, and we have no information about the callers or the people who have the health concern to facilitate further analysis.

Bearing in mind the above caveats, it nevertheless seems likely that callers' worries are driven by what they can readily see, feel and hear during high level flaring. The resulting impacts of these disturbances on physical and psychological health will vary from person to person.

Figure 1 illustrates the geographic location of callers to SEPA making complaints relating to health. Callers from the Cowdenbeath and Lochgelly areas appear to predominate.

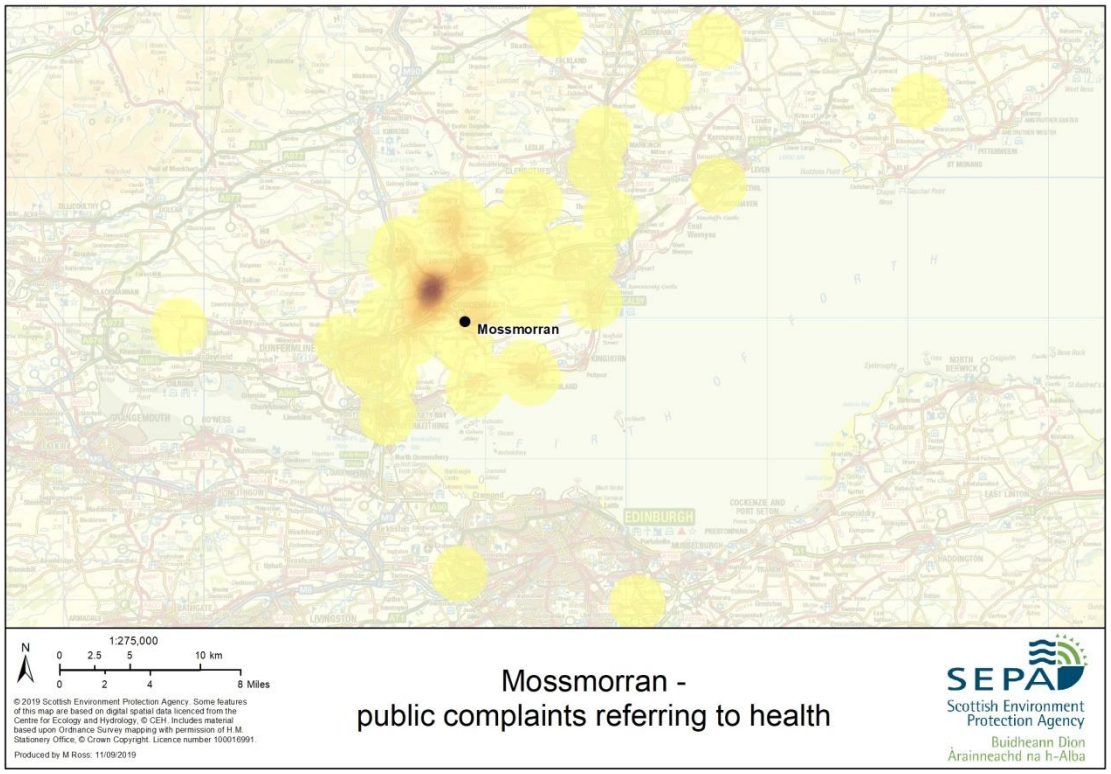

Figure 1 SEPA's heat map of calls

2) <u>Cancer incidence, morbidity and mortality</u>

Analysis of rates of cancer registration, hospitalisations and/or deaths has been undertaken by NHS Fife in recent years. Such analysis typically used publicly available data for the geographical areas in the vicinity of Mossmorran. We searched archived NHS Fife files for these studies. Below is a summary of the findings of these reports and some of the original source material can be found at appendix 1 and appendix 2. Although these electronic archives date from 2006, there is evidence of commentary deriving from earlier studies (although we no longer have access to the primary data on which these were based).

NHS Fife was reported in 2001 to have said 'We found that the rates of cancer in this part of Fife are no different from the rest of Fife, nor of Scotland as a whole'

(http://news.bbc.co.uk/1/hi/scotland/1183324.stm). This suggests that there was found to be no significantly increased risk of cancer attributable to living near the Mossmorran site.

a) Appendix 1 contains a study conducted in 2006 by NHS Fife in which a number of health concerns were considered: cancer, asthma and 'metallic taste'. Analysis of cancer (registration, admission and death) data collated for 2000-2004 in post code sector KY5 9 was presented. This work concluded 'we cannot prove a direct link between a number of environmental concerns and a number of health problems' and found hospital admissions for cancer were *slightly* above the Scottish average. This combined with a *below average* number of deaths from cancer suggesting an earlier diagnosis and better outcome rather than a higher risk.

b) In 2011 a report was produced by NHS Fife in response to a freedom of information request regarding cancer mortality in areas surrounding Mossmorran – see appendix 2. Using cancer mortality rates for geographical areas surrounding Mossmorran no significant difference was found between mortality rates in this area and Fife once deprivation had been taken into account. It is widely accepted that people who live in areas of higher multiple deprivation in Scotland are more likely to die early and have higher rates of illness from certain diseases including cancer and have more years of ill health. We try to take account of these effects to try to discern if there is any effect over and above that due to deprivation.

c) In 2013, NHS Fife reported that after controlling for age, sex and deprivation only one of the 13 areas within Cowdenbeath Area Committee boundaries (which includes those surrounding Mossmorran) had a cancer registration ratio that was significantly different from Fife, and none was significantly different from Fife when looking at cancer death ratios. The data were presented to Fife Council's Cowdenbeath Area Committee – chaired by Councillor Clarke. The Committee accepted the finding that there is no indication from the data of an increase in cancer in the area of Cowdenbeath and went on to discuss the causes of cancer and, in particular, the significance of deprivation.

d) In 2016 and 2017 contributions from NHS Fife to the Mossmorran and Braefoot Bay Air Quality review Group Annual Reports, based on examining publically available rates of new cancer registrations in the areas surrounding Mossmorran together with previous work on cancer mortality, concluded that there was no evidence of higher-than-expected cancer rates in the area surrounding Mossmorran once the effects of deprivation are accounted for.

4. Literature review of Flaring and Health impacts

In response to a request by NHS Fife, Health Protection Scotland (HPS) carried out a search and review of literature relating to reported health impacts of flaring (see Appendix).

Search Methods

In order to identify any available evidence, HPS searched dedicated literature review databases (OVID Medline), as well as Google Scholar, Google and a number of national and international organisations' websites.

Searches looked at a number of issues associated with the flaring process, namely emissions to air, noise, light and vibration. For emissions to air, because these are very dependent of the specific process or industry involved, evidence was only considered if it related specifically to ethylene cracker plants. Since any type of flaring process may generate noise, light or vibration issues, HPS also looked for evidence relating to flaring-associated noise, light and vibration at ***any*** industrial sites, including ethylene plants.

Searches aimed to identify evidence relating to general health impacts, as well as a number of specific health outcomes, which were thought might potentially be linked to flaring activity, including hypertension, sleep disturbance, mental health, respiratory conditions, and anxiety.

Findings

Despite carrying out an extensive search for evidence, very little relevant information was identified.

Airborne Emissions

The only evidence identified relating to health and airborne emissions did not specifically relate to ethylene cracker plants and was for different oil and gas industries. This evidence was not, therefore, considered relevant to the situation at Mossmorran. The only evidence relating specifically to airborne emissions associated with flaring at an ethylene plant was produced for the Mossmorran site itself (2017 Annual Report of the Mossmorran and Braefoot Bay Independent Air Quality Monitoring Review Group)[1]. This report concluded that "*in the areas around Mossmorran and Braefoot Bay, the 2010 air quality objective for benzene is being readily satisfied" and that "the work undertaken in 2017 demonstrates that, based on the available data, emissions from the facilities at Mossmorran and Braefoot Bay continue to pose no significant risk to the health of members of the local community*".

Noise, Light and Vibration

When the search was widened to capture evidence relating to noise, light and vibration associated with flaring as part of any type of industrial process (including ethylene cracker plants), no studies were identified that had specifically investigated noise, light or vibration in a systematic or objective manner.

A Health Impact Assessment (HIA) of a petrochemical complex (which included an ethane cracking unit) in the USA identified that flaring was a major community concern in terms of impacts on health and the environment[2]. The authors acknowledged flaring as a potential source of air, noise and light pollution. They also stated that noise and light pollution would continually be generated during operation of the plant, and might, in theory (based on understanding of the generic impacts that have been identified on health in other industrial situations), contribute to specific health impacts. These impacts include stress, cardiovascular disease, sleep interference, and hearing loss (associated with noise pollution), and disruption of the circadian clock potentially leading to health outcomes such as depression, insomnia, cardiovascular disease, and cancer (associated with light pollution). The authors commented in particular on night-time exposure to noise and light, based on the general literature on the impacts of noise and light, rather than based on any actual site investigation.

Conclusions from Literature Review

Despite an extensive search, a very limited amount of evidence on flaring and health was identified. Virtually no evidence was found relating to flaring specifically at ethylene cracker plants. Furthermore, no studies were identified that specifically investigated the impact of noise, light or vibration arising from any type of industrial flaring on health in a systematic or objective manner.

Based on the search and review of literature conducted by HPS, it was not therefore possible to draw any evidence-based conclusions regarding the impact of flaring as an industrial process on the health of nearby communities.

5. Conclusions and recommendations

The complaints to SEPA revealed that direct health concerns were dwarfed by the number of more general complaints about the sight and sound (‘nuisance’) of unplanned (especially high level) flaring events and site safety concerns. Callers far more frequently mentioned the sensory impact of the flaring and health effects mostly related to symptoms potentially attributable to raised levels of anxiety, annoyance and sleep disturbance. Cancer was a minority concern during the recent unplanned high-level flaring episode (six mentions amongst over 900 calls).

We might consider possible health impact mechanisms in the following categories:

a) Non-visible effects of flaring (air quality and cancer risk for example)
b) Direct physical effects of flaring (sleep disturbance, annoyance)
c) Anxiety and stress caused by concern about a) and b)

In relation to mechanism a) and the respiratory symptoms listed above, air quality has been subject to close scrutiny throughout the life of this site and NHS Fife and partners have an ongoing role in monitoring this through the Mossmorran and Braefoot Bay Independent Air Quality Review Group. SEPA, as regulator, monitor air quality more intensively during and after flaring incidents. No significant impact on local air quality has been found. For example, recent monitoring found levels to be four times lower than air quality standards.

It was noted that no evidence-based conclusions could be drawn from the HPS Literature Review.

Whilst the numbers of calls relating to perceived cancer risk have been small, this concern has been raised over previous years. Given the potential seriousness and long-term significance of a cancer health risk, these concerns have been considered carefully and given rise to cancer incidence and mortality studies on several occasions.

None of these have demonstrated any consistent significantly raised incidence of cancer or cancer mortality associated with Mossmorran with no evidence of higher-than-expected cancer rates in the area surrounding Mossmorran once the effects of deprivation are taken into account [1].

In future, should there be any further concerns about such illnesses appearing to cluster here, it might be possible to use a different approach to looking at these sorts of data. This may involve an analysis that takes into account both spatial (geographical) and temporal (time) factors and builds on in the information we have gathered previously. This would need to be undertaken with colleagues external to NHS Fife who have expertise in this field.

It would therefore appear that non-visible effects (mechanism a) of flaring are unlikely causes of local ill health. While there continues to be no evidence of significant negative impacts in terms of air quality or cancer incidence, it is clear that the degree of physical and psychological disturbance caused to people in the vicinity of Mossmorran has been considerable. While intermittent, and unpredictable, the impact of this flaring on local people appears to have increased recently. The sensory challenge presented to the local community by hydrocarbon flaring here is not subtle. Given the degree of nuisance presented by such intense flaring, it would not be surprising if people experienced anxiety, interrupted sleep, or other physical symptoms mediated by their response to

what they can readily see and hear. This indeed appears to be reflected in the calls made to SEPA. It is also clear that some people have experienced ill health that they attribute to the flaring activity. These types of disturbances will be different for some parts of the population than for others. For example, a child or adult with a sensory processing condition will experience some of the above impacts differently to someone without it. Experiencing these disturbances for someone like this could be distressing for both the individual and their family. It is perhaps noteworthy that many of the reported health effects are those which can be caused by or aggravated by anxiety and stress. Thus mechanisms b) and c) above therefore remain as plausible causes of ill health.

For these reasons, it is our view that the overall impact of flaring on people local to Mossmorran in recent years has not been acceptable and could plausibly affect health in the widest sense. NHS Fife would therefore recommend that every reasonable effort to be made to reduce the frequency, duration and intensity of these events.

1. Mossmorran and Braefoot Bay Independent Air Quality Monitoring Review Group. 2017 Annual Report. October 2018. Available from: http://publications.fifedirect.org.uk/c64_MossmorranBraefootBay2017AnnualReportFinal.pdf [accessed 6th August 2019].
2. Minott J.O., et al. Health Impact Assessment of the Shell Chemical Appalachia Petrochemical Complex. Clean Air Council, 2014. Available from: http://cleanair.org/wp-content/uploads/HIA-Final.pdf [accessed 4th September 2019].

Appendix 1

NHS Fife

Lochgelly Community Council
Health and Environmental Investigation

June- August 2006

1. INTRODUCTION

1.1 Lochgelly Community Regeneration Forum and Lochgelly Community Council have been approached by a number of Lochgelly residents expressing concerns about health and environmental issues. The Regeneration and Community Council members have been responding to some of the concerns based on findings from previous investigations. However it was agreed that some additional work would be undertaken to assist with queries.

2. ENVIRONMENTAL CONCERNS

2.1 *Noise from flaring* †

Noise – The Mossmorran & Braefoot Bay Independent Air Quality Monitoring Group is considering the request for tree planting to reduce noise levels.

2.2 *Vibration from flaring* †

There was a report of damage to windows arising from the vibrations from Mosmorran. This problem is being addressed by the Mossmorran & Braefoot Bay Independent Air Quality Monitoring Group.

2.3 *Environmental pollution*

There are concerns that pollutants from the Mosmorran Plant may be giving rise to environmental pollution. The ongoing monitoring and reporting systems led by Professor Wilson Sibbett (Chair of the Mosmorran & Braefoot Bay Independent Air Quality Monitoring Review Group) report that emission levels from the plant are within National Air Quality Standards. In addition ongoing monitoring of air pollution levels in the local area show no abnormal levels.

† (It was clarified subsequent to the preparation of this investigation report that noise and vibration concerns are issues which fall under the remit of Fife Council's Environmental Services and/or the Scottish Environment

Protection Agency (SEPA), rather than directly the Mossmorran & Braefoot Bay Independent Air Quality Monitoring Review Group).

3.0 HEALTH CONCERNS

3.1 *Cancer incidence*

Members of the public have raised concerns about a number of cancers arising in the area. We do not have information on the types of cancer, age groups affected, occupations, lifestyle factors for the individuals affected. These are all factors which contribute to the development of cancer so we cannot comment on the potential link between environmental factors and cancer development in these instances. Even if this information were available, it may still be difficult to prove a link between cancer and environmental issues in small areas such as at street level where very small numbers of people are involved.

We would be able to investigate an environmental or behavioral link if there was evidence of the same, or similar cancers occurring in a small area within a few years of each other. We do not have this evidence at present to undertake such an investigation. However, all cancer data is registered and if any unexpected trends appear they will be investigated.

Investigations in the past have shown no increased incidence of cancer in the Lochgelly area. Information shows that in the Lochgelly area the number of admissions to hospital with a diagnosis of cancer is slightly above the Scottish average. However the number of deaths from cancer is below the Scottish average suggesting we are seeing an earlier diagnosis but better outcome. This information is attached as Appendix 1.

3.2 *Asthma rates*

There is a view that the number of children suffering from asthma has increased in the area in recent years. Local GPs (General Practitioners) confirmed that they are not aware of any unusual increase in diagnosis. There may be a change in the management of children with asthma as a result of recent guidelines on treatment resulting in more attention given to managing symptoms.

The symptoms of asthma are made worse by passive smoking so it is important to look at how smoking and asthma may be related in the area. The estimated number of smokers in Lochgelly is above the national average. Lochgelly also has above average smoking during pregnancy and smoking related deaths. There is therefore, a considerable amount of work underway to support smokers in smoking cessation programmes.

3.3 *Metallic taste*

Some members of the public reported experiencing a metallic taste. We contacted Scottish Water about the possibility that this could arise from chlorination of the local water supplies. Scottish Water have informed us that no secondary chlorination is used at the two reservoirs in the area: - South Street Service Reservoir & Spion Kop Service Reservoir. In Lochgelly the water supply is from Glendevon WTW and there have been no major problems there. There have been no reports of network flow problems. The perception of taste varies between individuals so it may be that some people are more sensitive to changes in the chlorination levels than others.

4.0 SUMMARY

4.1 The purpose of this investigation was to consider a potential link between exposure to an environmental substances and possible ill health. This is often difficult to prove because many things affect health. Unfortunately it is more difficult to prove a link where there are many symptoms and many environmental exposures, as is the case in Lochgelly. This is because the more symptoms experienced, the more possible causes there may be.

4.2 In this case we cannot prove a direct link between a number of environmental concerns and a number of health problems. This does not mean that the concerns are not real – only that we cannot prove that environmental exposures have caused this range of problems.

4.3 In order to follow up any specific concerns it would be helpful if we could speak directly to members of the public who are raising concerns. In this way we can look at the range of environmental and lifestyle issues which might be possible sources of the problem and identify the most likely cause.

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For further queries please contact Dr Jackie Hyland on 01592 226912

Lochgelly Cancer Statistics ["Appendix 1"]

Summary

For the three year period 2002-2004 KY5 9 had a higher standardised rate than Fife for both cancer registrations and admissions to hospital with a principal diagnosis of cancer (Tables 1 and 2). Standardised cancer registration rates were also higher in KY5 9 than in Scotland as a whole which in turn had a higher rate than Fife. Standardised cancer mortality rates were higher in KY5 9 than in Fife and Scotland for the three year period 2003-2005 although the difference is not as great as observed for registrations and admissions (Table 3).

The number and rates of cancer registration increased in all three areas being considered between 2000-02 and 2002-04 (Table 1). The number and rate of cancer admissions increased between 2000-02 and 2002-04 in KY5 9 but decreased in Fife as a whole. The number of deaths from cancer remained the same in KY5 9 between 2000-02 and 2003-05 but the standardised rate has increased slightly reflecting changes in the population during this time. The number of cancer deaths in Fife and Scotland showed a small increase with a small reduction in the standardised rates.

The population of KY5 9 is just over 6800 and its age profile is not significantly different to that of Fife and Scotland (Table 4). However the deprivation profile using the Scottish Index of Multiple Deprivation (SIMD) is mixed but with more data zones in the most deprived categories. The SIMD is based upon data zones, which are small geographical areas, each data zone has been ranked from most to least deprived. The postcode sector of KY5 9 encompasses 11 data zones, eight fully and three in part. Deprivation population quintiles were generated from the ranked data zones in SIMD so that 20% of the population was allocated to each quintile. Table 5 shows that of the data zones within KY5 9 three are within the most deprived Fife quintile (quintile 5), seven are within quintile 4 and one data zone is within the least deprived quintile.

There are a number of factors to consider when interpreting this data. The information presented is based on an average annual number of events over a rolling three year period. This method has been used due to the small number of events within KY5 9 and is preferable to single year data being used as any changes from one year to the next could have a significant impact. The number of events presented for KY5 9 in the tables below is still relatively small with average annual numbers of cancer deaths being just 24. Calculations based on small number of events are subject to random fluctuations and therefore should be interpreted with caution.

A greater proportion of the KY5 9 area is within the more deprived categories – 89% of the population live in Fife's two most deprived SIMD quintiles. This may also have a bearing on the numbers and rates observed as it is well documented that rates of cancer registrations, hospital admissions and mortality are greater among more

deprived populations (e.g. 26.5% of cancer deaths in Fife in 2004 were people living in the most deprived quintile in Fife).

Table 1: Cancer Registrations

	Average number per year		Crude rate per 100,000		Standardised rate per 100,000[1]	
	2002-2004	2000-2002	2002-2004	2000-2002	2002-2004	2000-2002
KY5 9	75	56	1083.9	817.7	799.2	610.9
Fife	2,940	2,455	834.5	702.2	660.3	537.5
Scotland	49,373	34,457	975.1	680.9	770.6	545.6

Table 2: Cancer Admissions[2]

	Average number per year		Crude rate per 100,000		Standardised rate per 100,000[1]	
	2002-2004	2000-2002	2002-2004	2000-2002	2002-2004	2000-2002
KY5 9	287	225	4166.1	3270.9	3394.2	2564.6
Fife	10344	10636	2935.5	3042.7	2512.5	2600.3

Table 3: Deaths[2]

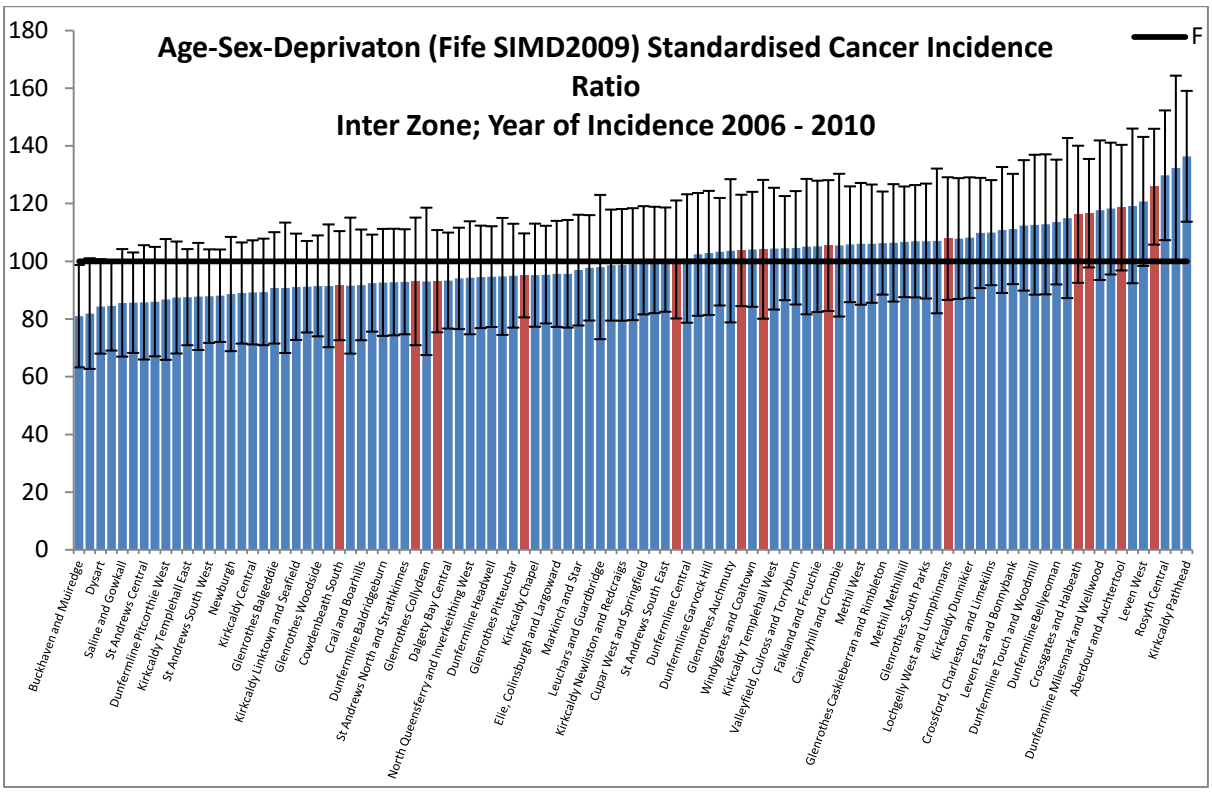
	Average number per year		Crude rate per 100,000		Standardised rate per 100,000[1]	
	2003-2005	2000-2002	2003-2005	2000-2002	2003-2005	2000-2002
KY5 9	24	24	353.2	343.5	229.3	211
Fife	1020	1017	286.2	290.9	199.6	207.4
Scotland	15072	15056	297.8	297.5	212.1	219.1

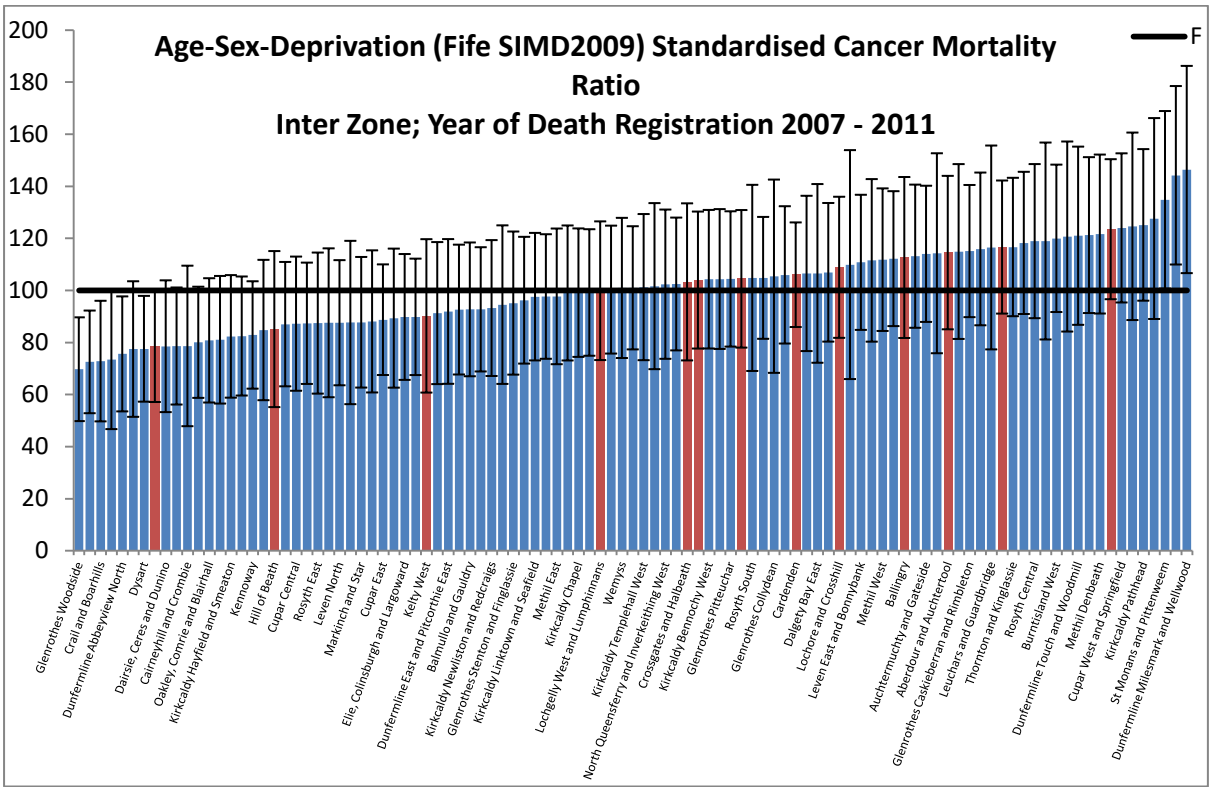
Table 4: 2001 Census population by age group

	0-15	16-64	65+
KY5 9	19.1	62.2	18.7
Fife	19.6	61.4	18.9
Scotland	19.2	62.2	18.6

Appendix 2

Cancer incidence and mortality rates for *intermediate zones* surrounding Mossmorran





Flaring and Health
Literature Search and Review v2.0

Health Protection Scotland,
Environmental Public Health Team,
October 2019

Flaring and Health: Literature Search and Review

Introduction

HPS was asked by NHS Fife to conduct a review of literature in relation to possible adverse health impacts associated with the process of “flaring”; a process used to dispose of unwanted or surplus gaseous material produced from chemical and/or petrochemical plants by burning the gases with oxygen via industrial chimney stacks. Such stacks can be low level (ground level), which may be unobtrusive, or high level, using tall vertical stacks which are highly visible. The review was requested to support an ongoing health risk assessment by NHS Fife, associated with intermittent but repeated events at the Mossmorran gas plant in Fife, where flaring events at the plant had given rise to complaints from local communities. Complaints related to the noise generated by high-level flaring, light pollution caused by the very bright flames associated with the flaring, vibration felt locally in homes, and air pollution due to the combustion of unwanted gases.

Background

The plant at Mossmorran in Fife processes ethane from North Sea gas to produce ethylene. Occasionally, there is a need to burn off surplus feedstock gases or waste products at the site using a high-level stack. To assist the burning process and improve the efficiency, steam is injected into the venting system to reduce the risk of producing a sooty flame and associated carbon particulate by-products. This combination of high-level, highly visible flares plus steam injection results in an extremely prominent bright flame visible for many miles around the plant. It is also linked to high noise levels, typically described as a “roaring” sound, which is audible for some considerable distance from the Mossmorran site. This noise is accompanied by vibration reported to be sensed within buildings in a local area.

Local residents have reported that the light pollution caused by the flaring episodes has been associated with anxiety and disturbance among children and pets. The noise and vibration has been cited as being linked to sleep loss and deprivation as well as other complaints.

Air pollution, linked by residents to the flaring events, has also been blamed for exacerbations of chronic respiratory illness such as asthma and other conditions.

In order to inform NHS Fife's assessment of the relationship between residents' concerns about noise, light, vibration and air pollution and flaring episodes, HPS was asked to identify, consider and comment on the available published evidence describing health impacts associated with flaring.

Aim

The aim of this report was to summarise the results of the requested search and review of literature relating to reported impacts of flaring on health, including the consideration of airborne emissions, noise, light and vibration.

It is important to note that, whilst it is acknowledged that there is a separate body of literature on these issues, it was not the aim of this review to consider that wider (general) evidence on the impacts of noise, light and vibration on health. Only evidence on impacts specifically associated with noise, light or vibration from industrial flaring (of any type) was within scope of this review.

Literature Review Question

What are the reported human health effects of flaring, including those associated with exposure to noise, light and vibration?

Search Methods

In order to identify any available evidence, HPS searched dedicated literature review databases (OVID Medline), as well as Google Scholar, Google and a number of national and international organisations' websites.

Searches looked at a number of issues associated with the flaring process, namely emissions to air, noise, light and vibration. For emissions to air, because these are very dependent on the specific process or industry involved, evidence was only considered if it related specifically to ethylene cracker plants. However, given that any type of flaring process may generate noise, light or vibration issues, HPS looked for evidence relating to flaring-associated noise, light and vibration at ***any*** industrial sites, including ethylene plants.

Searches aimed to identify evidence relating to general health impacts, as well as a number of specific health outcomes thought to be potentially linked to flaring activity, including hypertension, sleep disturbance, mental health, respiratory conditions, and anxiety.

Due to the lack of relevant evidence being identified in the initial searching process, and in order to ensure that the original (specific) search strategy did not lead to key

evidence failing to be returned, the search strategy was modified as the work progressed. A much broader search was subsequently conducted in Ovid Medline, and the results were compared with those from the original search strategy.

Results

Despite carrying out extensive searching for evidence, very little relevant information was identified.

The specific Ovid Medline searches as detailed in Appendix 1 generated a total of 49 articles. The full text of these articles was reviewed for relevance; none of the articles were considered relevant to the review.

In order to ensure that the original (specific) search strategy did not lead to key evidence failing to be returned, the Ovid Medline search strategy was then modified. To ensure that searches were as broad as possible, additional searches were re-run using the terms "flar* AND health", This search returned a total of 1153 articles, which were reviewed to determine their relevance to the specific aim of this review. Only 11 out of these 1153 articles were considered to be of potential relevance, and all of these articles had already been identified in the earlier specific search (that yielded 49 citations). These 11 articles were excluded due to lack of relevance to the Mossmorran context. Therefore, even using a broad, labour-intensive search, no additional relevant evidence was identified. It is doubtful, therefore, that further searching of peer-reviewed literature would yield more useful information.

Online searches for evidence (grey literature) were also carried out, to supplement the Ovid Medline searches for peer-reviewed evidence. The results of these searches are presented in Appendix 2. Whilst these searches identified a broad range of material, this was largely relating to the oil industry, environmental modelling or environmental contamination. Where health impacts were mentioned in these sources, the impacts were mainly relating to air and water contamination.

However, two reports relevant to flaring at ethylene cracker plants were identified.

- The 2017 Annual Report of the Mossmorran and Braefoot Bay Independent Air Quality Monitoring Review Group concluded that "*in the areas around Mossmorran and Braefoot Bay, the 2010 air quality objective for benzene is being readily satisfied*" and that "*the work undertaken in 2017 demonstrates that, based on the available data, emissions from the facilities at Mossmorran and Braefoot Bay continue to pose no significant risk to the health of members of the local community*" [1]. This report did not, however, consider noise, light or vibration. An additional search was carried out to identify any

more recent evidence from the Group; however nothing subsequent to the 2017 Annual Report (published October 2018) was identified.

- A Health Impact Assessment (HIA) of a petrochemical complex (which included an ethane cracking unit) in the USA identified that flaring was a major community concern in terms of impacts on health and the environment [2]. The authors acknowledged flaring as a potential source of air, noise and light pollution. They stated that noise and light pollution would continually be generated during operation of the plant, and might, in theory (based on an understanding of the generic impacts that have been identified on health in other industrial situations), contribute to specific health impacts. These impacts included stress, cardiovascular disease, sleep interference, and hearing loss (associated with noise pollution); and disruption of the circadian clock potentially leading to health outcomes such as depression, insomnia, cardiovascular disease, and cancer (associated with light pollution). The authors commented in particular on night-time exposure to noise and light, based on the general literature on the impacts of noise and light This assessment did not investigate the association between noise and light and identify impacts based on the local situation itself.

A number of publications were identified that addressed airborne emissions from flaring in different industries. However, the relevance of their findings was difficult to assess.

- A series of papers, relating to benzene exposure following a significant flaring incident in Texas, were identified. On full-text review, these were excluded as these focussed only on airborne emissions relating to the oil industry, so were not considered directly transferrable to the Mossmorran scenario involving only pollution associated with flaring at an ethylene cracker plant.

- A number of papers relating to the oil and gas industry in the Niger Delta [3-5] were also identified. These studies suggested that flaring may be associated with hypertension, changes in haematological values, and reported symptoms. However, the quality of these studies was very low, with little control of confounding variables and few details about participant selection.

Given these limitations, plus the differing environmental contexts and links to the oil industry, these findings were considered to be of very limited applicability to the Mossmorran situation.

Assessment of the Evidence

Despite an extensive search, a very limited amount of evidence on flaring and health was identified. Virtually no evidence was found relating to flaring specifically at ethylene cracker plants. Furthermore, no studies were identified that specifically investigated the impact of noise, light or vibration arising from flaring in any other type of industry on health in a systematic or objective manner.

The initial search (detailed in Appendix 1) focussed specifically on flaring at ethylene cracker plants. However, when broader searches were re-run there was no additional evidence identified. Therefore, the specific search strategy is not believed to have led to a failure in identifying key evidence. Screening at full-text level excluded papers focussing only on airborne emissions from flaring in the oil industry in Nigeria and Texas, given that these findings are unlikely to be directly transferable to flaring carried out at the plant in Mossmorran. Also, there is little objective evidence to indicate that air pollution is an issue at Mossmorran itself.

In line with the review methodology adopted, one scientific database (Ovid Medline) was searched, supplemented by searching of Google Scholar and online searches for grey literature. In this instance, the latter two searches provided more relevant evidence than Ovid Medline.

Whilst noise and light pollution are reported to be associated with negative health impacts in the general literature [6-7], no studies were identified that specifically looked at these exposures related to flaring and health in a systematic or objective way. Evidence from general literature on health impacts associated with sources of noise, light and vibration, particularly for those sources that produce intermittent and unpredictable exposure, could be used to draw inferences about the potential health impacts of flaring. However, a full review of all the evidence relating to such impacts was beyond the scope of this particular review.

Key Findings

- A very limited amount of literature on flaring and health was identified.
- Virtually no evidence was found relating to flaring specifically at ethylene cracker plants.
- No studies were identified that specifically considered noise, light and vibration arising from flaring at ***any*** kind of industrial site and health in a systematic or objective manner.

Based on these findings, it is not therefore possible to comment, from an evidence-based perspective, on the likelihood that noise, vibration or light generated at

Mossmorran by flaring operations is or is not associated with adverse health impacts in nearby communities.

Conclusions

There was inadequate evidence to allow any meaningful conclusions to be drawn regarding the impact of flaring on health, including those associated with noise, light and vibration. Given the extensive searching, screening and reviewing undertaken as part of this review, it is doubtful whether further literature searching on adverse health impacts of flaring as an industrial process would yield more useful information.

References

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Appendix 1: Ovid Medline Search Strategy

Explanation of Strategy Approach

The following table summarises a number of searches that were conducted to identify relevant peer-reviewed literature. Each row in the table relates to a specific search term, or a combination of search terms. The number in the "Results" column is the number of articles identified by each combination.

The main search term used was "flaring", or variants of the word, aimed at capturing anything that might mention flare or flaring. As can be seen from line 1 of the table, this returned 15,270 results.

In order to capture evidence relating to industrial flaring (rather than results that might talk about irrelevant topics such as "flare up" of conditions), individual searches were run using search terms relating to industry, e.g. refinery, chemical, oil and gas, ethylene, as well as a general search term "environmental exposure". These could also be grouped to catch all of the results associated with any of these industries or environmental exposures.

Evidence relating to "noise", "light" and "vibration" was identified through specific searches. Evidence relating to any of these aspects was also grouped, as can be seen from line 19 of the table.

To capture evidence relating to health outcomes, a number of searches were run, including one to capture general "health" results, as well as some to capture specific health effects or outcomes, e.g. "hypertension", "anxiety", "sleep", "mental health". These could also be grouped to catch all of the results associated with any of these outcomes (this is shown at line 12 in the table).

Finally, to capture evidence that specifically considered the health outcomes associated with flaring from industrial processes, and evidence that considered noise, light and vibration associated with flaring at industrial processes, the results of the relevant individual searches were combined. When this was done, the number of results reduced greatly, as can be seen from the following flowcharts.

#	Search Term	Results
1	(flare or flaring or flar*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	15270
2	ethylene.mp. or Ethylenes/	61880
3	ethylene crack*.mp.	5
4	environmental exposure.mp. or Environmental Exposure/	75879
5	health.mp. or Health/	2726962
6	Hypertension/ or hypertension.mp.	467522
7	Anxiety/ or anxiety.mp.	219768
8	mental health.mp. or Mental Health/	175771
9	Sleep/ or sleep.mp. or Sleep Deprivation/	181257
10	respiratory.mp. or Respiratory System/ or Respiratory Tract Diseases/	534323
11	2 or 3 or 4	137357
12	5 or 6 or 7 or 8 or 9 or 10	3888346
13	1 and 11 and 12	23
14	from 13 keep 2,4,6-7,9-10,12-13	8
15	Noise/ or noise.mp.	138998
16	lighting.mp. or Lighting/	18979
17	Light/ or light.mp.	668174
18	Vibration/ or vibration.mp.	40374
19	15 or 16 or 17 or 18	844336
20	refinery.mp.	2139
21	chemical.mp.	1158396
22	(oil and gas industry).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary	644

	concept word, unique identifier, synonyms]	
23	2 or 3 or 4 or 20 or 21 or 22	1275141
24	1 and 19 and 23	16
25	1 and 12 and 19	26

Inclusion Criteria

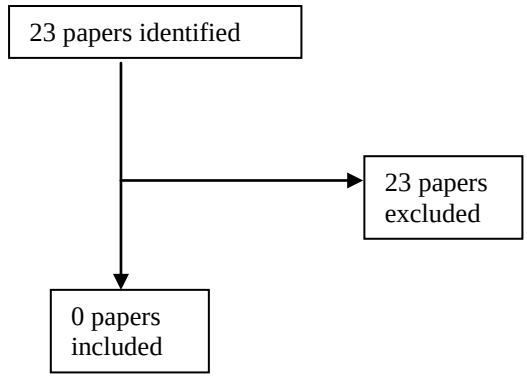
To identify the most relevant literature, a number of criteria were applied to the results that were found from the searches.

Firstly, papers had to be in English language. Furthermore, they had to consider health outcomes. Finally, where publications only looked at airborne emissions, the only evidence to be considered was that relating to emissions from flaring at ethylene cracker plants. Where publications talked about noise, light or vibration, flaring from ***any*** kind of industrial process was included.

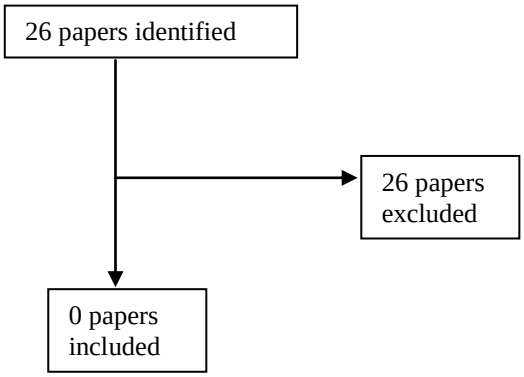
➔ 0 relevant publications were identified following review of their title and/or abstract.

Flowcharts for Ovid Medline Searches

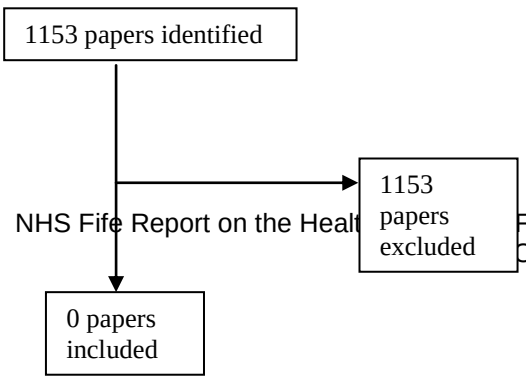
Search 1 (flaring generally)



Search 2 (noise, light and vibration)



Search 3 (flar* AND health)



Appendix 2: High Level Grey Literature Search Results

Date searched	Source *e.g. Google, CDC*	Search terms *e.g. flaring, health etc*	Resources identified *List of documents found, one per line*	Comments
05/07/2019	Google Scholar	Flaring	Flaring in the energy industry https://www.sciencedirect.com/science/article/pii/0360128576900095	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Global impact of gas flaring http://ir.library.ui.edu.ng/handle/123456789/1823	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Negative Effects of Gas Flaring: The Nigerian Experience https://pdfs.semanticscholar.org/beff/236d35ba9f544ccebf8b8cda1e304c89b4a9.pdf	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Gas flaring and resultant air pollution: A review focusing on black carbon https://www.sciencedirect.com/science/article/pii/S0269749116304638	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Estimates of global, regional, and national annual CO_2 emissions from fossil-fuel burning, hydraulic cement production, and gas flaring: 1950—1992	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Perception on Effect of Gas Flaring on the Environment https://www.airitilibrary.com/Publication/alDetailedMesh?DocID=20410492-201010-201507240028-201507240028-188-193	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Determination of greenhouse gas emission resulting from gas	First 200/199,000 results

			flaring activities in Nigeria https://www.sciencedirect.com/science/article/pii/S0301421512002236	
05/07/2019	Google Scholar	Flaring	Perceptions and attitudes towards gas flaring in the Niger Delta, Nigeria https://link.springer.com/article/10.1007/s10669-009-9244-2	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Gas flaring and venting associated with petroleum exploration and production in the Nigeria's Niger Delta https://www.researchgate.net/profile/Aniefiok_Ite/publication/256273551_Gas_Flaring_and_Venting_Associated_with_Petroleum_Exploration_and_Production_in_the_Nigeria's_Niger_Delta/links/0deec5220e1d015476000000.pdf	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Effects of gas flaring on surface and ground waters in Delta State Nigeria https://academicjournals.org/journal/JGMR/article-full-text-pdf/920BED95994	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Gas flaring in Nigeria: Analysis of changes in its consequent carbon emission and reporting https://www.tandfonline.com/doi/abs/10.1016/j.accfor.2013.04.004	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Gas Flaring and its Implication for Environmental Accounting in Nigeria https://scholar.oauife.edu.ng/sites/default/files/tjayoola/files/11356-37509-1-pb.pdf	First 200/199,000 results
05/07/2019	Google Scholar	Flaring	Environmental impact analyses of gas flaring in the Niger delta region of Nigeria	First 200/199,000 results

			http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.659.2940&rep=rep1&type=pdf	
05/07/2019	Google Scholar	Flaring	GAS FLARING IN INDUSTRY: AN OVERVIEW https://pdfs.semanticscholar.org/f19a/48b3a4f9e48ce756e0d6b4137c279bec9c7b.pdf	First 200/199,000 results
05/07/2019	Google Scholar	Flare	Investigations of flare gas emissions in Alberta https://www.osti.gov/etdeweb/biblio/430151	First 200/904,000 results
05/07/2019	CDC	Flaring	n/a	First 200/813 results
05/07/2019	CDC	Flare	n/a	First 200/813 results
05/07/2019	USEPA	Flaring	Review & Peer Review of "Parameters for Properly Designed and Operated Flares" Documents https://www.epa.gov/stationary-sources-air-pollution/review-peer-review-parameters-properly-designed-and-operated-flares	First 200/8588 results
05/07/2019	USEPA	Flaring	Enforcement Alert: Routine Flaring May Violate Clean Air Act (CAA) https://www.epa.gov/enforcement/enforcement-alert-routine-flaring-may-violate-clean-air-act-caa	First 200/8588 results
05/07/2019	USEPA	Flaring	Louisiana SIP: LAC 33:III Ch 1105. Smoke from Flaring Shall Not Exceed 20 Percent Opacity; SIP effective 2011-08-04 (LAd34) to 2016-02-28 https://www.epa.gov/sips-la/louisiana-sip-lac-33iii-ch-1105-smoke-flaring-shall-not-exceed-20-percent-opacity-sip	First 200/8588 results
05/07/2019	USEPA	Flare	n/a	First 200/8588 results
05/07/2019	WHO	Flaring	Cutting carbon emissions, cleaning our air, saving lives https://www.who.int/globalchange/commit/EN-health-	First 80/80 results

			commitment2_finance_final.pdf	
05/07/2019	WHO	Flaring	Incidence of congenital malformation in 2 major hospitals in Rivers state of Nigeria from 1990 to 2003 http://www.emro.who.int/emhj-volume-17/volume-17-issue-9/article-10.html	First 80/80 results
05/07/2019	WHO	Flare	Middle East Air quality an overlooked casualty of war Gas flare-offs from oil fields https://www.who.int/heca/infomaterials/HECANETJune2005.pdf	First 200/525 results
05/07/2019	PHE	Flaring	n/a	First 5/5 results
05/07/2019	PHE	Flare	n/a	First 5/5 results
05/07/2019	DEFRA	Flaring	n/a	First 2/2 results
05/07/2019	DEFRA	Flare	n/a	First 2/2 results
05/07/2019	EA	Flaring	Onshore oil and gas sector guidance https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/8-flares-at-onshore-oil-and-gas-sites	First 23/23 results
05/07/2019	EA	Flaring	Monitoring emissions for onshore oil and gas activities https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/13-monitoring-emissions-for-onshore-oil-and-gas-activities	First 23/23 results
05/07/2019	EA	Flare	Onshore oil and gas sector guidance https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/8-flares-at-onshore-oil-and-gas-sites	First 23/23 results
05/07/2019	EA	Flare	Onshore oil and gas sector guidance	First 23/23 results

			https://www.gov.uk/guidance/onshore-oil-and-gas-sector-guidance/8-flares-at-onshore-oil-and-gas-sites	
05/07/2019	SEPA	Flaring	Flaring at Mossmorran - previous updates https://www.sepa.org.uk/regulations/air/air-quality/previous-incidents/	First 5/5 results
05/07/2019	SEPA	Flaring	Mossmorran and Braefoot Bay complexes https://www.sepa.org.uk/regulations/air/air-quality/mossmorran-and-braefoot-bay-complexes/	First 5/5 results
05/07/2019	SEPA	Flaring	Mossmorran Complex investigation update February 2019 https://www.sepa.org.uk/regulations/air/air-quality/mossmorran-investigation-update-27-april-2019/	First 5/5 results
05/07/2019	SEPA	Flare	Mossmorran Complex investigation update February 2019 https://www.sepa.org.uk/regulations/air/air-quality/mossmorran-investigation-update-27-april-2019/	First 3/3 results
05/07/2019	SEPA	Flare	Mossmorran and Braefoot Bay complexes https://www.sepa.org.uk/regulations/air/air-quality/mossmorran-and-braefoot-bay-complexes/	First 3/3 results
09/07/2019	ECDC	Flaring	n/a	First 1/1 results
09/07/2019	ECDC	Flare	n/a	First 1/1 results
09/07/2019	European Commission	Flaring	THE REDUCTION OF UPSTREAM GREENHOUSE GAS EMISSIONS FROM FLARING AND VENTING https://ec.europa.eu/clima/sites/clima/files/transport/fuel/docs/studies_ghg_venting_flaring_en.pdf	First 200/12984 results

09/07/2019	European Commission	Flaring	Gas flaring and residential burning pollute the Arctic more than previously thought http://ec.europa.eu/environment/integration/research/newsalert/pdf/349na5_en.pdf	First 200/12984 results
09/07/2019	European Commission	Flaring	Technical workshop on public health impacts and risks resulting from oil and gas extraction http://ec.europa.eu/environment/integration/energy/pdf/health_impacts_and_risks-from-oil_and_gas_extraction.pdf	First 200/12984 results
09/07/2019	European Commission	Flare	n/a	First 200/316 results