

Paul Mobbs,
Mobbs' Environmental Investigations,
3 Grosvenor Road,
Banbury OX16 8HN, England
Tel./fax 01295 261864
Email mobbsey@gn.apc.org

The Sea Empress Spill: The Potential for Human Health Effects

Abstract

The Sea Empress spilled 70,000 tonnes of light crude oil following its grounding on the 15th February, 1996. Of this 70,000 tonnes, it has been stated that up to 30,000 tonnes has 'evaporated'. This is not however a benign method of dispersal for the very light, volatile fraction of the oil, and the presence of known carcinogenic compounds within the oil gives cause for concern.

At this moment there is insufficient information to give a certain answer about the potential health effects of the airborne pollution caused by the oil spill. However, by the same circumstance, it is impossible for the authorities to give a certain assurance that there will be no short or longer term adverse effect from the spill. Studies should therefore be urgently sought to establish the concentration and distribution of contamination from the oil split from the Sea Empress, and the health effects modelled upon the basis of this data.

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1. The Problem

The Sea Empress spilled around 70,000 tonnes of light crude oil into the sea off the West Wales Coast. According to 'official' data, of the 70,000 tonnes spilt, perhaps 30,000 tonnes of this oil evaporated. This process must not be seen as 'benign', since the air pollution caused by the evaporation of the oil will have some effect on local ecology, and upon human health.

It is in general very difficult to predict the toxic effects of crude oil because of its very complex chemical composition. Crude oil consists of thousands of different organic molecules, the majority of them chain hydrocarbons with between 4 and 26 atoms per molecule. There are also traces of sulphur and nitrogen compounds, heavy metals such as vanadium, and other trace contaminants depending upon the strata from which the oil was taken.

Crude oils from different sources have widely differing compositions. For example 'heavy crude' from the Middle East contains a greater proportion of long chain hydrocarbons, whereas 'light crude' from the North Sea contains a greater proportion of short chain hydrocarbons. In general there are four major groups of hydrocarbon molecules present in the oil:

- **Alkanes:** These are chain hydrocarbons such as ethane, butane and propane - primarily gases. Much of the gaseous content of the oil will have been lost after extraction, but small quantities may be dissolved in the oil;
- **Alkanol/alkanamines:** These are again chain hydrocarbons, but their different molecular structure gives them a much higher melting/boiling points, and so they are generally liquid;
- **Cyclohexanes/Polynuclear aromatic hydrocarbons (PAH):** Naphthenes (cycloalkanes and their alkyl derivatives) and phenyl compounds. A group of volatile compounds such as benzene, phenol, and toluene.

The crude oil refining process is essentially one of distillation. Likewise, as the oil spilt from the Sea Empress evaporates the compounds that pollute the air will not be in the same proportion to that in the crude oil. In fact the more volatile compounds, with lower boiling points, will be preferentially removed from the crude oil on the surface of the sea. This process will lead to the heavier chain hydrocarbons (alkanols/alkanamines) being left behind, and the alkanes/PAH compounds being 'boiled' off into the atmosphere. Therefore, if the concentrations of PAH compounds in the oil were 0.5%, then it is entirely possible that the proportion in the gaseous pollution coming off the oil slick could be 10 or 100 times higher, dependent upon weather and temperature conditions.

2. Health Effects

It has been noted by some people assisting in the clean-up operations that their health has been affected. The obvious effect of the spill is odour - many of these compounds having very low odour thresholds. However, the other effects noted such as headaches or fatigue are all symptoms of exposure to compounds such as PAH's.

There are a number of compounds which are of concern since they are present in significant quantities within the oil. For example toluene, benzene, and 'cresols' (a group of phenolic compounds). The effects of these compounds vary, but in general the immediate (acute)

effects of these compounds may be showing up in those people most exposed to the oil slick, and the accompanying air pollution - for example problems of fatigue, headaches/nausea, and skin rashes. It is important to note also that these substances are not only harmful by ingestion or inhalation. If the skin is exposed they can be absorbed into the body - an obvious problem for those coming into direct contact with the oil.

Guidance on the health effects of these substances is available from a variety of sources. The following summaries have been extracted from documents provided (electronically via the Internet^[1]) by the US Agency for Toxic Substances and Disease Registration (US ATSDR), and from 'material safety data sheets' from the University of Utah^[2].

2.1 Cresol:

The group of phenolic compounds known as 'cresols' is a known constituent of crude oil. The US ATSDR has this to say about cresols...

Most exposures to cresols are at very low levels that are not harmful. When cresols are breathed, ingested, or applied to the skin at very high levels, they can be very harmful. Effects observed in people include irritation and burning of skin, eyes, mouth, and throat; abdominal pain and vomiting; heart damage; anaemia; liver and kidney damage; facial paralysis; coma; and death. Breathing high levels of cresols for a short time results in irritation of the nose and throat. Aside from these effects, very little is known about the effects of breathing cresols, for example, at lower levels over longer times. Ingesting high levels results in kidney problems, mouth and throat burns, abdominal pain, vomiting, and effects on the blood and nervous system. Skin contact with high levels of cresols can burn the skin and damage the kidneys, liver, blood, brain, and lungs. Short-term and long-term studies with animals have shown similar effects from exposure to cresols. No human or animal studies have shown harmful effects from cresols on the ability to have children. It is not known what the effects are from long-term ingestion or skin contact with low levels of cresols. The Environmental Protection Agency (EPA) has determined that cresols are possible human carcinogens. No studies are available in people on the carcinogenic effects of cresols. Animal studies show that cresols may increase the ability of some carcinogenic chemicals to cause tumours.

2.2 Toluene:

Toluene is a known constituent of crude oil. The US ATSDR has this to say about Toluene...

The most important health concern for humans from either intentional or occupational exposure to toluene is its harmful effects on the nervous system. These effects of toluene depend on both the amount and length of exposure. Short-term exposure to moderate amounts of toluene, such as in elevated workplace exposures, can produce fatigue, confusion, general weakness, drunken-type actions, memory loss, nausea, and loss of appetite. These symptoms disappear when exposure is stopped. Short-term exposure to high amounts of toluene results first in light-headedness and euphoria. This is followed by dizziness, sleepiness, unconsciousness, and, in some cases, death because the person cannot breathe prior to death. When exposure is stopped before death, these symptoms disappear. Long-term exposure to low and moderate amounts of toluene has caused slight effects on the kidneys in some people, but these people were also exposed to other solvents at the same time and it is difficult

to tell which chemical may have caused the effects. Long-term exposure to high amounts of toluene by intentional abuse has been linked with permanent damage to the brain. Effects such as problems with speech, vision, and hearing; loss of muscle control; loss of memory and balance; and reduced scores on psychological tests have been reported. Researchers have seen possible effects on resistance to disease in persons exposed to moderate and high amounts of chemical mixtures that contained toluene. However, it is not possible to tell exactly which chemical in the mixture may have caused the effects.

In animals, as in humans, the main effect of toluene is on the nervous system. Exposure of animals to moderate and high amounts of toluene also produces slightly harmful effects on the liver, kidneys, and lungs. Several studies have shown that the development of unborn animals is affected or harmed when high levels of toluene are breathed in by pregnant animals. However, when pregnant animals were fed high amounts of toluene, the unborn animals did not show any developmental problems. It is not known if toluene will harm an unborn child when a pregnant woman drinks water or breathes in air containing toluene because studies in people are not complete enough to measure this effect. The National Toxicology Program (NTP) found that toluene did not cause cancer in a long-term study in rats and mice.

2.3 Polynuclear aromatic hydrocarbons:

The quantities of PAHs in crude oil are uncertain - as are the particular types of PAH. This makes consideration of the possible effects of the 'wider' family of PAHs difficult. The US ATSDR notes the following about PAHs...

PAHs can enter your body through your lungs when you breathe air that contains them. This is one of the most significant routes of exposure for people living near hazardous waste sites. Drinking water or swallowing food, soil, or dust particles that contain PAHs are other routes for these chemicals to enter your body. Under normal conditions of environmental exposure, PAHs could enter your body if your skin comes into contact with soil that contains high levels of PAHs (this could occur near a hazardous waste site); or with heavy oils or other products (such as coal tar, roofing tar, or creosote) that contain PAHs.

PAHs enter your body quickly and easily by all routes of exposure. The rate at which PAHs enter your body is increased when they are present in oily mixtures. They go to all the tissues of your body that contain fat, and tend to be stored mostly in your kidneys, liver, and fat, with smaller amounts in your spleen, adrenal glands, and ovaries. Results from animal studies show that PAHs do not tend to be stored in your body for a long time; most PAHs that enter the body leave within a few days, primarily in the faeces and urine.

The U.S. Department of Health and Human Services has determined that PAHs may reasonably be anticipated to be carcinogens. Several of the PAHs have caused tumours in laboratory animals when they ate them, when they were applied to their skin, or when they breathed them in the air for long periods of time. Reports in humans show that individuals exposed by breathing or skin contact for long periods of time to mixtures of other compounds and PAHs can also develop cancer.

Mice fed high levels of benzo(a)pyrene during pregnancy had difficulty reproducing and so did their offspring. The offspring from pregnant mice fed benzo(a)pyrene also showed other harmful effects, such as birth defects and decreased body weight. Similar effects could occur in humans, but we have no information to show that these effects do occur.

Studies in animals have also shown that PAHs can cause harmful effects on skin, body fluids, and the body's system for fighting disease after both short- and long-term exposure. These effects have not been reported in humans.

2.4 Benzene:

Benzene is a constituent of crude oil - but the amounts vary. The US ATSDR lists benzene as one of its 'top 20' toxic chemicals. It notes the following in its guidance notes...

Benzene is harmful, especially to the tissues that form blood cells. How benzene affects your health would depend on how much you are exposed to and how long you are exposed to it.

Brief Exposure at High Levels - Death may occur in humans and animals after brief oral or inhalation exposures to high levels of benzene; however, the main effects of these types of exposures are drowsiness, dizziness, and headaches. These symptoms disappear after exposure stops.

Long-Term Exposures at Various Levels - From overwhelming human evidence and supporting animal studies, the U.S. Department of Health and Human Services has determined that benzene is carcinogenic. Leukaemia (cancer of the tissues that form the white blood cells) and subsequent death from cancer have occurred in some workers exposed to benzene for periods of less than 5 and up to 30 years. Long-term exposures to benzene may affect normal blood production, possibly resulting in severe anaemia and internal bleeding.

In addition, human and animal studies indicate that benzene is harmful to the immune system, increasing the chance for infections and perhaps lowering the body's defence against tumours. Exposure to benzene has also been linked with genetic changes in humans and animals.

Animal studies indicate that benzene has adverse effects on unborn animals. These effects include low birth weight, delayed bone formation, and bone marrow damage. Some of these effects occur at benzene levels as low as 10 parts of benzene per million parts of air (ppm). Although benzene has been reported to have harmful effects on animal reproduction, the evidence for human reproductive effects, such as spontaneous abortion or miscarriage, is too limited to form a clear link with benzene.

These summaries of US studies show quite clearly that the known constituents of crude oil can pose a severe health risk to human and animal populations. How significant this risk is will depend upon the level and duration of exposure, along with other factors such as the particular exposure pathway.

A further complication in this case is the use of chemical surfactants to break up the oil slick. Many surfactants have effects on the skin and mucus membranes, and can act as an irritant. But at the level of the nervous and immune system, the components of surfactants can mimic the effects of the body's hormones - for example oestrogen or androgen - and cause problems with health and reproduction. This is still a new area of scientific study, and the effects of the industrial surfactants used to break up the spill, on the local ecology and upon human populations, need to be considered as part of the general health studies.

3. Quantifying exposure

The problems with estimating/quantifying exposure to harmful compounds from the Sea Empress spill is difficult because...

- A detailed composition of the crude oil is not readily available;
- Exposure by different pathways needs to be quantified - which means considering different 'exposed groups' within the population;
- The main exposure pathway in the short term is inhalation, but no air monitoring data is available to quantify the possible effects.

In terms of these procedures, the Government has already issued information about risk assessment and the need to protect the environment and human health^[3]. But in this case the procedures outlined in this document for assessing risk, and applying the precautionary principle, do not seem to have been applied.

This leaves this study with a particular problem. If the above data were readily available, it would be possible to conduct a limited assessment of the likely impact on certain groups involved with the spill - for example the general public, or those assisting with the recovery of oiled birds. But in this case we are faced - at least officially - with a lack of all the essential data necessary to model the health effects of the spill.

Quantifying exposure is difficult. It has been stated by Texaco that sampling has taken place around workers clearing oil from beaches, and levels of 'hydrocarbons' in the air has not exceeded the 50ppm (parts-per-million) level above which action to protect their health must be taken. But this monitoring - or at least how the results have been presented, is flawed because:

- I would assume, by the use of 'ppm' values, that only inhalation is considered - the effects of skin absorption of toluene, benzene and other PAH's is not being considered;
- It was not stated what monitoring equipment was used - if systems such as diffusion tubes were used then this would only give a general 'average' concentration, and would not give a realistic assessment of short-term peak values;
- The use of the 50ppm limit would, I assume, be based upon the 8-hour limit set by the Health and Safety Executive^[4] - this ignores the effect of compounds such as benzene which have an 8-hour limit 10 times lower.

In addition to the possible failure to quantify dermal (skin) absorption of these compounds, the possibility of ingestion, perhaps within sea spray or splashes from cleaning operations, must also be considered. Only when all the exposure pathways have been assessed can any definitive answer be given as to the effects of the oil cleanup on workers.

It is this lack of data that makes it impossible for the Welsh Office, the companies involved, or local authorities - with any certainty or truth - to deny the existence of any health effect on those involved in the cleanup or upon the public in general. Although some of the effects reported by those coming into contact with the oil could be due to simple allergies or merely the nauseating odour, it is possible that the more acute symptoms, especially those which do not clear after a few hours when exposure ceases, could be due to the intake of hydrocarbon compounds from the oil - either by inhalation, ingestion, or skin absorption.

On the basis of current knowledge about the 'toxic content' of crude oil, and the potential short and long term effects of exposure to these toxic substances, a precautionary approach

would advocate monitoring of environmental pollution in those areas affected by the oil spill, minimising public contact with the affected areas, and where people do come into contact with oil (such as those cleaning the beaches) there should be health monitoring undertaken.

4. Conclusions and Recommendations

It is not possible to draw any definite conclusions from this report - there are simply too many variables, and insufficient data, to make any meaningful deductions.

In general it is possible to say that there *will* be some health effects to those exposed, either directly (for example ingestion/skin absorption) or indirectly (for example by inhalation some distance from the shore), but the effects of this exposure cannot be quantified on the current available data. But the *significance* and *severity* of these health effects is indeterminable at this present time.

In order to rectify this situation I would make the following recommendations...

1. There should be an immediate effort to monitor the level of contamination, in air, soil and water, by the constituents of crude oil, and the breakdown products of crude oil/volatile hydrocarbons. It is only by gathering this data that the effect on the local population can be determined. The problem is that if this is not done as soon as possible, then much of the pollution will have dispersed, and it will be difficult to estimate, with reliability, a source term upon which to conduct future pollutant dispersion modelling.
2. As soon as possible, a chemical analysis of the oil on the Sea Empress, detailing the concentration of different organic and inorganic compounds, should be made available so that initial modelling of the effects of the spill can begin.
3. At some point, it may be necessary to carry out empirical test to assess the likely transfer of pollutants from sea to air, if this cannot be reliably modelled from the concentration of substances within the oil.
4. Steps must be taken to warn all those involved with the clean-up operations, and any other persons coming into contact with the oil, or those who may live close to the sea and be affected by atmospheric pollution, about the possible risks to their health, and practical ways to minimise this risk. Avoidance is the simplest way to minimise any future adverse health effects.
5. Those undertaking clean-up work should be monitored. This should be a mixture of 'reporting' of symptoms, as well as some actual studies of body tissue to assess the uptake and health effects of substances within the oil.

At the moment the health implications of the oil spill seem to be taking up very little time - much of the emphasis being placed on the direct effect of oil on local wildlife. However, if the implications of the spill are not quickly quantified, and actions/policies drawn up to minimise the effects of wildlife and human populations, then the adverse health effects of the spill may last many times longer than the immediate aesthetic or conservation impacts.

References:

1. US Agency for Toxic Substances and Disease Registry (ATSDR) 'home page' - <http://www.atsdr1.atsdr.cdc.gov:8080/>
2. University of Utah Gopher server
3. "*A guide to Risk Assessment and Risk Management for Environmental Protection*", Department of the Environment 1995. (Published by HMSO, ISBN 0 11 753091 3 - price £9.95)
4. Health and Safety Executive COSHH EH40 series 'occupational exposure limits', 1995.

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