Public Health England

Chemical Hazards and Poisons Report

From the Centre for Radiation, Chemical and Environmental Hazards

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Contents

Editorial

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Centre for Radiation, Chemical and Environmental Hazards, Public Health England

Welcome to the first Chemical Hazards and Poisons Report published by Public Health England (PHE). Public Health England is a new national executive agency that brings together public health specialists from more than 70 organisations into a single public health service whose mission is to protect and improve the nation's health and wellbeing and to address health inequalities. This report highlights recent examples of this, with the emphasis on multiagency working demonstrated through the wide range of articles, whose authorship includes government, emergency services, housing trusts and citizen groups, as well as PHE staff.

Emergency situations requiring specialised, skilled response occur regularly – be they chemical accidents, deliberate attacks or extreme weather events. A series of articles describes the ongoing preparation for such situations. The Home Office describes its initial operation response policy for blue-light services responding to hazardous material incidents, which is being launched this month, and the Government Decontamination Service explains its work as a source of decontamination and recovery expertise. The public health impact of major incidents can be assessed by setting up a register of people affected by such incidents, a concept that is introduced in a further article.

Air quality – both indoor and outdoor – is an important public health issue affecting all people, young and old, rich and poor, and urban and rural dwellers. In this edition a number of articles reflect on how poor air quality can affect health, and describe scientific projects and programmes to address this. Outdoor air pollution from traffic emissions disproportionately affects those specific communities living closest to main roads and Sheffield City Council has been supporting community groups, who are best placed to know areas of particular local concern, to conduct their own air quality monitoring.

Outdoor emissions contribute to indoor air pollution, but there are additional sources of pollutants inside the home, which is of particular interest as that is where most people, including vulnerable individuals, spend most of their time. PHE staff report the results of a recent analysis of air quality monitoring in a number of properties in response to complaints of ill health by residents. Measures to tackle indoor sources of carbon monoxide are the subject of an article by Halton Housing Trust. The impact of annoyance on public health is also discussed, following an analysis of annoyance reports in Wales, a study which identified such complaints to be significantly associated with deprivation.

And finally – the changing chemical components of our atmosphere can have other, less obvious effects on our health. PHE staff describe how they identified higher-than-expected levels of ultraviolet radiation in April 2013, which led to sunburn reports, due to a temporary decrease in stratospheric ozone.

The next issue of the report is planned for early 2014; please contact us if you would like to contribute to it. Guidelines for authors and a permission to publish form can be found on the website at www.hpa.org.uk/chemicals/reports. Please do not hesitate to contact us about any papers you may wish to submit on chapreport@phe.gov.uk, or call us on 020 7811 7141.

We are very grateful to Mary Morrey, Andrew Tristem and Matthew Pardo for their support in preparing this issue. Thanks also go to Allister Gittins and Rebecca Gay for their editorial assistance.

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Front cover images: Car exhaust (© Simon Carruthers), indoor fire, traffic, gas stove, household cleaning products and Beenham compost fire

Incident Response

Disused factory with large quantities of flammable materials – an example of cohesive emergency planning

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Background

In July 2012, the Health Protection Agency (HPA, now part of Public Health England) was alerted by the London Fire Brigade (LFB) and Metropolitan Police Service (MPS), to an abandoned factory site that formerly manufactured printer ribbons. Despite being in disuse, the site still contained large amounts of chemicals, primarily large industrial drums of toluene, ethyl acetate, methyl ethyl ketone and various quantities of acids and laboratory agents (Table 1). The site is located in a predominantly industrial and commercial area, but with several sensitive receptors (notably a railway station and several residential properties) in close proximity (Figure 1).

Of concern to the LFB and MPS were the potential fire and environmental hazards, particularly because the site had been illegally accessed on several occasions. It is understood that when the HPA was alerted to the presence of the site, up to 3,500 litres of ethyl acetate were stored in underground tanks, a large quantity of unspecified laboratory chemicals were stored with no inventory (Figure 2), and that most of the lead from the roof had been stolen. This had compounded the hazards already present as rainwater entered many of the rooms during periods of heavy rain, leading to concerns that the drums would corrode. Any spillage of materials from the site, or large-scale flooding of the underground tanks, had

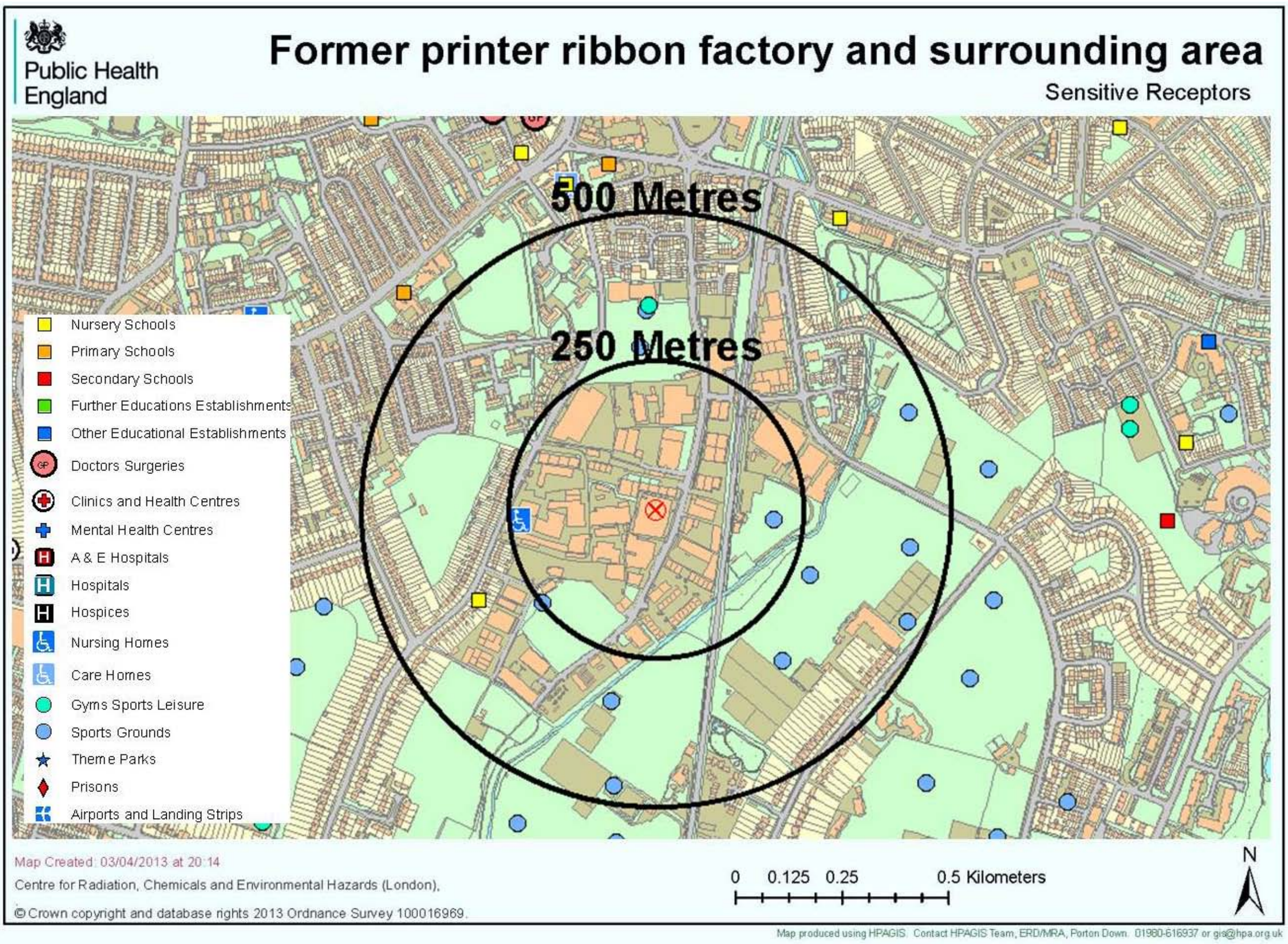

Figure 1: Location of the disused factory and the nearby sensitive receptors

Table 1: Chemicals stored on site and the potential environmental public health impacts

Chemical	Hazard
Ethyl acetate	Flammable
Acetone	Highly flammable. Inhalation of high concentrations can be irritant
Hydrochloric, nitric and sulphuric acids	Corrosive. Potential for toxic gas production if mixed with oxidising chemicals
Toluene	Highly flammable. Long-term inhalation has potential to cause serious harm
Unspecified laboratory reagents	Multiple
Carbon dioxide	Explosion risk from cylinders in the event of fire

the potential to rapidly make its way to a nearby river as local surface drainage would probably be fed straight to the river. The close proximity of a railway line and residential properties to the site also meant that a fire could have significant impacts on local transport and public health. A further concern for the MPS was the unsecured nature of the site and the potential for the large amounts of chemicals to be appropriated for illicit use.

Based upon the initial information obtained, the HPA had concerns that the site potentially posed a risk to wider public health. There was the potential for the public to come into direct contact with the chemicals due to the unsecured nature of the site, a fire could lead to the inhalation of smoke, or there could be a chemical release to the environment. The HPA was alerted so that a reference document could be prepared, comprising toxicological data on the known chemicals and incident response advice, which could be used by emergency responders in response to any potential incident.

A multiagency response

The ideal solution for this site would have been to remove all the chemicals and potential fire/environmental hazards. As this proved to be very time consuming, a multiagency group, brought together by the local health protection team (HPT), was formed to consider the potential hazards and risks associated with the site and the options available to the multiagency partners to prevent or minimise the risks. The group also considered the possible risk mitigating actions that could be taken by emergency responders if an incident, such as a major fire or spillage, were to occur at the site, and produced a multiagency contingency plan. This group

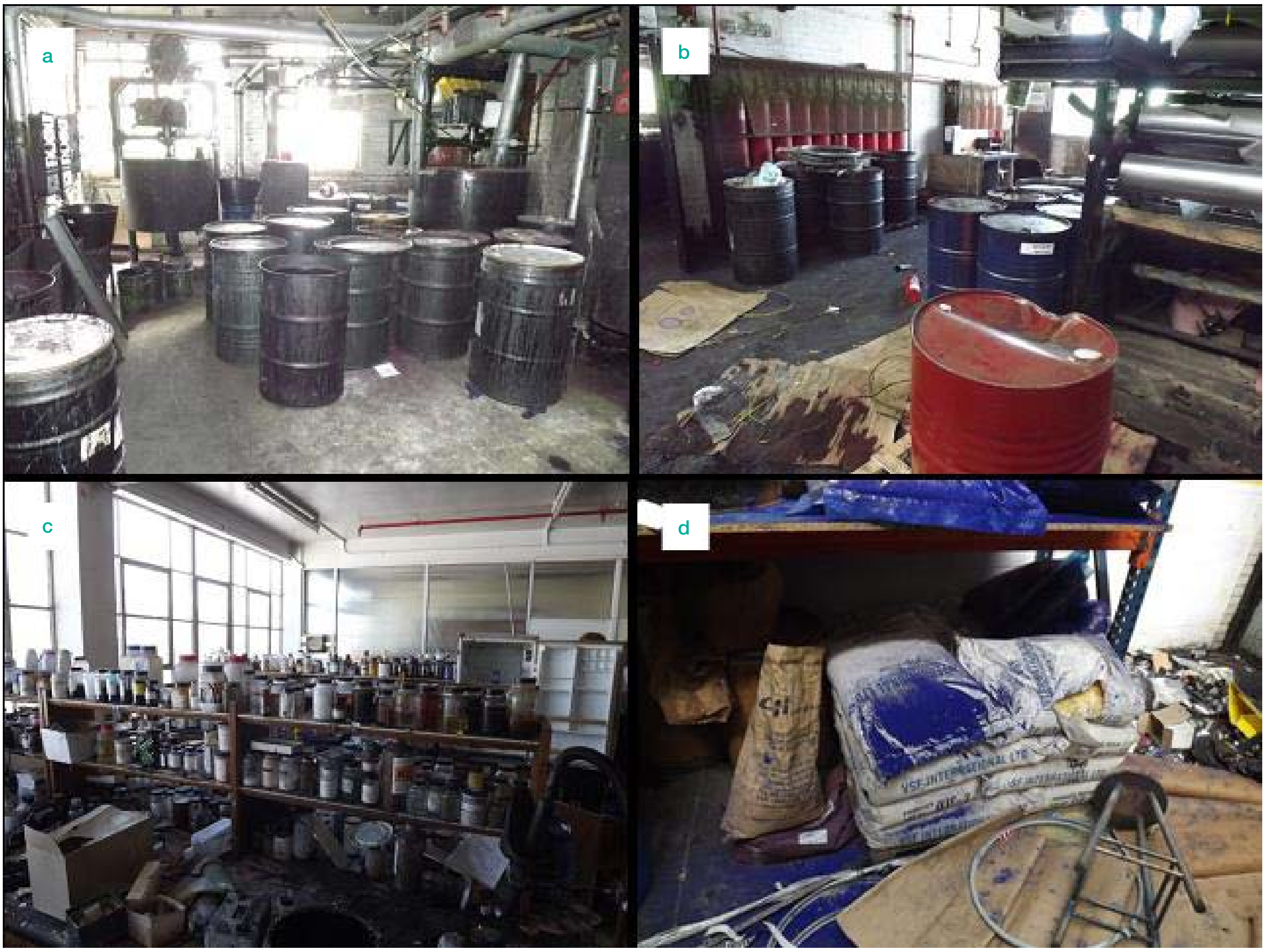

Figure 2: The disused factory site containing (a) large numbers of drums of industrial solvents, (b) bank of CO_2 gas cylinders, (c) laboratory containing various quantities of unknown reagents and (d) powders inks and dyes (images courtesy of the London Fire Brigade, 2012)

consisted of a number of stakeholders including the local council, the Environment Agency, the LFB, the MPS, the local primary care trust (PCT) and the HPA. The HPA Centre for Radiation, Chemical and Environmental Hazards (CRCE) provided comments from an environmental public health perspective and, in partnership with the local HPT, drafted an overview document for use by CRCE on-call scientists. CRCE also chaired and coordinated several teleconferences between stakeholders to ensure that all parties with a vested interest were kept informed of any developments and the potential consequences if a major incident did occur.

In the period up to the HPA being alerted, a number of mitigation measures had already been implemented, including securing the building with steel screens (local council) and regular patrols to deter unauthorised access (MPS). A geographical information system (GIS) was used by CRCE to inform a robust risk assessment to assist first responders and staff in the HPT in the event of an incident. The GIS maps identified the location, providing visualisation of the area, surroundings and sensitive receptors and likely population exposure risks. This helped to enumerate the resident population who would have been within a possible evacuation zone.

Clearing of the site and chemical disposal

The local council and the Environment Agency had already been liaising with the site owner in order to ensure that the site owner remediated before any incident occurred, and conducted invaluable work in assessing the site for environmental health risks and liaising with the MPS to prevent unauthorised access. A registered chemical contractor was employed to dispose of the residual waste in a controlled manner. Despite the lack of a full chemical inventory, the contractor was able to assess the site, remove drums of solvents and empty the contents of the underground storage tanks for salvage, remediation and re-sale. Any chemicals that could not be salvaged were disposed of as hazardous waste in the appropriate manner. The site is currently in the process of being sold for redevelopment.

Observations

This incident highlights the importance of involving health protection professionals in effective emergency planning and multiagency stakeholder communications, to confirm that a contingency plan can be in place for a potentially complex environmental incident. This ensures that all parties with a vested interest are fully briefed about the nature of the site in the interest of protecting the environment and public health.

Budgeting for the waste disposal was problematic due to the lack of a robust inventory of chemicals and there was concern that significant extra costs could be incurred depending on the products identified. Local councils may not always be in a position to underwrite potentially significant disposal costs.

Multiagency liaison for a compost fire in Beenham, Berkshire

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Background

Public Health England (PHE) provides chemical incident management advice and support on a 24/7, 365 days a year basis, and is frequently asked by the emergency services to provide advice on the potential public health impact of incidents involving chemicals.

Occasionally fires can continue for weeks or months depending on the materials involved, such as tyres or compost. In these incidents, PHE works with multiagency partners to ensure that any potential impact on public health is understood and minimised through health risk assessments and management, liaising with emergency responders and providing advice on the impacts of chemical exposure on health.

Compost can spontaneously combust, owing to a number of factors. Heat is generated by aerobic degradation and respiration. As a compost pile heats up to temperatures between 70 and 90°C, the moisture evaporates. However, oxygen is still entering the compost and reacting with plant chemicals (abiotic degradation) to produce heat[1]. If the heat lost is less than the heat generated, the pile may combust spontaneously. Once alight, the fire burns within the compost pile and smoke can be seen escaping from the pile. Fires may also occur on these sites for other reasons, such as vandalism; therefore it is important that composting facilities have contingency plans to deal with fires.

For composting facilities that are well managed the risk of spontaneous combustion is minimal. For example, waste should be maintained with adequate moisture, stockpiles should be monitored for increased temperatures and action taken to reduce temperatures.

The smoke generated from a compost fire is likely to contain organic irritant gases, such as acrolein and formaldehyde, and, depending on the conditions, small amounts of particulate matter, polycyclic aromatic hydrocarbons and potentially contaminants from any wood preservatives[2].

Incident overview

On 1 December 2012 a fire started in a compost and woodchip pile at a site near Beenham, Berkshire. The operator held a permit exemption at the site for chipping and shredding wood, issued by the Environment Agency (EA).

This exemption allows waste wood and waste plant matter to be chipped, shredded, cut or pulverised to make it easier to store and transport, or to convert it into a suitable form for use. The waste treated by these methods must be suitable for its intended use, which can include feedstock for production of such products as panel board, animal bedding, mulch, surfacing of tracks, including paths and bridleways, or for fuel. Further details on this can be found at www.environment-agency.gov.uk/business/topics/permitting/116193.aspx.

An environmental permit for in-vessel composting at Beenham was granted on 8 July 2003 by the EA. On 14 June 2012 this was transferred to the current operator. The permit allows composting of wastes including vegetation, wood, cardboard and paper, with up to 50,000 tonnes of waste to be accepted each year.

There were several piles of compost on the site (Figure 1) and five ‘eco pods’ (enclosed forced aeration composting systems). Initially, only one of the compost piles spontaneously combusted.

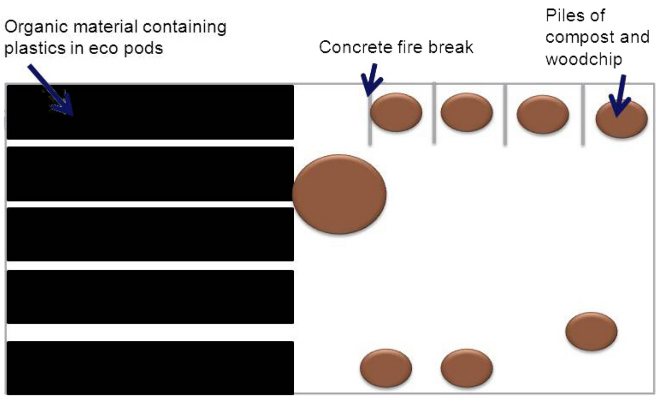

Figure 1: Schematic of the site layout, covering approximately one hectare (it has proved difficult to determine which pile of compost ignited first)

On 6 December 2012, the Health Protection Agency (HPA, part of Public Health England, PHE, from 1 April 2013) was informed of the incident by the EA, requesting public health advice. Royal Berkshire Fire and Rescue Service (RBFRS) had attended the site on 4 December 2012. Following its standard protocol for compost fires, RBFRS established that this fire was not an acute incident and therefore a controlled burn tactic would be implemented, meaning that the fire would not be actively tackled but a watching brief would be adopted to assess the fire. Local residents had started contacting West Berkshire Council (the local authority) on 4 December 2012 to complain about smoke and odour from the fire.

On 7 December the first of several multiagency meetings was convened; in attendance were representatives of the HPA, RBFRS, the EA, the landowner and the local authority. RBFRS estimated that the fire would burn for a further two weeks, and therefore it was agreed by all parties that a controlled burn would be a suitable approach to take. The HPA identified any potentially sensitive receptors within the area that may be affected by the smoke plume (Figure 2). The closest sensitive receptor identified was a nursery school approximately 550 m from the composting site. Owing to the intermittent nature of the smoke the HPA provided public health advice as follows:

"Residents in areas affected by the smoke should stay indoors, keep their doors and windows closed. Motorists who have to travel through the smoke should keep windows closed, turn off air conditioning and keep their air vents closed.

"Any smoke can be an irritant and as such, if people need to be outdoors, they are advised to avoid outside areas affected by any smoke or ash, or to limit the time that they spend in them.

"Some of the substances present in smoke can irritate the lining of the air passages, the skin and the eyes. Respiratory symptoms include coughing and wheezing, breathlessness, sputum (phlegm) production and chest pain. If symptoms occur, people should seek medical advice or call NHS Direct 0845 4647."

The HPA suggested that it may be most appropriate for a single organisation to lead the incident in order that messages were proactively issued to local residents and to deal with all complaints and media enquiries through a single point of contact. Normally the local authority would take the lead; however, the difficulty with this site was that an environmental permit and an exemption had been granted, with the EA as the regulator, therefore it was less clear who should lead the incident. RBFRS led in compiling the multiagency messages, the local authority led in communicating the messages to members of the public and the EA convened the multiagency meetings. All media queries and complaints from members of the public were dealt with separately by the organisations who had been contacted, which resulted in there being no single point of contact for the public and media.

The fire was not extinguished within two weeks and in fact continued to burn for several months; however, agencies were repeatedly assured that it would cease in a short time. Over the following weeks multiagency meetings continued to be convened and a watching brief was adopted on the site,

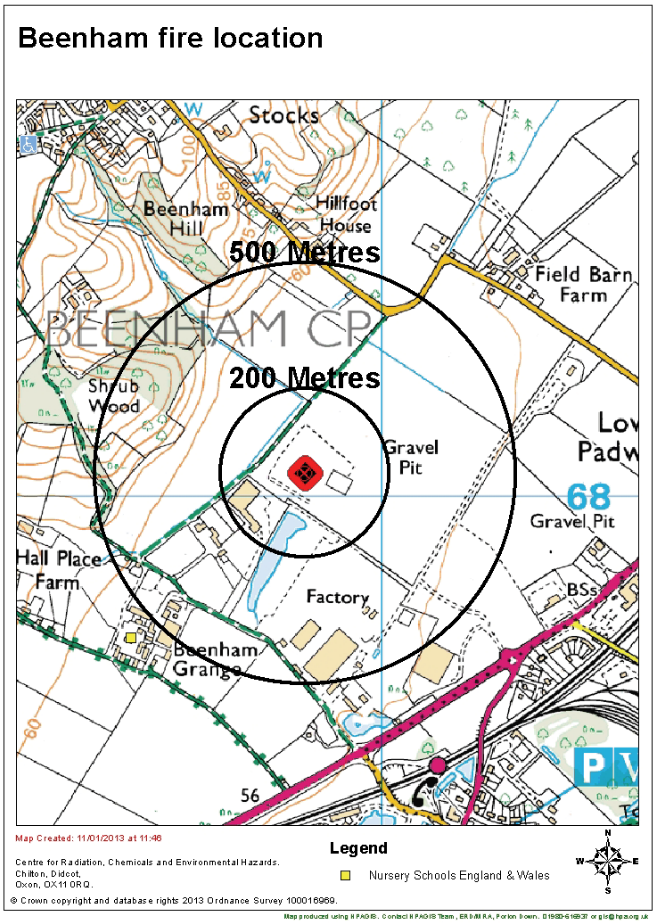

Figure 2: Location of the Beenham compost fire, showing sensitive receptors and 200 m and 500 m buffer zones

with continuing predictions that the fire was likely to die out naturally within a short period of time. During these meetings there were discussions regarding the piles of compost that were not currently on fire but were thought to be at risk of spontaneous combustion. Concern was raised by the HPA about the approximately 0.5 hectare of organic material, which contained plastic contamination, located within the eco pods (see Figure 1). The numbers of complaints received were also reviewed at these meetings. The risk assessment undertaken by the HPA suggested smoke and odour from the fire were unlikely to be of concern to health. This incident was complex in terms of organisations involved and who should take the lead in communications, particularly as the local authority and RBFRS were not in agreement as to which organisation should lead the incident.

On 9 May 2013 PHE was notified by the landowner that additional piles of compost had spontaneously combusted. There was a subsequent increase in the number of complaints from members of the public received by the local authority and the EA. RBFRS considered that the fire may continue to burn for several more months, which could result in a continued smoke nuisance to local residents. In response to the number of complaints, on 14 May 2013, the local authority served an abatement notice (under the Environmental Protection Act 1990, Section 80) on the operator of the site.

The notice identified the smoke coming from the premises as being a statutory nuisance, and identified that the owners needed to:

1 "Formulate a plan of action to extinguish the fire. This plan must have the full agreement of Royal Berkshire Fire and Rescue Service. This should include any appropriate steps to ensure there are no further fires in any of the remaining stockpiles of composting material.

2 "Undertake each and every action specified in the plan until the fire has been extinguished."

The multiagency partners agreed the tactical plan which was developed by RBFRS. The plan was to use machinery to dig out the piles of organic matter and spread these out over the site concrete apron whereupon RBFRS would wet them down. The wet material would then be removed from the site and disposed of appropriately to ensure that it did not combust spontaneously again. The action plan was implemented on 5 June 2013 and within two to three weeks all of the piles that had been on fire were extinguished. Ash, and material that had not previously caught fire, were removed from site.

Discussion

An estimated 2,100 people live within 2 km of the site of the incident and, depending on the wind direction, were potentially affected by the smoke plume for up to six months. Between 4 December 2012 and 25 May 2013, 51 different complainants made a total of 60 complaints to the local authority. Some complaints covered multiple aspects of the fire (eg health and smoke). This resulted in a total of 93 complaints being logged. Complaints were received from residents up to approximately 3 km from the incident. The majority of the complaints were about health (29%), smoke (25%) and odour (20%).

While the risk assessment undertaken by PHE suggested smoke and odour from the fire were unlikely to be of concern to health, it is difficult to quantify the health impact from any stress associated with such a prolonged incident.

This incident provided valuable opportunities for engaging effectively with multiagency partners. It highlighted the importance of implementing a coordinated communications strategy and engaging with other responders at the outset of the incident. This ensured that all aspects of the incident were addressed, particularly as there was extensive local media coverage of the incident and local residents were extremely concerned about their exposure to products of combustion associated with the fire.

Lessons and further work

The complexities of this incident have highlighted the importance of identifying early on which organisation should take the lead as a single point of contact for all public and media enquiries and for proactively putting out information.

This fire highlighted the differences between estimated and actual burn times of incidents. It can be difficult to predict the longevity of a fire and, when the actual burn time exceeds the initial predictions, there can be knock-on impacts on the multiagency messages that are being released to the media and public.

This incident, amongst others, has led to the EA identifying similar high risk sites that may be involved in fires in the future. Fires which continue for extended periods of time lead on to subjective discussions about when an incident ceases to be in the acute phase and moves into a sub-chronic or chronic phase. This is an important consideration when providing public health advice, as the advice for an acute incident will generally be for members of the public to shelter. Sheltering is usually an appropriate public health intervention for short-lived incidents. In longer term incidents, evacuation should be considered if sheltering poses risks greater than those associated with the removal of people from their sheltering locations (eg evacuation through a plume). However, the effectiveness of a given intervention strategy depends on the incident and situation-specific factors, and each case must be judged on its merits. A number of factors affect effectiveness (they include the pollutants' physicochemical properties, the duration of the incident and decisions taken with regard to tackling the fire, population at risk and building factors); judgements about effectiveness can be complex and the best protective option may not be clear-cut. For the compost fire in Beenham, the probable constituents in the smoke, based on previous air monitoring close to fires at composting sites, and the associated risk to public health taking into account the proximity of nearby receptors, were not considered to be significant enough for PHE to recommend evacuation. PHE is currently undertaking a review of research on sheltering and evacuation to better inform future public health advice.

This fire identified valuable learning points for all the organisations involved. The important task of disseminating experiences, lessons identified and best practice will continue within each organisation and through multiagency emergency planning and multiagency exercises.

Acknowledgments

Thanks to the Environment Agency, Paul Anstey from West Berkshire Council and Dr Rebecca Gay for reviewing this paper prior to submission.

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Indoor air quality enquiries received by the Centre for Radiation, Chemical and Environmental Hazards (CRCE) London

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Introduction

Historically, air quality research has focused on outdoor air and the potential impacts on public health of traditional pollutants from sources of combustion (eg traffic pollution). Outdoor air pollution influences indoor air quality but there is increased recognition that personal exposure to air pollution predominantly takes place in the indoor environment. Given that the majority of the population spend more time at home rather than in other indoor locations, air quality in the home is likely to play a significant role in determining exposure to air pollutants[1]. This is particularly significant when considering exposure over a lifetime for vulnerable groups and those in occupations where exposure to the same pollutants might occur within the home and occupational settings.

Although outdoor air pollutants contribute to the indoor air pollution mixture, indoor air quality is predominantly influenced by pollutants generated inside the home: from building materials, appliances and furniture or household activities such as cooking, smoking, cleaning, hobby activities and home improvements. Levels of indoor air pollution thus depend on a range of internal and external factors. Moreover, concentrations of pollutants can vary from room to room and can be influenced by external weather conditions.

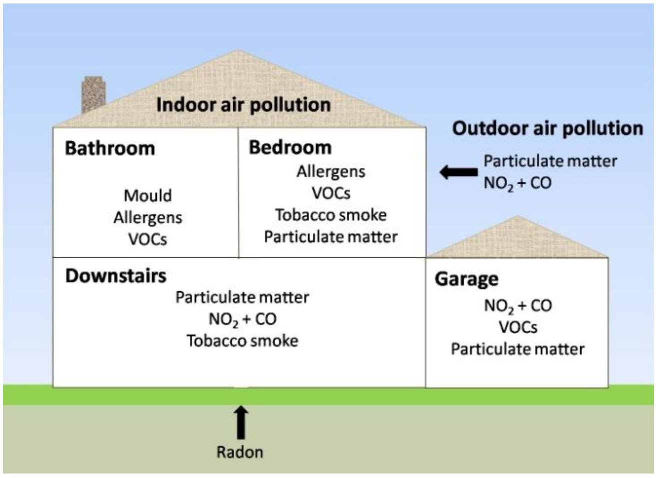

Figure 1: Typical distribution of main air pollutants in a home (from Parliamentary Office of Science and Technology, 2010[2])

The London unit of Public Health England's (PHE) Centre for Radiation, Chemical and Environmental Hazards (CRCE London) has received a number of enquiries in relation to poor indoor air quality in private residential properties and has been asked to make independent assessments of air quality monitoring undertaken by private companies. Monitoring was usually undertaken in response to adverse health effects ascribed to poor indoor air quality.

Methods

The indoor air quality data monitoring methodologies employed by the private companies varied considerably, resulting in data being received in a range of formats, with a variety of monitored compounds over different time periods. The data from seven enquiries relating to five recently built flats was analysed. It included monitoring for the following indoor air pollutants: carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), formaldehyde (a common volatile organic compound) and total volatile organic compounds (TVOCs). Monitoring periods at these flats varied from 24 hours to one week. CRCE London collated the data to determine the range of concentrations recorded throughout all the flats for each pollutant. In addition, the highest mean concentration noted at a specific flat for each pollutant was identified. The monitoring data was then compared to appropriate health standards including the WHO guidelines for indoor air quality[3], other international standards[1] where available, and against typical background concentrations previously monitored in UK properties by the Building Research Establishment (BRE)[4]. The air quality assessments provided by private companies were also scrutinised for monitoring methodology and other observations (eg presence of damp and mould) within the flats which aided the risk assessment process.

Results

The results for each pollutant are shown in Table 1 and then described and interpreted on an individual pollutant basis.

Carbon dioxide

Carbon dioxide is naturally present in air at concentrations of 300 to 450 ppm. The main source in outdoor air is through the combustion of fossil fuels. In indoor air, the primary source of CO_2 is human exhaled air that may accumulate in poorly ventilated buildings. Other sources include fossil fuel based cooking and heating appliances.

Exposure to CO_2 is not generally associated with adverse health effects. However, its occurrence at higher

Table 1: Range and highest observed mean concentrations from enquiries received by CRCE London in comparison to typical background concentrations and relevant guidelines

	Pollutant				
	CO_2 (ppm)	CO (ppm)	NO_2 (ppb)	TVOCs	Formaldehyde (ppb)
Indoor guideline value [a]	1,000 [b]	87.3 (15 min) 30.6 (1 hour) 8.7 (8 hours 6.1 (24 hours) [c]	110 (1 hour) [c]	0.2–0.5 mg/m^3 [d]	81 (30 min) [c]
Typical background concentration [e]	N/A	0.34 [e]	6.3 [e]	0.21 mg/m^3 [e]	18 [e]
Range from data received	440 – 2657	0–18.946	7–346	0.125–13.291 ppm	18–95
Highest observed mean concentration from data received [a,f]	>1,300 (2 days)	2.224 (25 hours)	64 (6 days)	0.535 ppm (25 hours)	71 (6 days)

Notes

Conversion to mg/m^3: CO 1 ppm = 1.15 mg/m^3; CO_2 1 ppm = 1.80 mg/m^3; NO_2 1 ppb = 0.00188 mg/m^3; formaldehyde 1 ppb = 0.00123 mg/m^3; TVOC conversion not possible, discussed further in the TVOC section below.

a Value in brackets indicates the averaging period
b Chartered Institution of Building Services Engineers, 2006[4]
c WHO Indoor Air Quality Health Guidelines, 2010[3]
d Range of TVOC international health guidelines, from Raw et al, 2004[1]
e Mean concentration from indoor air monitoring in 830 UK bedrooms, from Raw et al, 2004[1]
f Represents figures from flat with highest level of pollutant from enquiries received (figure in brackets represents the averaging period)

concentrations may indicate poor ventilation and the potential for other contaminants to be present as well. The Chartered Institution of Building Services Engineers (CIBSE) recommends that properly ventilated buildings should have CO_2 levels below 1,000 ppm[4]. The average concentration in three of the five flats was above this guideline value and all the flats had periods where 1,000 ppm was exceeded. Figure 2 illustrates the CO_2 concentrations in a poorly ventilated flat that had visible evidence of damp and mould.

Research has indicated that exposure to CO_2 at an airborne concentration of 5,500 ppm for six hours produced no adverse effects. However, exposure to 2% (20,000 ppm) CO_2 for several hours has produced headache, shortness of breath on exertion and increased depth of breathing[5]. The maximum CO_2 concentration recorded throughout the five flats (2,657 ppm) is significantly below the exposure levels noted in these studies.

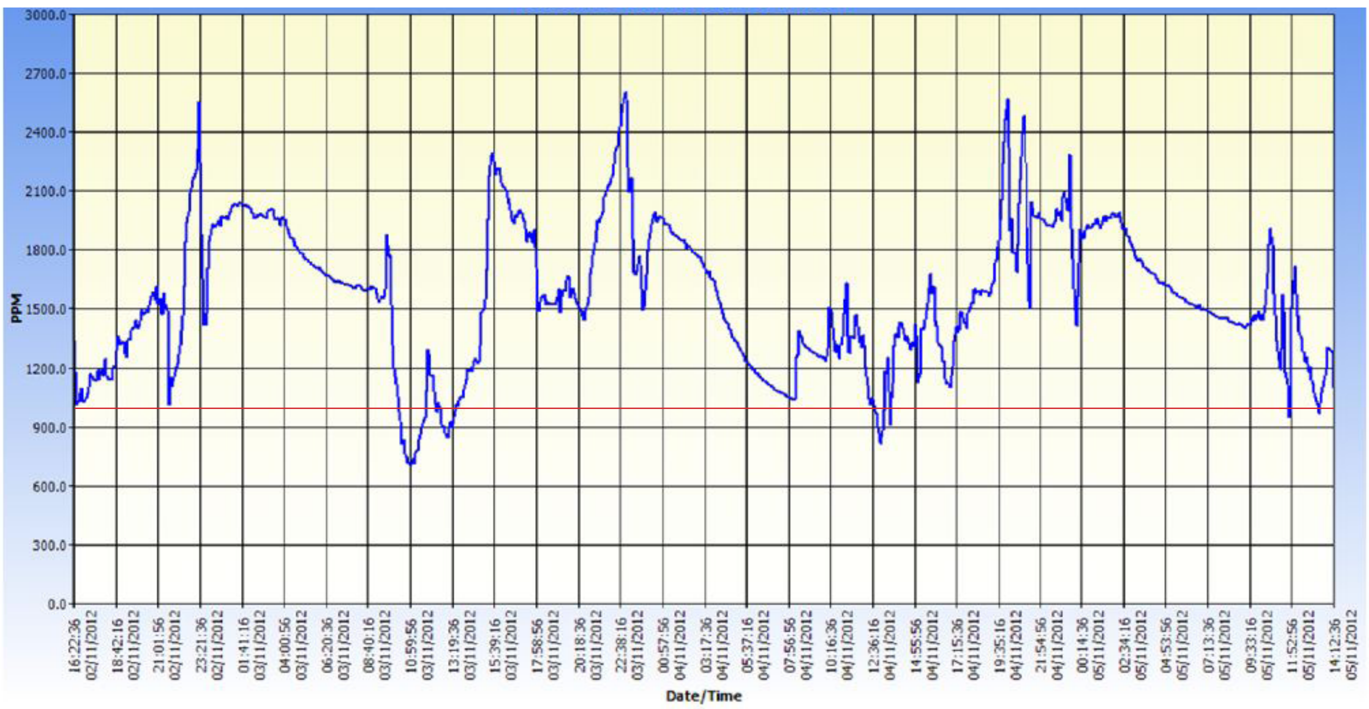

Figure 2: CO_2 concentrations in a poorly ventilated flat (source: Riverside Environmental Services Ltd)

Nitrogen dioxide

Road traffic is the principal source of NO_2 in outdoor air but it is also considered to be a significant indoor air pollutant; sources include tobacco smoke and cooking and heating appliances that use fossil fuel.

The recorded concentrations of NO_2 ranged between 7 and 346 ppb with a highest observed mean concentration of 64 ppb. Some of the peak concentrations observed in the flats appear intermittently to exceed the WHO one-hour average guideline of 110 ppb for short periods. However, studies have indicated that reported maximum measured NO_2 levels associated with the use of gas appliances in homes are in the range 80–1,092 ppb over one hour, with peaks of up to 212–2,023 ppb for one minute[2]. The concentrations reported were well within these ranges and assessed to be below those likely to pose a significant threat to health.

Formaldehyde

Raised indoor concentrations of formaldehyde are usually associated with newer properties, where sources include new flooring (especially particleboard) and furniture. Recent painting and decorating in properties are also associated with increased concentrations[1].

The recorded concentrations of formaldehyde ranged between 18 and 95 ppb and the highest observed mean concentration was 71 ppb. The WHO guideline value for formaldehyde of 81 ppb (as a 30-minute average concentration) was exceeded marginally for a single short period in one flat. Given that the mean concentration was significantly below the guideline value and there was only a single exceedance noted, it was considered unlikely to represent a risk to health.

Carbon monoxide

Carbon monoxide is produced indoors by poorly maintained, malfunctioning or poorly ventilated cooking and heating appliances which burn solid or fossil fuels; it can be released into the indoor environment when chimneys or flues fail. It may also infiltrate indoors from outdoor sources such as exhaust from motor vehicles or other combustion processes. Occupant behaviour also influences the source of CO in the indoor environment: it is found in tobacco smoke, produced when candles burn and when outdoor camping equipment such as BBQs and kerosene lamps are inappropriately used indoors.

The recorded concentrations of CO over the monitoring period were between 0 and 18.9 ppm. All of the recorded values (including the peaks) were below the 15-minute and one-hour WHO guideline values. Similarly, the mean concentration of CO in all the flats fell below the WHO guideline values set for a 24-hour average. Intermittent increases in CO concentration were associated with an inhabitant being a smoker in one flat.

Total volatile organic compounds

There are numerous VOCs that can be found in the indoor environment, some of the most commonly present include toluene, acetone, benzene, formaldehyde (discussed above) and xylene. Generally, volatile organic compounds (VOCs) in indoor air can originate from outdoor air (eg air, soil and water sources) as well as from indoor sources including building materials and furniture, and materials often stored in attached garages such as solvents (eg adhesives and white spirit), petrol and paints. Household cleaning products, air fresheners and personal hygiene products are also notable sources indoors. Small quantities are released from heating and cooking appliances and the burning of scented candles and incense.

The WHO indoor air quality guidelines include nine chemicals in total but do not provide a value for TVOCs. There are no definitive target guidelines for TVOC in indoor air, although values between 200 and 500 mg/m^3 have been proposed internationally[4]. Unfortunately monitoring equipment employed by private companies in this study recorded TVOCs in parts per billion (ppb). It is not possible to convert ppb for TVOCs into mg/m^3 for comparison to relevant health guidelines due to the different molecular weights of VOCs. It is possible to adopt a precautionary approach and assume that the composition of the VOCs is 100% benzene. However, this is likely to give an inaccurate reflection of the pollution within a property and result in an unnecessarily conservative risk assessment. Similarly, it is not possible to compare the monitoring results to typical background concentrations in UK properties as these are also typically measured in mg/m^3. However, a number of potential sources of VOCs such as cleaning and decorating products were observed in some of the properties.

Air quality 'events'

The reports provided by private companies often described numerous air quality 'events' where increases in pollutant concentrations were noted at similar times (eg CO and TVOCs), as in Figures 3 and 4. The assessments provided often assumed these events to be linked to sources of pollution such as boiler flues from neighbouring properties.

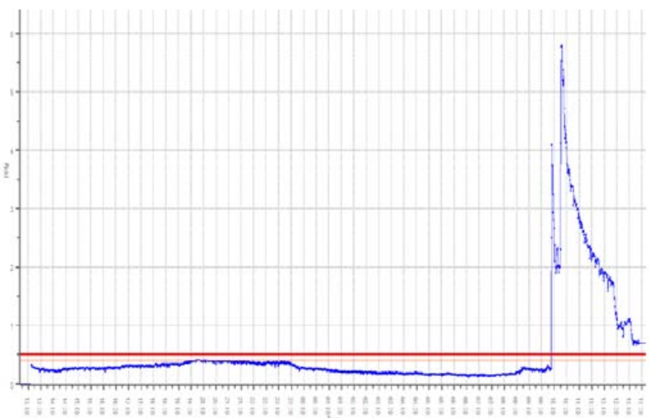

Figure 3: Air quality 'event' for CO (source: Riverside Environmental Services Ltd)

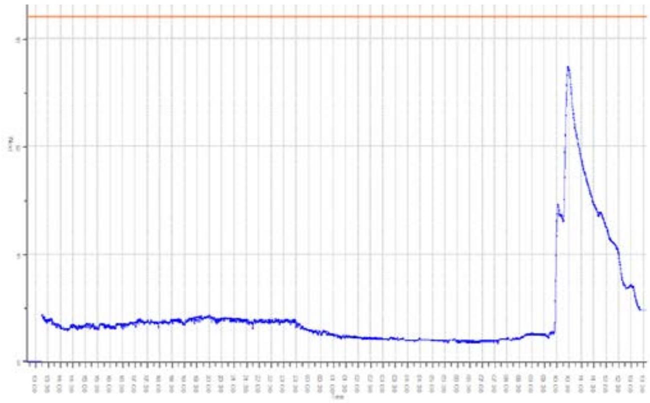

Figure 4: Air quality 'event' for TVOCs (source: Riverside Environmental Services Ltd)

Following an appropriate risk assessment and comparison to relevant guidelines CRCE London concluded that these events were unlikely to represent a risk to health and it was not possible to link the events to a particular source given the limited data provided.

Discussion

In general, CRCE London found limited evidence that indoor air pollution was posing an immediate threat to health, based on the studies reviewed. Temporal peaks in pollutants such as VOCs were potentially associated with the use of household products such as polishes or white spirit. However, in a number of cases indoor air complaints were linked to reduced ventilation highlighted by increased CO_2 concentrations[4]. In one flat high CO_2 concentrations and poor ventilation were apparent by visible damp and mould. Residential properties built during the last decade are likely to be the most airtight, due to the requirements of current UK building regulations. However, this requirement for improved energy efficiency within new homes may be contributing to a deterioration of indoor air quality due to reduced ventilation. If monitoring is undertaken for groups of chemicals (eg TVOCs) rather than for individual chemicals there may not be relevant health standards for comparison. Where an indoor air health guideline does not exist, it may be more difficult to assess the potential risk to health especially if monitoring data for typical indoor background concentrations is unavailable. There is considerable research being undertaken into indoor air quality and health. The development of indoor health guidelines for additional chemicals should enable more thorough risk assessments to be undertaken for enquiries such as these.

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Bromate contamination of the Hertfordshire chalk aquifer and how it was remediated

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Incident overview

Affinity Water (formerly Veolia Three Valleys Water) supplies water services to parts of Bedfordshire, Berkshire, Buckinghamshire, Essex, Hertfordshire, Surrey and the London boroughs of Barnet, Brent, Ealing, Harrow, Hillingdon and Enfield. It is the largest 'water only' supplier in the UK, providing over 800 million litres of water every day to over three million customers. Of Affinity's water, 42% is derived from rivers and reservoirs and 58% from boreholes and aquifers. Affinity also supplies water by 83 treatment works, 137 service reservoirs and 14,277 km water mains[1].

In May 2000, during routine preliminary sampling at the Hatfield pumping station, the then Veolia Three Valleys Water detected bromate concentrations of 135–140 µg/l; well in excess of the proposed drinking water standard at the time (10 µg BrO_3/l). This paper describes the recovery methods implemented to protect public water supplies following identification of the raised bromate levels, both in the immediate aftermath and in the long-term. This event was widely reported in the media at the time.

Potential public health implications

Bromate can be formed during disinfection of drinking water as a result of a reaction between the strong oxidants used (usually ozone) and naturally occurring bromide in the water. Bromate may also be generated during the manufacture of sodium hypochlorite disinfectant, and in some circumstances groundwater beneath industrial sites can become contaminated with bromate. The current UK water quality standard that came into force at the end of 2003 is 10 µg BrO_3/l [1].

It was estimated that the bromate contamination identified in 2000 could potentially impact over 40 km^2 of the Hertfordshire chalk aquifer, involving several supply boreholes (Northern New River – NNR – wells).

The levels of bromate in this event were elevated (135–140 µg/l) above the drinking water standard (10 µg BrO_3/l)[2], but were unlikely to cause a significant risk to public health as concentrations would need to be between 2% for potassium bromate and 10% for sodium bromate to cause acute toxicity (see the box). As a precautionary measure, the contaminated water source was removed from public supply, which involved the immediate cessation of water abstraction at the Hatfield pumping station.

As part of the ongoing management of the bromate contamination of the groundwater water source, the water companies affected undertook various remediation measures to ensure that the bromate contamination did not affect the public water drinking supply. These measures are discussed below and are described in more detail in the UK Recovery Handbook for Chemical Incidents[6].

A water quality monitoring programme was initiated in June 2000, which confirmed pollution of the chalk aquifer came from the site of a former chemical works 5 km away in Sandridge, where bromine-based chemicals were manufactured some years previously (from 1955 until 1980). In response, the site was determined as 'contaminated land' and designated a 'special site', as defined under Part IIA of the Environmental Protection Act 1990. In November 2005 the Environment Agency served a legal notice under Section 78E of the Environmental Protection Act 1990 on the two companies that had previously occupied the site. This notice required the companies to investigate and monitor the extent of the bromate contamination.

Protecting public water supply boreholes was a key objective in establishing the monitoring programme, with particular attention paid to key 'indicator' boreholes located at the

Box: Toxic effects of bromate salts

Signs or symptoms of bromate exposure include nausea, vomiting, abdominal pain, anuria and diarrhoea, varying degrees of central nervous system depression, haemolytic anaemia and pulmonary oedema. Most of these effects are reversible[3].

Most cases of human poisoning from bromate are due to accidental or intentional ingestion of home hair treatment solutions, which may contain either 2% potassium bromate or 10% sodium bromate[3].

In children, serious poisonings have been reported following ingestion of 60–120 ml of 2% potassium bromate (equivalent to 46–92 mg of bromate per kg of body weight per day for a 20 kg child).

Lethal doses of potassium bromate are estimated to be 200–500 mg/kg of body weight (150–385 mg of bromate per kg of body weight)[4]. Irreversible effects include renal failure and deafness, both of which have been observed following the ingestion of 240–500 mg of potassium bromate per kg of body weight (185–385 mg of bromate per kg of body weight)[5].

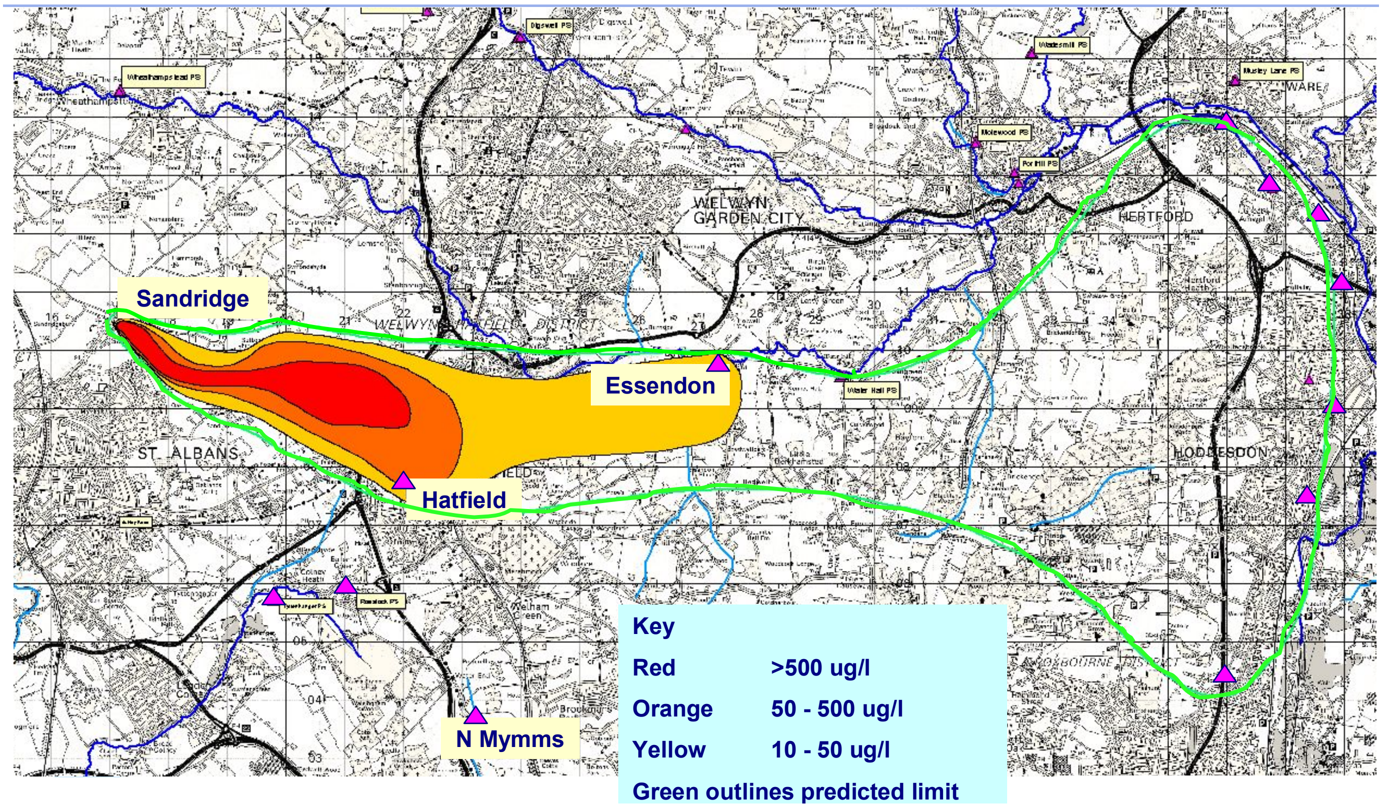

Figure: Bromate plume (on 1 km grid square mapping) (image courtesy of Affinity Water)

edges of the main body of the plume to assess plume boundary movement. The Environment Agency, Affinity Water and Thames Water continue to monitor water quality and water levels at a number of locations throughout the bromate-contaminated area, with 50 locations still subject to continued monitoring on a routine basis in 2013.

Following the immediate cessation of water abstraction and pumping at the Hatfield pumping station in 2000, the bromate concentrations recorded at public water supply sources downstream subsequently started to rise. In an attempt to ameliorate this, a trial was initiated in July 2005 where the Hatfield pumping station was restarted with the contaminated water being pumped to a waste sewer. As a result, peak concentrations of bromate in the downstream sources declined again. Therefore it seemed that abstraction at the Hatfield pumping station acted to intercept some of the bromate released into the aquifer from the source site that would otherwise lead to contamination of further downstream water sources. This arrangement is still in place today.

Bromate concentrations also appeared to respond to seasonal variations in water level. Further down the hydraulic gradient from the source zone at Hatfield, Essendon and the NNR wells, it was noted that seasonal fluctuations in bromate concentrations closely followed the seasonal cycle of soil moisture deficit (SMD). Seasonal peaks in bromate concentrations corresponded to peaks in SMD, ie higher measured bromate concentrations corresponded to dry conditions (high SMD) and lower bromate concentrations were observed during higher water levels.

Key points

- This incident was probably the largest groundwater pollution plume in England to date
- The discovery of bromate contamination had a major impact on water resources – drinking water quality, operational flexibility and deployable output
- Remediation measures to date have involved protecting consumers from direct exposure by implementing a sampling and monitoring strategy, controlled blending of drinking water supplies and implementation of interception pumping to protect downstream sources still used for public drinking water supplies
- It is still not known how the problem may develop in the future and what the wider impacts might be
- There were significant problems modelling the plume between the Hatfield area and the Northern New River (NNR) wells (the last 10 km of the plume), which could indicate that bromate flows in discrete fractures

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Emergency Preparedness and Response

Initial operation response (IOR) to a CBRN incident

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What is the IOR?

The Home Office, in collaboration with the Department of Health, Public Health England, University of Hertfordshire, Department for Communities & Local Government, Cabinet Office, Health and Safety Executive, and UK fire, ambulance and police services, has carried out a major review of the initial response to a CBRN (chemical, biological, radiological and nuclear) incident. This could also have utility in other incidents involving hazardous materials. The focus has been on the initial life-saving actions carried out by the emergency services. This has led to the production of the initial operation response (IOR) policy and a suite of products to support its delivery and implementation.

Why have we introduced the IOR?

The current guidelines instruct initial police and ambulance responders at a CBRN incident to await the arrival of trained specialists with appropriate protective equipment. However, there are some actions that it might be possible for these initial operation responders to undertake before the specialists arrive, without increasing their own risk.

Figure: Initial response teams exercising chemical incident response

The changes

Public Health England, working with the University of Hertfordshire under the ORCHIDS project (Optimisation through Research of Chemical Incident Decontamination Systems[1], see www.orchidsproject.eu), has carried out extensive research on the most appropriate methods of decontamination and how this can be achieved.

The findings show that by evacuating a contaminated casualty from the scene to a safe environment, disrobing and carrying out improvised decontamination, the majority of skin surface contamination will have been effectively removed, greatly improving the casualty's survival rate. The maximum benefit of this will be achieved within 15 minutes of exposure, ie in the period before any hazardous materials specialists are likely to have arrived on scene.

The findings also show that dry decontamination – the blotting and rubbing of exposed skin surfaces with dry absorbent material – is the most effective means for non-caustic agents. It should be considered the default process for an incident involving chemicals, unless the use of water is justified following medical advice.

The project

Over the past 18 months, a multiagency project board has developed policy and procedure for first responders at a CBRN incident that will focus on life-saving actions, while ensuring personal safety. The project board has liaised with the Health and Safety Executive, police federations, unions, legal departments and other key stakeholders as the products have been developed (see below).

The policy

The focus of the IOR is to save as many lives as possible by making the emergency services aware of what they can do to save life and the most effective time in which this action needs to be taken.

The IOR starts from the very first call to the emergency services or when a self-presenter arrives at a healthcare premise.

The key messages are:

- Evacuate
- Communicate and advise the people contaminated
- Disrobe
- Decontaminate – dry being the default, but wet remaining an option in certain circumstances

The first responders must work together quickly and efficiently to save life, including conducting a joint dynamic hazard assessment to inform multiagency decision making, achieve a safe multiagency response and deliver a safe resolution to the incident for the public and emergency responders alike.

What are the products?

The policy and procedure has been incorporated into an IOR guide and an aide memoir. The project has also produced a short (15-minute) film.

It is intended that every first responder from the police, fire and rescue, and ambulance services (including acute trusts) will receive an aide memoir and undergo a short (20-minute) elearning-training package.

When will it be launched?

The IOR will be launched in September 2013 and the products will be distributed to pre-identified single points of contact in each agency within each county/area shortly after, for all first responders.

We hope to have the products distributed during September 2013 and the training completed by the end of 2014.

What are the next steps?

To embed the IOR principle, a short multiagency tabletop exercise is being developed centrally for local delivery from October 2013. The exercise will be part of a wider programme of CBRNE and hazardous materials testing and exercising that is being considered to provide a more structured and cost-effective approach to this complex multiagency response.

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How the UK Government Decontamination Service is aiding preparedness in the event of a CBRN or major HazMat incident

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The Government Decontamination Service (GDS) was set up in 2005 following a review of the UK Government's resilience to deal with the consequences of a range of emergencies.

The primary functions of the GDS are:

- To provide advice, guidance and assistance on decontamination related issues to responsible authorities in their contingency planning for, and response to, chemical, biological, radiological and nuclear (CBRN) and HazMat incidents
- To maintain and build on the GDS framework of specialist suppliers and ensure that the responsible authorities have access to these services if the need arises
- To advise central government on the national capability for the decontamination of buildings, infrastructure, transport and open environment, and be a source of expertise in the event of a CBRN incident or major release of HazMat materials

The GDS achieves these functions through its ongoing programme of work, which includes a wide range of projects and workstreams designed to bridge gaps in recovery capability. The GDS manages a framework of specialist private sector suppliers who can be called upon to provide sampling, decontamination and waste management services following an incident. The GDS assures supplier capabilities through a number of evaluations and a contract management process.

The work of the GDS typically benefits a range of public and private sector stakeholders. For example, during January and February 2012 the GDS organised a joint response (acute) and recovery workshop, based around the scenario of a CBRN incident at a major transport node. Delegates representing the emergency services, private sector businesses, recovery experts, local government and central government departments were invited to the event, as participants and observers.

The workshop was designed to build on the work already conducted in the US on the resilience of major transport nodes. The main aim was to take those responsible for response and recovery through the various phases of a CBRN incident from start to finish, up to the 'new normality'. Recovering to a new normality is the process of rebuilding, restoring and rehabilitating the community following an emergency, ensuring that the community is progressed to a new normality by identifying any opportunities that go beyond recovery and could achieve longer term regeneration and development.

Figure 1: Framework supplier during an evaluation (A Arkell © GDS 2012)

The workshop aimed to identify the impact that decisions made during the response and recovery phases can have on the overall recovery timeline using the current state UK structures and guidance such as the Cabinet Office strategic national guidance (SNG)[1] and the Public Health England UK Recovery Handbook for Chemical Incidents[2]. It also allowed stakeholders representing businesses affected to identify critical points of failure.

The workshop was very interactive and resulted in a huge amount of discussion and consideration for the initial responders and those concerned with recovery. The response workshop enabled organisations that would be involved in the initial stages of a CBRN incident, such as the police, fire and rescue, and other emergency services, to run through the scenario. This gave recovery organisations not typically involved in the acute phase of an incident, including the GDS and its suppliers, an opportunity to really understand and appreciate the immediate and short-term constraints in response. It provided the observers with an opportunity to see how incidents are approached. This was reversed for

Figure 2: Workshop discussions (G Knight © GDS 2012)

the recovery phase of the workshop whereby the response delegates, not involved in the recovery phase, were able to see how their initial decisions and actions impacted on those dealing with the recovery.

By running the workshop through both the response and recovery process all attendees were able to appreciate and understand what was involved. Importantly the workshops highlighted how decisions made, and actions undertaken, during the initial response can assist in the timely recovery just by adapting or considering recovery during the response phase. This also helped to improve understanding of the communications process during an incident and how information can be passed to the recovery organisations to allow decontamination strategies to be initiated at the earliest opportunity. None of these adaptations or considerations compromised the acute response, effort to save life or the criminal investigation.

Following the workshop the GDS framework of specialist suppliers were asked to submit decontamination plans covering their respective areas of remediation. This allowed the key decision points for response and recovery to be identified, further information to be gathered on indicative response and recovery timelines, and an estimate of potential economic impacts to the businesses affected by the incident to be made.

The outputs of this workshop have assisted the GDS in developing accurate advice and guidance to support the recovery phase response should an incident similar to the scenario occur. It provided an opportunity to test the GDS framework suppliers, allowed the identification of business-critical functions and, where gaps were found in the response and recovery phases, indicated how improvements to systems and processes can be made in the future.

Furthermore, it was possible to assess the economic impacts of variations in the response and recovery approaches to the scenario. Some costs of the economic impact of a CBRN release can be difficult to assess given the unique aspects of such an event, so a range of assumptions must be considered. For example, issues such as public perception could drive remediation work above and beyond that which is technically required to render an area safe. Accurate clearance goals, those levels of contaminant deemed sufficiently safe for the public, tend to be generated on an incident-specific basis. Setting clearance levels before recovery begins could reduce the overall recovery timeline.

Feedback received from the workshop was very positive and highlighted a number of learning points that have led to the GDS developing a course with the Police National CBRN Centre for tactical advisers. The course aims to make first responders aware of the impact their decisions could have on recovery and how they can assist the recovery process as part of the acute response. This work would not have been possible without the input and wide-ranging expertise of the attendees at the GDS workshop.

The workshop contributes to the ongoing work programme of the GDS, which involves a wide range of projects and workstreams, all of which assist the UK in preparing for low probability, high impact events such as CBRN releases.

The GDS is always interested in engaging with stakeholders who would like to improve their understanding of the link between response and recovery. If you would like any further information please contact Annabel Townley, Gerry Knight or Anthony Arkell who designed the workshops, by email at gds@gds.gsi.gov.uk.

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After a major incident – a register to benefit all

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Picture the scene: the aftermath of a major chemical explosion or covert attack. Hundreds of people have been caught up in the blast and there are many injured, perhaps a number of people have been killed or will die in the next few hours as a result of their injuries. The emergency services have responded quickly and the police, fire and ambulance services are all on the scene in minutes. Decontamination structures have been erected and the injured are being triaged, showered and taken to hospitals by ambulance for treatment. Those less badly injured are making their way home independently, perhaps to see their GP for treatment later.

How do the health services know who has been involved in the incident, who might need treatment in the near future and who, while not apparently hurt immediately after the incident, might later need support or even treatment as a result of the effects on their health? How can we assess whether there are any unforeseen long-term health effects?

Currently, no UK system exists for the systematic collection of patient data in the immediate aftermath of a major incident. In the events of 7 July in London 52 innocent lives were lost. Although a register was established, for various reasons its success was limited so valuable health data on the long-term health effects of this incident was lost forever.

The London Assembly Report of the 7 July Review Committee published in July 2006 made the following recommendation:

> "Plans for responding to major incidents should include plans that extend into the months following an incident, setting out how survivors will be informed of any health risks, including post-traumatic stress disorder, and what support will be provided to them and by whom."

This situation is all about to change for the better. Public Health England, with support from the Department of Health, has developed plans to establish and implement follow-up registers for monitoring the health of people involved in major incidents.

The purpose is to ensure that, following a major incident, PHE, in collaboration with other organisations, is in a position to compile and maintain a timely register of those whose exposure to the incident may present a threat to their health. Through the development of the register, PHE and NHS colleagues will aim to ensure that individuals who are affected by such an incident are subject to appropriate risk assessment and management and are offered contact with health support services after the event.

One of the most challenging issues in the aftermath of the 7 July bombings was the caution and even reluctance of responding organisations to share patient data with each other. Clarification of this matter has now been given by the Cabinet Office to the effect that clauses under both the Data Protection Act 1998 and the Civil Contingencies Act 2004 allow for data sharing in the public interest.

Immediately following a major incident, a team of PHE staff specifically trained to work with healthcare teams in the early phase of an emergency response will be deployed to the receiving hospitals, with their agreement, to collect relevant demographic and exposure data at the front line without compromising clinical delivery. The collection of data from primary care, local authority rest centres* and other sources will also be implemented as soon as possible after the incident has occurred. Staff dealing with phone calls or any other method of communication with survivors will receive relevant training.

Another key aspect will be to raise awareness, through local resilience forums, among front-line staff to the importance of the establishment of the register, so that in the event of a major incident they have an understanding of why data is being requested and collected.

Being able to better understand the experiences and longer term health prognosis of people who survive major incidents will be of significant benefit to all those planning for and preparing their organisations and staff to respond to emergencies in the future. Following the incident, as more information and resulting updated advice become available, those people whose details have been collected on the register can be contacted and provided with additional health guidance and support. The information collected through the register can also be an important evidence-base for providing reassurance about the absence of long-term health consequences among survivors. Individuals who have experienced such incidents are often very philanthropic and pragmatic about giving their consent and time to being part of longer term psychological and public health assessments, so the register will allow for this to be carried out routinely where possible.

The aim is to have a system and the trained professionals to deliver it – to benefit us all.

* Premises used for temporary accommodation of evacuees from an incident (CCA 2004 Guidance).

Recovery, remediation and environmental decontamination – practical aspects associated with developing a recovery strategy following a chemical incident

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Introduction

Chemicals have an important role in the development of human society. However, accidents or chemical incidents, eg during the extraction, manufacture and transport of chemicals, have led to the contamination of the natural environment, resulting in socioeconomic and ecological damage. Chemical incidents can have a large impact on human health and ecosystems, and need to be controlled and managed appropriately. Owing to the necessity for appropriate recovery of an affected environment to protect societies, a UK Recovery Handbook for Chemical Incidents[1] has recently been published by the Health Protection Agency, which is now part of Public Health England. The handbook can be downloaded from the PHE website, and is a technical guidance document, reflecting scientific, technical and societal information relevant to the recovery and restoration of a contaminated environment[2,3].

There are few publications or reports in the literature regarding the constraints and effectiveness of the varied and different remediation techniques available. This paper presents an overview of the Aznalcóllar mine spill, which resulted in an extensive metal and metalloids contamination of an ecosystem in Spain in 1998. This incident required a novel long-term recovery strategy never implemented before in response to a chemical incident.

Overview of the incident

The Boliden Apirsa's Aznalcóllar/Los Frailes Silver-Copper-Lead-Zinc mine is 45 km west of Seville, in the south-western corner of Spain. On 25 April 1998, the walls of the pond containing the ore-processing residues from the Aznalcóllar pyrite mine collapsed. This flooded approximately 4,600 hectares of land along the Agrio and Guadiamar rivers with approximately 4 million m^3 of acid mine drainage (ie sludge) and 2 million m^3 of toxic mine tailings (mine waste considered uneconomic to work) rich in metals and metalloids. On the following days the spill flowed downstream in the Agrio and Guadiamar rivers and threatened the Doñana Natural and National Parks, a UN world heritage area and the largest reserve of bird species in Europe[4,5]. The acidic water-sludge (mine drainage) was prevented from contaminating the Doñana ecosystem by several temporary walls. However, the agricultural soils and sediments along the course of the Agrio-Guadiamar river system were severely impacted by metals and metalloids that are highly toxic to human health and ecosystems, such as arsenic, copper, cadmium, lead, zinc and other sulphide-related elements[6]. A total area of 4,286 hectares was covered by a mud layer averaging 7 cm in thickness[7]. The accident resulted in significant socioeconomic and ecological damage, mainly to the agricultural activities of the Guadiamar valley, and attracted worldwide media attention[8].

Clean-up and recovery process

The area affected (the Agrio and Guadiamar rivers) are surrounded by marshes and include a natural park and national park of great ecological value in close proximity. A natural park is an area of special diversity, uniqueness and beauty, which is suitable for recreational purposes. A national park is an area of great ecological value, with unique biodiversity and beauty (equivalent to a protected area in the UK) in which public access is restricted and which cannot be put to economic use. As a result, immediate recovery/remediation was required. The first phase of clean-up involved physical removal of the toxic mine tailings and sludge. This was done manually by mechanical excavation, using specialised machinery to protect the soil[5]. However, the levels of contaminants in the soil remained significant and two more similar clean-up phases were required in 1999 and 2000[9,10]. After each clean-up phase, the soils affected were treated by the use of additives and were enhanced with ploughing methods. The objectives of these remediation measures were to immobilise elements to protect groundwater systems and prevent the spread of contaminants, and also to increase soil pH and improve land fertility[11]. Soil treatments were applied in the following order[10]:

Phase one	application of organic matter and calcium rich additives (1998)
Phase two	liming with sugar-refinery scum (1999)
Phase three	application of organic matter plus iron-rich clay materials (2000)

Long-term recovery options

The high levels of metals and metalloids involved in the Aznalcóllar mine spill and their physicochemical characteristics (persistent in soils and water environments), made a reduction in the total concentration of these substances in the Agrio-Guadiamar ecosystem impractical. These special circumstances resulted in the implementation of two long-term recovery options that had not been implemented before over such an extensive area (4,600 hectares of land). One encompassed the whole ecosystem restoration through the recovery and restoration of plants and animals, land and fluvial system, and was entitled the *Ecological Green Corridor* (EGC) of Guadiamar. This recovery strategy was in effect assisted natural attenuation, and was based on phyto-management (also called phyto-remediation), involving the application of soil additives (organic matter and calcium-rich material) and re-vegetation of the affected area with native woody plants[11,12]. The EGC programme started in January 1999 and is still ongoing. During this time (14 years after the initial incident) an advanced stage of ecological regeneration and recovery has been observed. Recovery and re-establishment of the river has been very successful and the vegetation is also significantly improved. The functionality of this EGC programme has also been reflected in the recovery and re-colonisation of fauna[9].

The second long-term remediation option implemented was the construction of a *Permeable Reactive Barrier* (PRB) in the alluvial aquifer of the Agrio river in September 2000[6,8]. An alluvial aquifer is an area of water-bearing sand and gravel typically found near lakes and rivers. A PRB consists of a layer of reactive material buried in a narrow trench, which treats the contaminated groundwater as it flows through the reactive material. The PRB built in the Agrio aquifer was based on the only PRB for acid mine drainage described in the literature at that time[6]. The reactive material within the PRB used in this incident included a mixture of calcite ($CaCO_3$), vegetal compost (a mixture of decaying vegetal matter), iron and sewage sludge, which provides a continuous neutralisation of pH and removal of metals from groundwater within the PRB[6,8]. The PRB is still functioning and in place and has been up to 95% effective[13].

Effectiveness of the recovery options implemented

When identifying an appropriate recovery strategy (ie what recovery options should be considered) it is important to assess and appraise the effectiveness and constraints of all available techniques. An overview of the recovery options associated with the remediation and restoration of the environment following the Aznalcóllar mine spill, is given below.

Effectiveness of implemented recovery options

- Rapid construction of walls to protect the Doñana Natural Park was effective, as it prevented the spill from entering the park
- Removal of toxic sludge (acid mine drainage) from the Guadiamar river 'in dry' was successful. This 'in dry' process involves constructing cofferdams (walls) in the river, the evacuation of water and the subsequent removal of sludge, working in the same direction as the natural flow of the river
- Implementation of the EGC programme has been successful and reliable for the restoration of an ecosystem damaged by high quantities of persistent metals and metalloids
- Application of soil additives, ploughing methods and re-vegetation (phyto-management) was effective in stabilising metals and metalloids in soils, thus limiting the potential for leaching into groundwater systems
- Phyto-management was effective in improving the fertility of affected soil
- The EGC programme has improved the landscape and provided an opportunity for increased recreational activities, which has had positive socioeconomic benefits in the community
- The PRB continues to neutralise the pH and facilitate removal of metals from groundwater in the alluvial aquifer of the Agrio river

Considerations and constraints

- The mechanical cleaning and removal processes carried out involved heavy machinery, which may have buried toxic residual tailings within the soil
- Use of heavy machinery and large vehicles during the clean-up phases (ie physical removal of the toxic mine tailings and sludge) may have resulted in large amounts of aerosolised contaminants
- Soil additives should have low metals and metalloids content, and an appropriate content of nutrients and substances to treat the contaminated soil
- The EGC programme is a very slow process and has required continuous surveillance (sampling and monitoring), which can be expensive and require specialist skills for sampling and analysis
- Plants used for phyto-remediation absorb contaminants from the soil. These plants are known as accumulator plants. They should be resistant to the contaminants involved, grow quickly and not accumulate high concentrations of pollutants into their leaves and fruit because of the risk of entry into the food chain
- The complexity of the internal structure of the Agrio alluvial deposits affected the design of the PRB. Owing to the design requirements, the heterogeneities of the filling material in the PRB resulted in preferential flows within the PRB, which impacted on capture of the contaminated plume in the groundwater
- Compost used to fill the PRB showed poor degradability which prevented the complete reduction of the sulphate pollutants

Conclusions

Reclamation of an ecosystem extensively affected by metals and metalloids is a very slow process, and complete restoration may not be possible. The natural structure of an ecosystem may affect the dispersion of contaminants following a chemical incident, resulting in a heterogeneous distribution of pollutants, and thus impede their removal. The complex natural structure of the Agrio-Guadiamar river system and valley influenced the effectiveness of recovery options implemented to remediate the environment following the Aznalcóllar mine spill.

The success of any clean-up process is linked to the distribution of contaminants within the environment, with the success of clean-up seen to decrease linearly with increasing heterogeneity of distribution. Thus, a geochemical and biological study of the area should be carried out prior to the selection of the recovery options.

The cleaning-removal processes applied in response to the Aznalcóllar mine spill have been successful but are not sufficient to recover the agricultural land used. However, the implementation of long-term recovery options, such as an assisted natural remediation (the EGC programme) and the construction of the PRB have been shown to be effective for economic and social restoration purposes. Through the improvement of the landscape the EGC programme has provided a new land use for the area contaminated, that provide economic benefits for the community affected. This programme has also introduced projects to promote conservation and protect biodiversity, enhancing the public awareness of environmental protection.

The UK Recovery Handbook for Chemical Incidents is available at

> https://www.gov.uk/government/organisations/public-health-england/series/recovery-remediation-and-environmental-decontamination

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Environmental and Toxicological Research

Geophagia and Calabash chalk – a toxic habit?

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Background

Public Health England (PHE) has recently published an advisory leaflet on the health risks of eating chalks and clays to raise awareness of the practice and risk(s) associated with the intentional consumption of chalks (focusing on Calabash chalk) and clays (Figure 1).

The intentional eating of earthy materials (such as clay, soil and chalk) is termed 'geophagia' or 'geophagy'. Medically speaking, geophagia falls under the umbrella of pica disorders – as it is the deliberate and often habitual consumption of non-food materials. Particular reference was made in the leaflet to the use of chalk and clay products by pregnant and nursing mothers. Pregnant women from some minority communities have been reported to be the more likely consumers of chalks and clays[1,2], for the perceived benefit of providing an antiemetic effect, ie as an antidote to morning sickness.

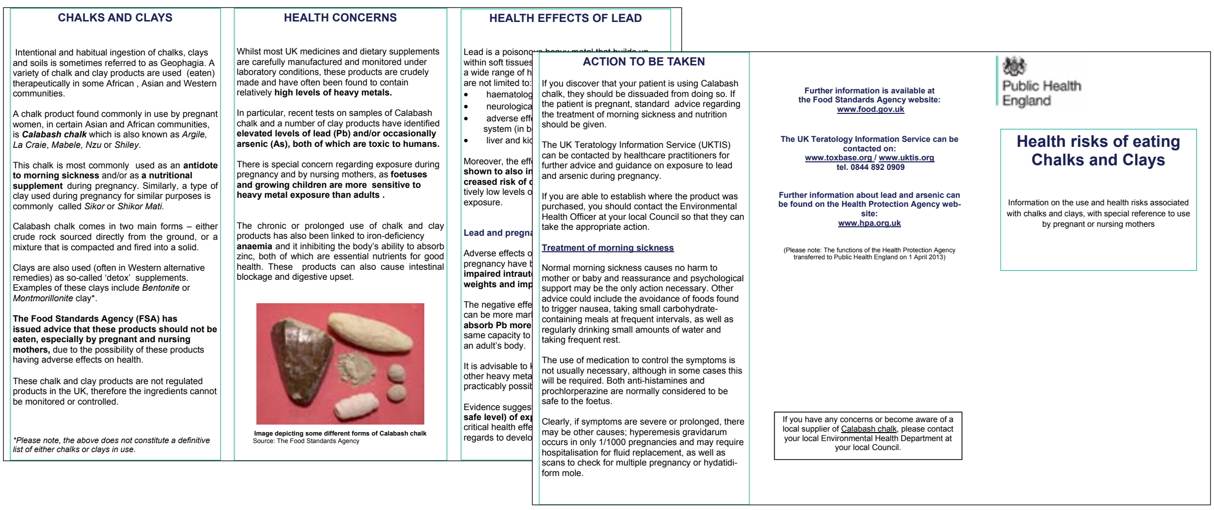
The leaflet was produced after an enquiry for advice on the health implications of the use of Calabash chalk by London-based environmental health professionals, following a number of seizures of the product across London boroughs. The leaflet contains information on Calabash chalk and some clays, and discusses the possible health risks associated with eating these materials, as well as providing advice on the management of morning sickness and what action can be taken by health professionals. It is primarily aimed at promoting awareness of and providing information on the use of calabash chalk for health professionals who may encounter members of the community practising geophagia.

Geophagia

Geophagy is not a new phenomenon or practice by any means, and has been documented historically in many countries across the world.

The aetiology of geophagia is complex and not fully understood, but the cultural/social inheritance of the practice is thought to feature strongly. Perceived beneficial or therapeutic effects from eating such earthy materials, eg as an antidote to morning sickness or as a potential nutritional supplement, have been suggested as probable motivational factors behind the practice. Geophagia has been documented globally, with a general consensus in the literature showing a cultural and prevalence of use in much of Africa, in particular in Nigeria, South Africa and Kenya. Case reports and the literature also point to prevalent geophagic activities in Asia[3,4] and of the habit being predominantly exhibited by pregnant women.

As a virtue of globalisation, many urban areas in the UK which are multicultural hubs, such as London and Birmingham[5], also have communities which practise geophagy[4]. It is difficult to characterise the prevalence of geophagic behaviour, and the current epidemiological data regarding the eating of chalks and clays is insufficient to accurately characterise geophagic prevalence especially in the UK where geophagia is not



CHALKS AND CLAYS

Intentional and habitual ingestion of chalks, clays and soils is sometimes referred to as Geophagia. A variety of chalk and clay products are used (eaten) therapeutically in some African , Asian and Western communities.

A chalk product found commonly in use by pregnant women, in certain Asian and African communities, is ***Calabash chalk*** which is also known as *Argile, La Craie*, *Mabele, Nzu* or *Shiley*.

This chalk is most commonly used as an **antidote to morning sickness** and/or as **a nutritional supplement** during pregnancy. Similarly, a type of clay used during pregnancy for similar purposes is commonly called *Sikor* or *Shikor Mati.*

Calabash chalk comes in two main forms – either crude rock sourced directly from the ground, or a mixture that is compacted and fired into a solid.

Clays are also used (often in Western alternative remedies) as so-called 'detox' supplements. Examples of these clays include *Bentonite* or *Montmorillonite* clay*.

The Food Standards Agency (FSA) has issued advice that these products should not be eaten, especially by pregnant and nursing mothers, due to the possibility of these products having adverse effects on health.

These chalk and clay products are not regulated products in the UK, therefore the ingredients cannot be monitored or controlled.

**Please note, the above does not constitute a definitive list of either chalks or clays in use.*

HEALTH CONCERNS

Whilst most UK medicines and dietary supplements are carefully manufactured and monitored under laboratory conditions, these products are crudely made and have often been found to contain relatively **high levels of heavy metals.**

In particular, recent tests on samples of Calabash chalk and a number of clay products have identified **elevated levels of lead (Pb) and/or occasionally arsenic (As), both of which are toxic to humans.**

There is special concern regarding exposure during pregnancy and by nursing mothers, as **foetuses and growing children are more sensitive to heavy metal exposure than adults .**

The chronic or prolonged use of chalk and clay products has also been linked to iron-deficiency **anaemia** and it inhibiting the body's ability to absorb zinc, both of which are essential nutrients for good health. These products can also cause intestinal blockage and digestive upset.

Image depicting some different forms of Calabash chalk
Source: The Food Standards Agency

HEALTH EFFECTS OF LEAD

ACTION TO BE TAKEN

If you discover that your patient is using Calabash chalk, they should be dissuaded from doing so. If the patient is pregnant, standard advice regarding the treatment of morning sickness and nutrition should be given.

The UK Teratology Information Service (UKTIS) can be contacted by healthcare practitioners for further advice and guidance on exposure to lead and arsenic during pregnancy.

If you are able to establish where the product was purchased, you should contact the Environmental Health Officer at your local Council so that they can take the appropriate action.

Treatment of morning sickness

Normal morning sickness causes no harm to mother or baby and reassurance and psychological support may be the only action necessary. Other advice could include the avoidance of foods found to trigger nausea, taking small carbohydrate-containing meals at frequent intervals, as well as regularly drinking small amounts of water and taking frequent rest.

The use of medication to control the symptoms is not usually necessary, although in some cases this will be required. Both anti-histamines and prochlorperazine are normally considered to be safe to the foetus.

Clearly, if symptoms are severe or prolonged, there may be other causes; hyperemesis gravidarum occurs in only 1/1000 pregnancies and may require hospitalisation for fluid replacement, as well as scans to check for multiple pregnancy or hydatidiform mole.

Further information is available at the Food Standards Agency website: www.food.gov.uk

The UK Teratology Information Service can be contacted on: www.toxbase.org / www.uktis.org tel. 0844 892 0909

Further information about lead and arsenic can be found on the Health Protection Agency website: www.hpa.org.uk

(Please note: The functions of the Health Protection Agency transferred to Public Health England on 1 April 2013)

If you have any concerns or become aware of a local supplier of Calabash chalk, please contact your local Environmental Health Department at your local Council.

Public Health England

Health risks of eating Chalks and Clays

Information on the use and health risks associated with chalks and clays, with special reference to use by pregnant or nursing mothers

Figure 1: PHE advisory leaflet on the health risks of eating chalks and clays, published in June 2013 and available at www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317139340150

Figure 2: Different forms of Calabash chalk (source: Food Standards Agency © 2006)

common practice. Often these materials are sold 'under-the-counter' in ethnic markets and grocery shops in areas where culturally established geophagic habits are commonplace.

The primary concern with the consumption of such products is that they may contain heavy metals at concentrations that are harmful to health, as well as possibly containing microbial pathogens[2].

Calabash chalk

One geophagic material is Calabash chalk (Figure 2), on which the PHE advisory leaflet focuses. Other names for the chalk include Argile, La Craie, Mabele, Nzu or Shiley. A type of clay used during pregnancy for similar purposes, most commonly in the Asian subcontinent, is called Sikor or Shikor Mati. It is usually eaten for perceived therapeutic gains as an antidote to morning sickness[6] and/or as a nutritional supplement during pregnancy and breastfeeding.

Calabash chalk is not a regulated food product and thus the source, 'ingredients' and/or constituents cannot be controlled. As such, local authorities have the regulatory power to seize such products when found on sale as a foodstuff.

As the chalk is not a conventionally produced foodstuff it is not possible to state definitively the ingredients, make-up of these products or health risks associated with the different sources of the chalk. Abrahams et al[7] reported low organic content of (Nigerian-sourced) Calabash chalk, as did Dean et al[8] in their respective samples, which suggests that the product is sourced from strata at depths below surface soils. Depending on the historical land use and natural geology of an area, levels of heavy metals could vary greatly between chalks (as could other physicochemical properties), and therefore pose varying health risks if ingested.

Scientific literature discussing the analysis of various Calabash chalk samples has reported relatively high levels of lead and sometimes arsenic, as well as other trace metals, at concentrations which would render the product unsafe for consumption as a foodstuff (see below for more detail). Moreover, an association between iron-deficiency anaemia and geophagia (including the use of Calabash chalk) has been reported[9,10], possibly by virtue of the geophagic materials sorbing such essential nutrients, which means the body cannot absorb them easily, if at all[1]. However, there is currently no consensus on whether iron-deficiency anaemia is caused by geophagic habit or whether anaemia is a precursor and cause of geophagy.

Following concerns of the possibility for deleterious health effects from eating the product, and in light of the most likely population group engaging in geophagy being pregnant women, British and other North Atlantic health authorities have produced various advisory press releases to raise awareness and to dissuade members of the public from practising geophagy through the use of Calabash chalk (eg New York City Department of Health[11], US Food and Drug Administration[12] and Health Canada[13]). The UK Food Standards Agency (FSA)[14] has issued advice that these products should not be eaten, especially by pregnant and nursing mothers, due to the possibility of these products having adverse effects on health, in particular due to elevated levels of lead.

Lead content in Calabash chalk

Calabash chalk seized by local authority officials from vendors in East London in 2012, were analysed for a variety of heavy metals. The data was shared with PHE for public health advice. Elevated concentrations of lead were identified. The concentrations of lead, identified from four different samples of Calabash chalk, ranged from 12.5 to 24.5 mg/kg (Table 1).

Similarly, other published studies have described elevated concentrations of lead in Calabash chalk. For example, Dean et al[8] reported mean lead concentrations of 40 mg/kg, Abrahams et al[7] reported concentrations of 20–43 mg/kg and the FSA[15] reported concentrations of 8.2–16.1 mg/kg. With regard to Sikor clay, Al-Rmalli et al[4] reported concentrations of 21–26.7 mg/kg total lead.

The European Commission's limit on lead in food supplements is set at a maximum permissible level of 3 mg/kg (Regulation (EC) No. 629/2008)[16]. The concentrations reported from the East London Calabash chalk samples exceed this

Table 1: Reported concentrations of total lead and arsenic from samples of four different batches of Calabash chalk, seized from East London vendors by environmental health officers (data source: London Borough of Hackney 2012/13)

	Concentration (mg/kg)			
Analyte	Sample 1	Sample 2	Sample 3	Sample 4
Arsenic	18.8	1.3	7.3	3.3
Lead	16.7	23	24.5	12.5

Health effects of lead

Lead is a poisonous heavy metal that builds up within soft tissues, bones and teeth, and can cause a wide range of health problems, including but not limited to:

- haematological effects such as anaemia
- neurological disturbances and headaches
- adverse effects on the reproductive system (in both genders)
- liver and kidney damage

Infants and children are more sensitive to lead than adults, and the effects of lead on children have been shown to include a reduced IQ and an increased risk of cognitive deficit, even with relatively low levels of prolonged exposure.

Adverse effects of lead exposure during pregnancy have been identified, and the possibility for negative fetal effects from a high maternal lead intake is a cause for concern. Lead effects during pregnancy can include:

- impaired intrauterine growth
- reduced birth weight
- impaired neurodevelopment

The negative health effects on a fetus or a young child can be more marked as their growing bodies absorb lead more readily, and they do not excrete chemicals as efficiently as an adult. Evidence suggests that there is no threshold (or safe level) of exposure to lead for a number of critical health effects, in particular with regards to developmental neurotoxicity. It is well established that lead can be maternally transferred through breast milk after birth, and that lead stored in bone can be metabolised during gestation and transferred to the fetus/child.

value by up to 641%. Although there have been some studies showing a relatively low bioavailability of the lead in Calabash chalk[4], which may reduce uptake within the body, lead is a non-threshold substance and exposure should be kept as low as practicably possible.

Arsenic content in Calabash chalk

Arsenic concentrations have been less widely reported; however, the Calabash chalk samples from East London which were tested for lead, exhibited concentrations of total arsenic of 1.3–18.8 mg/kg.

Future work

As information on the prevalence of use and health effects of eating chalks and clays is somewhat fragmented, especially with regard to its prevalence In the UK, improving and increasing such knowledge would be beneficial for public health interventions, and is key to tailoring advisory health programmes. Moreover, increased knowledge of the source of these products and quantitative evidence of its heavy metal constituents from further sampling would be beneficial to characterising the health risk(s) posed.

Acknowledgements

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Health effects of arsenic

Arsenic is also a non-threshold chemical which should be reduced in the diet as far as is possible. Currently there is no maximum arsenic level set in foodstuffs across European countries. With regard to the health risks posed by arsenic exposure, chronic ingestion can result in a range of non-specific symptoms of the respiratory tract, central nervous system, endocrine system, liver, kidneys or gastrointestinal system. The inorganic form of arsenic is also a known human carcinogen.

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Brominated flame retardants – balancing the risk

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Flame retardants and fire safety

In the event of a fire, an increase in escape time will reduce the risk of death or serious injury. One means of achieving this is to delay the spread of a fire. In the UK, this is accomplished partly through requirements for goods and materials to comply with fire safety legislation. A good example is the Furniture and Furnishings (Fire) (Safety) Regulations 1998 as amended, the effectiveness of which was assessed by the Department for Business, Innovation & Skills in 2008[1]. This assessment is supported by some of the world's most comprehensive fire statistics, although the efficacy of fire safety standards in other countries may not be similarly supported. In principle, the Regulations require articles and materials to meet standardised tests that measure the rate of onset of combustion. Although this may be possible through the use of non- or low-combustion materials, a common means of meeting the required standard is to incorporate chemicals known as flame retardants. These can be added to textiles covering furniture and incorporated into internal foam, reacted with the plastic used for casings of electronic and electrical equipment and even added to construction materials[2]. In order to be effective, flame retardants often have to be added in significant quantities (eg adding several hundred grams to the weight of a sofa). It is important to note that no regulations stipulate the use of flame retardants.

However, against the benefits of flame retardant use in terms of saving people from death or injury, disadvantages and problems created by the use of some flame retardants are becoming increasingly apparent. This article focuses on one subclass, the brominated flame retardants (BFRs).

The first BFRs to be manufactured on a large scale were the polybrominated biphenyls (PBBs). These are the brominated equivalent of polychlorinated biphenyls (PCBs) which were a major industrial product from the 1920s until the 1970s, when production and use of PCBs was phased out due to health concerns. It was also about this time that PBBs were implicated in a very serious feed and food contamination incident in Michigan[3]. Two more-recent, widely used categories of BFR are polybrominated diphenyl ethers (PBDEs), which replaced PBBs, and hexabromocyclododecanes (HBCDs), both of which have a wide range of additive uses. Another very high volume BFR is tetrabromobisphenol-A (TBBP-A). This is reactively incorporated into materials such as the plastic casings of electronic equipment. New generations of BFRs are now being produced and marketed. These include decabromo-diphenylethane, (DBDPE), hexabromobenzene (HBB), 1,2-bis(2,4,6-tribromophenoxy)ethane (TBE) and Firemaster 550, the active component of which is 3,4,5,6-tetrabromo-1,2-di(2-ethylhexyl) phthalate. In fact, there is such a wide and complex range of new brominated and related flame retardants that an international team found it necessary to produce a paper devoted to abbreviations and nomenclature[4].

Environmental concerns

To be effective in products with a long lifetime, flame retardants need to be very stable. However, this can also make them environmentally persistent. Since the 1990s, BFRs have become so widespread globally that they have been detected in environmental samples taken in remote places far from potential sources, such as the Arctic and on mountain tops. The highest concentrations have been reported in species at the top of their food chains, eg marine cetaceans (killer whale and bottlenose dolphin), pinnipeds (sea lion and harbour seal) and birds of prey[5]. Almost all BFRs are predicted to be biologically active, although this does not mean that they will necessarily cause adverse health effects. Although BFRs are considered as a group, when toxicological effects are observed they can vary widely between individual compounds, even between those with closely related structures. The occurrence and toxicology of BFRs have been reviewed in some detail in a series of opinions published by the European Food Safety Authority[6–11]. Another valuable source of reference is the supplementary information to the San Antonio Statement on brominated and chlorinated flame retardants[12].

In 2009, two groups of BFRs (two formulations of polybrominated diphenyl ethers, PBDEs) were listed as substances of concern under the Stockholm Convention on Persistent Organic Pollutants and a further group (hexabromocyclododecanes, HBCDDs) is being considered for inclusion[13]. Production of PBDEs has now ceased and their usage phased out, although many PBDE-containing items remain in use. Deca-BDE has been identified under the Regulation, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulations as a substance of very high concern (SVHC), not on the basis of deca-BDE itself but because of its environmental breakdown products[14]. Subsequently, Norway has submitted a proposal to add deca-BDE to the list of chemicals in the Stockholm Convention.

Health concerns

As mentioned in the opening paragraph, BFRs are incorporated into or reacted with a wide range of textiles, consumer products, and electrical and electronic appliances. However, it has been found that they do not always remain within the product and will migrate into the surrounding environment. The mechanisms of migration are not fully understood. Nevertheless, there have been numerous investigations into levels of BFRs in dust in offices and domestic homes in the US, Canada, Sweden, Norway, Belgium and the Netherlands, as well in as the UK, and house dust has been identified as a potentially important route of exposure to BFRs, especially in toddlers[15]. High levels of various flame retardants have also been reported in cars. It is uncertain at this time how much dust is consumed by toddlers or by any other age group.

There is limited information about the human health risks from exposure to brominated flame retardants but acute effects that were reported in relation to accidental contamination (ie relatively very high levels of exposure) included acne[3]. Animal studies have raised a number of possible concerns about chronic exposure, which include effects on the nervous system, immune response and cancer.

Furthermore, flame retardants do not necessarily stop fires and reports suggest that they could introduce fresh hazards. It has been reported that, compared with untreated furniture, once ignited foam furniture containing BFRs burns more slowly and at a lower temperature, producing a higher concentration of carbon monoxide, thicker smoke and a much greater cocktail of toxic compounds, including brominated dioxins[16]. This may present an increased hazard to those fighting a fire or cleaning up afterwards, and potentially to the environment[17]. Occupational exposure to BFRs and related products is not limited to fire-fighters. There have also been reports of increased exposure for aircraft maintenance workers and operators in the rubber industry[18,19].

BFRs are of significant concern to the Food Standards Agency because both the parent compounds and their combustion byproducts persist in the environment and have entered the food chain. The FSA has been investigating the presence of BFRs in food since 2002, prompted by concerns about localised contamination around a factory producing BFRs in Northeast England. Very high levels of HBCDs were found locally in trout and eels in the Skerne-Tees river system[20]. In 2003–04 over 50 composite samples of farmed and wild fish were tested for BFRs and related compounds and contamination was found to be widespread, although at levels that did not raise immediate health concerns[21]. Mixed halogenated compounds had long been known to be byproducts of the combustion of materials containing both chlorine and bromine. Although reported in some environmental media, the analysis of these compounds in food has previously been very difficult to achieve due to the very large number of potential congeners, the lack of available laboratory standards and the complexity of food matrices. However, in 2010 the FSA reported the results of the first significant survey for mixed halogenated dioxins, furans and biphenyls in food[22]. The levels were low in comparison with their chlorinated analogues, although with less than 10% of the congeners of most concern being quantifiable. The mixed halogenated congeners have been reported to have similar and possibly even higher potency than chlorinated dioxins[23].

Balancing the benefits with the risks

Trying to balance the prevention of death or serious injury in a fire with potential, but unquantifiable long-term adverse health impacts, which may not be fatal (for example, reported effects include disruption of the thyroid system and of neurobehavioural development) is a complex matter of public policy. The elimination of the need for flame retardants through better product design may be an objective for the long term. In the meantime, two important but distinct issues need to be addressed:

- What long-term health risks are associated with the BFRs (and other halogenated flame retardants) that are already in the environment, in homes and work premises, transport and food and how, if need be, can these be mitigated
- How can the use of newer generation halogenated flame retardants (and, indeed, organophosphorus flame retardants) be better controlled and regulated to ensure that they are not being considered as candidates for the Stockholm Convention in the years to come

The Food Standards Agency has just started a new project to investigate the presence of known, as well as novel and emerging, flame retardants, in food and feed in response to certain recommendations in the EFSA opinions[6–11].

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Annoyance from common environmental hazards: a cause for public health concern?

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Introduction

Societal drivers, policy and legislation and scientific and technological advances have raised levels of public health protection, but professional and public concerns continue to grow around the potential for some environmental hazards to impact adversely upon human health.

Concerns primarily relate to cardiopulmonary diseases, cancers, congenital anomalies and injuries[1–3]. However, in line with the World Health Organization's (WHO) definition of health being "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity", impacts on psychological health, well-being and quality of life have developed an elevated level of public health significance[4].

While it is recognised that environmental factors can affect health, it is often difficult to tease out and quantify their impacts because of interactions with many other health determinants. The WHO has estimated that 24% of the global disease burden can be attributed to environmental factors; at the UK level the estimate is believed to be around 14%[3,5]. Our understanding of the complex and multifaceted relationships that exist between environmental hazard exposures and health outcomes at the local level is limited.

In contrast to measuring physical health impacts arising from occasional acute environmental hazard exposures, it is difficult to quantify the physical and psychological impacts that might result from more common exposures (eg dust, odour or noise). Yet it is these more frequently occurring exposures that might represent a significant, albeit less tangible, public ill-health burden.

Common environmental factors that cause annoyance are important since they are a useful indicator of the general well-being in, and satisfaction of, a community. Understanding complex relationships between exposures and health outcomes is difficult and perhaps this is why, to date, there has been little critical analysis of annoyance occurrence, trends, patterns, links with other factors and quantification of associated health impacts. It has been reported, however, that such impacts can disproportionately affect deprived populations[6]. Evidence also suggests that *perceived* as well as *actual* annoyance from environmental hazards is linked to poor health outcomes[4].

In 2011, we reviewed the literature pertaining to public health implications associated with common annoyance-inducing environmental hazards (noise, odour, smoke/fumes/dust, light, and waste/accumulations/pests). While the detailed findings of this literature review are not provided here, we concluded that, at present, the evidence for quantified public health impacts from common environmental annoyances is weak.

Despite inconclusive evidence in this area, to understand better and scope the problem in Wales, we carried out a review of routinely collected annoyance complaint data. Our findings are presented here, together with a discussion of some key issues.

'Nuisance' and 'annoyance'

In this paper, we do not deal with 'statutory nuisance' as defined under Section 79 of the Environmental Protection Act 1990, as amended[7], but rather refer to environmental-hazard-related 'annoyance' complaints.

Methods

In 2011, routinely collected annoyance complaint data was obtained from 12 (of 22) local authority environmental health departments across Wales: Rhondda Cynon Taff, Pembrokeshire, Torfaen, Vale of Glamorgan, Swansea, Bridgend, Monmouthshire, Flintshire, Conwy, Carmarthenshire, Cardiff and Gwynedd. The data received from Cardiff was incomplete and omitted from the analysis. Data was categorised by the following complaint types: drainage, dust, smoke and fumes, infestations and pests, light pollution, noise pollution, odour and waste/accumulations. The data covered the five-year period between 1 April 2005 and 31 March 2010. Only annoyance complaint data with valid postcodes was analysed: a total of 285,352 annoyance complaints were recorded during the study period, of which 240,825 (84.4%) were geo-coded.

Crude complaint rates per 1,000 persons (including 95% confidence intervals) were derived by dividing the total number of complaints occurring in the population by the total number of individuals in that population at a specified time period. The numerator was local authority complaint data and the denominator was Office for National Statistics mid-year population estimates. The analysis was primarily by local authority middle super output area (MSOA) geographies (to avoid potential identification of individuals), although lower super output area (LSOA) geographies (to match the index of multiple deprivation data availability) were used to investigate relationships between annoyance complaint and deprivation.

For numerators with more than 100 counts, 95% confidence intervals were calculated using a normal approximation to the Poisson distribution[8]. For numerators of less than 100 counts, 95% confidence intervals were calculated using the Poisson distribution[8]. The first and last years' rates of complaints were compared and, if there was overlap between the 95% confidence intervals, deemed to be similar.

The chi-square test for trend was used to assess the presence of an association between the rates of complaint and deprivation status.

Results

Annoyance complaint data was obtained from only half of all local authorities in Wales. The data analysed covered approximately 53% of the population of Wales (3,006,430 people, based on 2009/10 mid-year population estimates) and covered urban and rural localities with varying socioeconomic profiles. The quality of the data varied across datasets; owing to incompleteness, 15.6% of all the recorded complaints (285,352) could not be geo-coded. Also, data was obtained from local authorities only; complaints may also be received by Natural Resources Wales (formerly Environment Agency Wales).

Of the 240,825 complaints analysed, *pests and infestations* were the cause of most complaints, while *light pollution* accounted for the least number of complaints (Table 1).

Table 1: Annoyance complaints (all types combined), 2005/06–2009/10

Complaint type	Number of complaints	Proportion of complaints (%)
Pests and infestations	117,295	48.7
Waste and accumulations	55,389	23.0
Noise	50,955	21.2
Drainage	8,456	3.5
Dust, smoke and fumes	4,520	1.9
Odour	3,794	1.6
Light	416	0.1
Total	240,825	100

Crude rates of complaint (all causes combined) for each local authority varied across Wales over time, but were consistently highest in Swansea and lowest in Flintshire (Figure 1). Over the five-year study period, annual crude complaint rates for all environmental annoyance types combined showed a downward trend in all but three (generally more rural) local authorities: Conwy, Pembrokeshire and Vale of Glamorgan. The increases in crude complaint rates observed in Pembrokeshire and Vale of Glamorgan were significant (there was no overlap in the 95% confidence interval between the

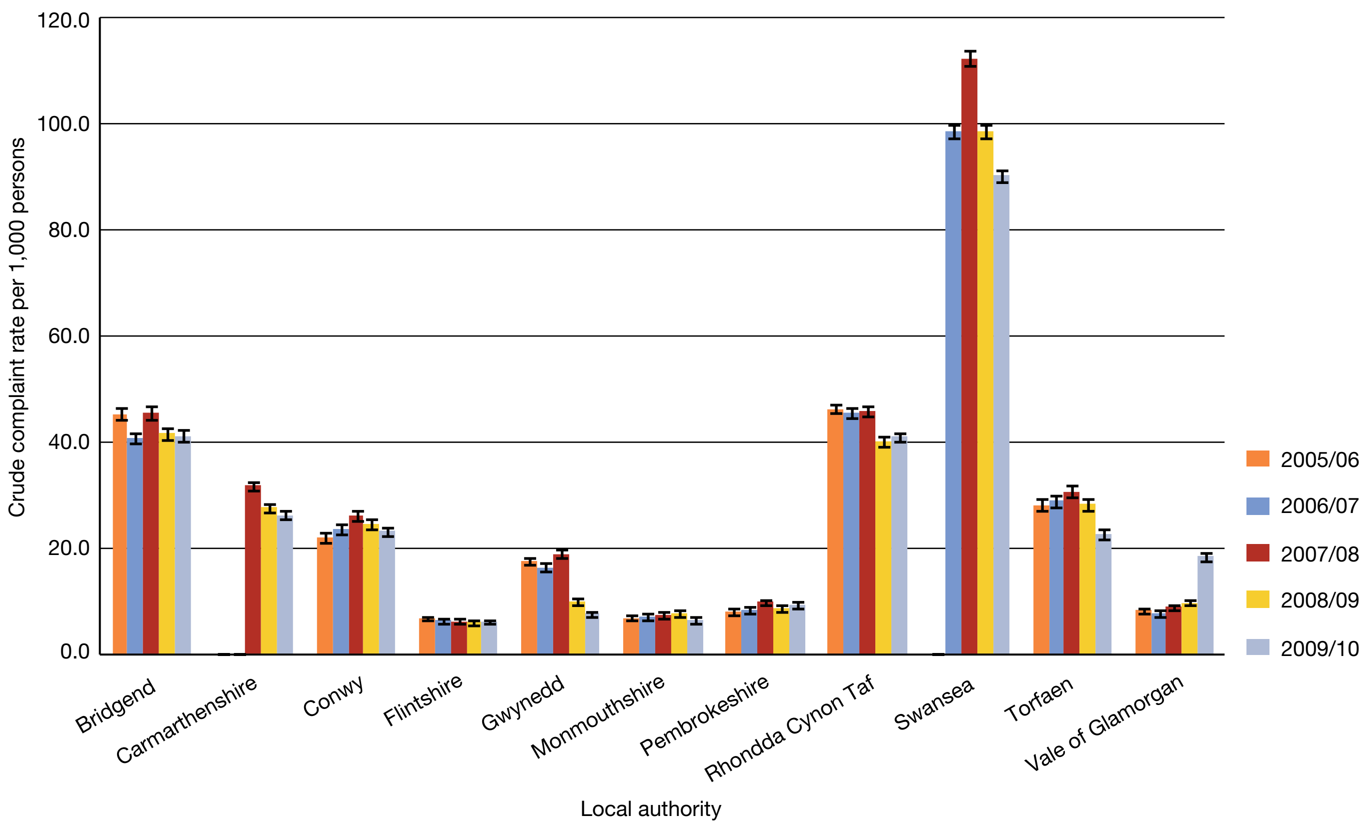

Figure 1 : Crude annoyance complaint rate per 1,000 persons (all types combined) by local authority, 2005/06-2009/10

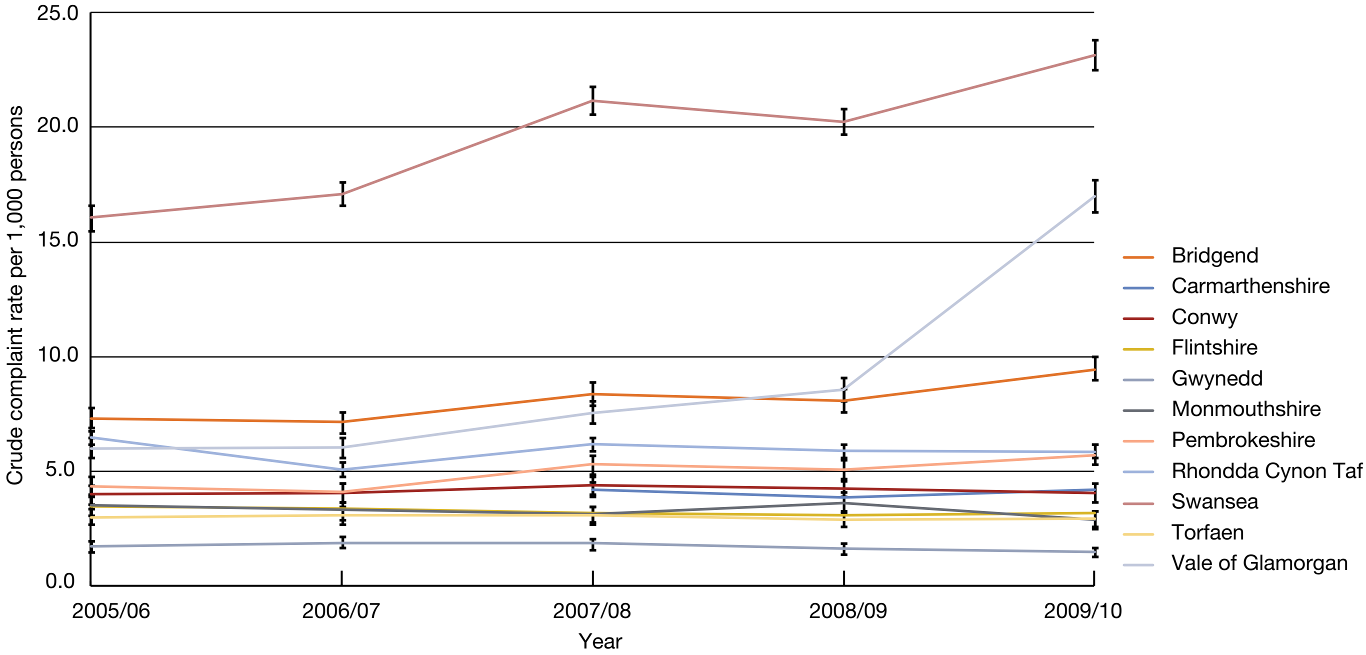

Figure 2: Crude noise annoyance complaint rate per 1,000 persons by local authority, 2005/06–2009/10

first and last year of data). There is insufficient data to attempt a more formal analysis of variation in complaint rates by year. The contribution of different types of complaint to these results also varied between local authorities – for example, noise complaint rates for the different local authorities are shown in Figure 2. The rates of reported annoyance from *noise* increased over the study period in four local authority areas, the differences in rates were observed by comparing 2005/06 rates with 2009/10 rates as described above. The rates of annoyance from *waste/accumulations* showed a significant increase in three local authority areas and a significant decrease in four local authority areas over the study period.; it should be noted that variation also occurred in intervening years. The rates of annoyance complaint from *pests/infestations* showed a significant decrease in six local authority areas.

A more detailed analysis at the MSOA level revealed considerable variation in annoyance occurrence (all causes combined) within all local authority areas. Annoyance complaint profiles were generated for each local authority area to provide a descriptive analysis showing variations in annoyance complaint rates across communities over time (see Figure 3 for a profile example: Vale of Glamorgan).

Strong associations were observed between complaint rates and deprivation status, where rates increased with rising levels of deprivation. Results of the chi-square test for

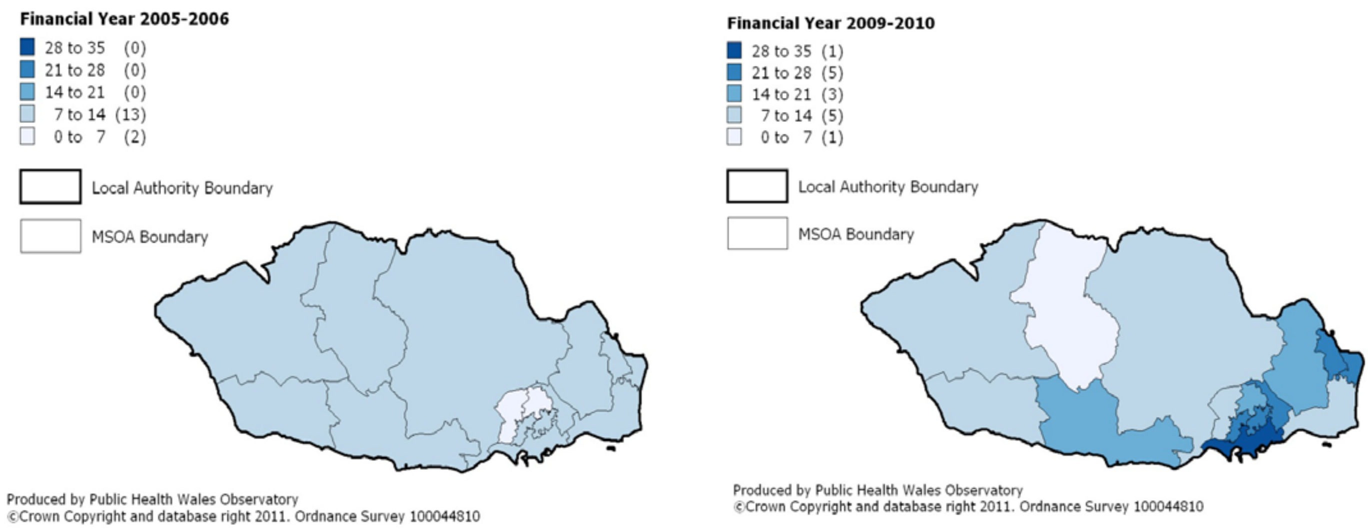

Figure 3: Annoyance complaints in Vale of Glamorgan Middle Super Output Areas (MSOAs), crude rate per 1,000 persons (data from Vale of Glamorgan Council and MYE (ONS))

For further information on MSOAs see the Interactive Atlas of Geographies in Wales, available at www2.nphs.wales.nhs.uk/InstantAtlas/GeographyTool/atlas.html

trend analyses for all complaint types (aggregated) across Welsh Index of Multiple Deprivation (2008) quintiles were all statistically highly significant (Table 2).

Table 2: Analysis of association between annoyance complaint occurrence (by type) and Welsh Index of Multiple Deprivation (2008) quintile, 2005/06–2009/10

Complaint type	WIMD quintile	Rate ratio	95% CI	χ^2 linear-by-linear (p<)
Pests and infestations	1 (least deprived)	1.00		
	2	0.86	0.84–0.88	
	3	1.20	1.18–1.22	
	4	1.50	1.47–1.53	
	5 (most deprived)	2.21	2.17–2.25	12,020.83 (0.00)
Waste and accumulations	1 (least deprived)	1.00		
	2	0.73	0.70–0.76	
	3	1.04	1.00–1.08	
	4	1.22	1.17–1.26	
	5 (most deprived)	5.62	5.45–5.79	24,310.62 (0.00)
Noise	1 (least deprived)	1.00		
	2	0.84	0.81–0.87	
	3	1.17	1.14–1.20	
	4	1.49	1.45–1.53	
	5 (most deprived)	2.33	2.27–2.40	5,538.64 (0.00)
Drainage	1 (least deprived)	1.00		
	2	1.00	0.93–1.07	
	3	0.92	0.86–0.99	
	4	1.25	1.17–1.34	
	5 (most deprived)	1.41	1.32–1.51	152.99 (0.00)
Dust, smoke and fumes	1 (least deprived)	1.00		
	2	1.26	1.14–1.40	
	3	1.71	1.55–1.89	
	4	1.81	1.64–2.00	
	5 (most deprived)	1.80	1.62–1.99	183.30 (0.00)
Odour	1 (least deprived)	1.00		
	2	1.24	1.12–1.37	
	3	1.33	1.20–1.46	
	4	1.32	1.20–1.46	
	5 (most deprived)	1.32	1.19–1.46	28.39 (0.00)
Light	1 (least deprived)	1.00		
	2	0.58	0.44–0.78	
	3	0.78	0.60–1.02	
	4	0.65	0.48–0.86	
	5 (most deprived)	0.71	0.53-0.96	4.41 (0.04)

Data for complaints and mid-year population estimates aggregated.

Discussion

Complaints may act as a proxy measure for common environmental hazard exposures and serve as an indicator of a person's dissatisfaction with their immediate environment. From the data obtained, it is unknown whether complaints were substantiated. Also, since the data was anonymised, it was not possible to determine whether one complaint represented one person complaining on one occasion or one person complaining several times.

Many factors influence annoyance occurrence and consequences, but it is not possible to explore these in more detail using routinely collected data. In addition to deprivation (where these results agree with previous findings[6]), future analysis should consider behaviours, tolerance, sensitivity and social cohesion.

Different approaches employed by local authorities to record and investigate complaints would also influence how this type of data can be analysed. There is great potential to improve our ability to understand trends, causes and effective interventions through a more coordinated use and surveillance of complaint data. This would require more detailed records of how complaints are handled and some form of qualitative evaluation, which could be an area for joint working between local authorities and Public Health Wales.

The analysis undertaken was unable to link annoyance complaint data with health outcome data in any meaningful way so quantifying the burden of ill-health (both physiological and psychological) was not possible. It is recognised that the propensity to complain is subjective; tolerance of exposure is likely to differ between individuals and populations, thus influencing the rate of complaint. Some populations will be sensitised to a particular problem and may be more likely to complain; others may be more reluctant to complain for a variety of different reasons. Health impacts resulting from exposures to environmental hazards are plausible if there is a complete *exposure pathway* that links the *source with receptor(s)*. While uncertainties exist around the true level of health impact associated with exposures to environmental factors that cause annoyance, this paper suggests that *source-pathway-receptor* chains exist for a significant number of people in Wales since they have been exposed to the extent that warrants a formal complaint. For each of the common environmental hazard types reviewed, it is likely that mitigation action is often feasible to minimise or eliminate exposure and break the *source-pathway-receptor* linkages. Thus, each complaint may represent an opportunity for an exposure to impact adversely upon health but more important perhaps is the fact that such exposures are often preventable in the first instance.

Given this evidence gap, gaining a greater understanding of exposure and health outcome links should be considered a priority for future collaborative surveillance work in this area. The same applies to assessing the effectiveness of interventions to resolve problems and mitigate health risks.

Conclusions

In our first attempt to scope the problem of annoyance from environmental hazard exposures in Wales, we found that a significant number of people in Wales are affected, with annoyance impacts appearing to vary by geography, cause and deprivation. Our findings may be an underestimate of the true scale of the problem but confirm that complaints disproportionately come from deprived populations, and highlight the need for this type of data to be collected and analysed on a regular basis. This would allow a greater understanding about these types of exposures and health outcomes.

It is recommended that public health agencies work with regulatory bodies to undertake routine surveillance of annoyance complaints and health impacts to monitor trends and patterns, explore associations, detect problems early, target services and evaluate interventions.

Until the health impacts of exposures to common environmental hazards that cause annoyance are investigated and robustly quantified, the possibility that this significant and preventable problem represents a cause for public health concern cannot be ignored.

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Improving gas and carbon monoxide safety in social housing

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Background

Carbon monoxide (CO) is a poisonous, colourless, odourless and tasteless gas that results from the incomplete combustion of fuels. The clinical presentation of CO poisoning differs with both the level and duration of exposure. Symptoms of acute poisoning, resulting from high levels of exposure over a short time period, range from headaches, nausea and vomiting through to loss of consciousness and death. Long-term health effects can include brain damage, kidney damage and renal failure. Symptoms of chronic poisoning, resulting from low levels of exposure over a longer time period include persistent headache, influenza-like illness and confusion in the short term and emotional, physical and mental health problems in the long term.

Current estimates of the burden of disease for CO suggest that in England and Wales, there are around 40 deaths from accidental CO poisoning each year[1], 200 hospital admissions and 4,000 accident and emergency consultations[2]. It is thought that these figures, however, represent only a small proportion of the total burden of disease attributable to CO exposure. This is largely due to the under-diagnosis and misdiagnosis of CO poisoning as the symptoms, particularly those of chronic poisoning, can be quite generic and often mimic other illnesses.

The World Health Organization (WHO), in 2010[3], produced guidelines that listed levels of exposure to CO which should not be exceeded in the domestic environment in order to protect health (see the table). These guidelines, although not enforceable, provide a limit which is measurable and, if exceeded, would indicate a potential risk to health of the occupants.

Of specific uncertainty is the burden of CO morbidity at community level. With the availability of the WHO guidelines, a study was developed involving the measurement of CO levels in homes, which could provide data that would feed into work to develop a greater understanding of CO exposure at the community level.

Table: World Health Organization indoor air quality guidelines concentrations for carbon monoxide[3]

Averaging time	Concentration (ppm)
15 minutes	90
1 hour	30
8 hours	10
24 hours	6

The study, by Liverpool John Moore's University[4], placed CO data loggers in 173 houses in Liverpool and Coventry and found that 21% of properties measured maximum readings of greater than 50 ppm and 46% measured maximum readings of between 10 and 50 ppm, although the duration of these peak levels was not made explicit. The researchers also stated that they found "a significant presence of low-level CO in homes that may not trigger a CO alarm but could still potentially lead to long-term health problems" [4]. This, combined with the finding that 90% of 27,000 homes investigated did not have a CO alarm, highlights the potentially large 'at-risk' population that exists. One area of community exposure that has gained interest more recently is that of CO in social housing, which formed the subject of a recent seminar by the All-Party Parliamentary Carbon Monoxide Group. Some recent research in this area is summarised in the box.

Research, such as that highlighted in the box, is crucial for contributing to the evidence base, not only to feed into work to quantify the burden of CO exposure on public health in

Box: Summary of some current research into carbon monoxide and social housing

Gas safety expert, Corgi Technical Services, conducted a survey in March 2013, which revealed that over half of social landlords have dealt with incidents related to CO poisoning in their properties over the past 12 months[5].

Croxford et al[6] found that of 270 vulnerable London homes, nearly 20% had mean eight-hour CO levels above 8.6 mg/m^3. The same authors found the presence of an unsafe gas appliance installation was linked to an increased risk of suffering neurological symptoms by the householder[7].

A recent study, which investigated CO alarm activations in social housing in Hackney, London, found over a third of CO alarm activations were likely to be due to a faulty gas appliance[8]. Around 10% of alarm activations were likely to be due to either misuse of the cooker or the cooking methods themselves (eg placing foil around the hob, using large pots on small ring hobs or bringing a barbeque indoors).

social housing and the community as a whole, but also to improve understanding of exposures to CO in the domestic setting, hazards relating to CO and effective interventions to reduce exposure and associated poisoning. At the same time, addressing gas safety and CO safety from a practical point of view is equally important. This has been recognised by a number of social housing trusts that are addressing the risks associated with CO in the houses for which they are responsible. The case study below presents an approach from one social housing trust, Halton Housing in the north of England, which has adopted a multifaceted approach to improving gas and CO safety.

Case study: Halton Housing Trust

Halton Housing Trust is a social landlord, responsible for 6,401 properties in the Cheshire area. Gas safety is a priority for the Trust, which believes that not addressing the issue could be catastrophic, as poorly maintained or poorly installed gas appliances have the potential to cause explosions or carbon monoxide (CO) poisoning. The Trust has taken a number of steps to address and improve gas safety within the properties for which it is responsible. This paper highlights four areas as examples of good practice: awareness, partnerships, robust safety procedures and innovation.

Raising awareness

Raising awareness of gas safety and of CO is key to prevention. The Trust has taken a dual approach to this, through both customer and staff awareness.

Methods used for increasing customer awareness include regular articles on gas safety or CO in the Trust's customer magazine, issued three times a year. The Trust also uses television screens in its public reception areas to display messages for its customers on relevant housing issues. This information addresses issues such as the dangers of using portable barbeques inside tents while camping. Whenever possible, the Trust attends events to promote gas safety and CO awareness. One such event was held recently at a local Tesco in conjunction with the charity Carbon Monoxide Awareness and Widnes Fire Brigade, where the aim was to promote the use of CO alarms within properties. A commonly identified misconception was the number of customers who had a smoke alarm and thought this would detect CO, highlighting the importance of education as part of awareness raising.

The second approach for raising awareness is to ensure the Trust's staff is informed of current gas safety issues and that CO awareness is at the forefront of staff awareness. The methods used are similar to those for the Trust's customers, with messages on internal TV screens and poster campaigns in public staff areas such as canteens and breakout areas. In addition, the Gas & Asbestos Coordinator and the Gas Team maintain a visual presence as much as possible, so when any issues do arise, everybody within the Trust knows the first point of contact. The Trust's intranet is also used to publicise monthly figures and performance including the number of properties without a valid CP12 Landlord Gas Safety Record, First Time Access figures, jobs referred to the legal department and First Time Fix statistics, so as to highlight both good work and areas for improvement. For example, since introducing these measures, the Trust achieved 100% coverage for CP12 records five times in the last 12 months, whereas previously full coverage had never been achieved.

Partnership working

The most important partnership for the Trust is its relationship with its gas contractor, Sure Maintenance. It is essential that the contractor buys into the Trust's philosophy of promoting gas safety and raising customer awareness of CO. The Trust has used Sure Maintenance for several years, with a further three-year contract recently awarded. This continuity offers stability to both the Trust and more importantly the customers: staff turnover is very low, thus increasing familiarity between customers and contractor staff. This ensures engineers gain entry into properties to undertake the annual gas service. Other partnerships the Trust is involved with include the North West Inter-Authority Gas Forum and the Northwest Gas Managers Forum, which offer essential opportunities to network with other trusts that are attempting similar strategies. This exchange of ideas and methodologies is invaluable to ensure continuous improvement.

The Trust also works closely with charities such as Carbon Monoxide Awareness and organisations such as West Cheshire Fire Service, promoting literature and disseminating leaflets to customers during engineer visits. A lot of emphasis is placed on internal partnerships within the Trust, to prevent a silo mentality and encourage interdepartmental cooperation – for example, the Gas & Asbestos Coordinator liaises daily with housing officers to facilitate gaining access.

Safety procedures

Last year, the Trust's gas policy and procedures were reviewed and updated. Some of the changes, although seeming very simple, have proved to be the most successful, and the benefits are seen in the increase in the number of properties accessed for undertaking the annual gas service.

The first change was to ensure the initial appointment letter was worded a lot more strongly than previously, with bold tag lines stating 'carbon monoxide kills', 'poorly maintained appliances put you and your family at risk', and highlighting the fact that failure to allow access would lead to court action and incur costs. A simple, yet truly effective, measure was to personalise the initial appointment letter. Previously the letter was addressed simply to 'The Occupier' and an all-day appointment was specified. Now the letter is addressed to the customer and gives a morning or afternoon appointment. Evening and weekend time slots are also offered. The number of visits has also reduced from three to two prior to instigating the 'No Access Procedure' as analysis of data collected showed that if no access was gained after two visits the likelihood of gaining access on the third visit was minimal. These procedures have helped us to gain access to undertake the annual gas service.

Innovation in gas and carbon monoxide safety

The final area targeted – and this is hard to quantify – is *innovation*. The Trust empowers its employees to “think outside the box” and this approach is adopted across all departments. In terms of gas and CO safety, the Trust recognised that it was not just its customers who could be at risk of CO exposure and poisoning, but also many of its front-line staff, who visit customers in their properties on a daily basis. As a result, employees were issued with a personal CO alarm. This intervention goes hand in hand with the Trust’s policy of installing and maintaining CO detectors in all of its 6,401 properties. We have also introduced a policy of replacing gas fires with electric fires as the benefits include zero CO emissions, and lower installation and maintenance costs.

Conclusions

As a consequence of applying all the above approaches to gas safety, the Trust is helping to ensure that our customers have well-maintained and thus safe gas appliances. As a result, we are reducing the carbon monoxide exposure and poisoning risk to our customers, but we are always looking for new ways to ensure this, as complacency can be just as dangerous.

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The legacy of Rachel Carson

Review of a scientific meeting to commemorate the 50th anniversary of *Silent Spring*, Royal Society of Chemistry, London, October 2012

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Introduction

The Royal Society of Chemistry (RSC) Toxicology Group* is one of the many interest groups of the Society. It has a particular interest in environmental chemicals and their potential health effects.

To commemorate the 50th anniversary of the publication in 1962 of Rachel Carson's seminal work *Silent Spring*, the Toxicology Group, in collaboration with other RSC groups, held a one-day meeting to explore a number of perspectives on how Rachel Carson's work contributed to the legislative, chemical and societal world we see today.

Rachel Carson and the pesticide debate: DDT as a paradigm

The meeting began with Professor Andy Smith (MRC, University of Leicester) giving a brief history of Rachel Carson's work, highlighting amongst other things the difficulties of being a female scientist at that time. Although Carson first published an environmental work in 1941 *Under the Sea-Wind*, it wasn't until her 1951 publication, *The Sea Around Us* (which won many prizes), that she gained widespread public attention. Carson then became increasingly concerned with the effects of widespread pesticide use, culminating in the publication *Silent Spring* in 1962. The publication resulted in Carson being attacked by the chemical industry and even the US Department of Agriculture, but her research findings were backed by President Kennedy's Scientific Advisory Committee. By this time, Carson was in poor health and she died in 1964, thus undoubtedly cutting short her contribution to the field.

One of the lead chemicals researched in Carson's work was DDT (dichlorodiphenyltrichloroethane). Professor Smith provided an overview of DDT use and toxicity. Prior to DDT, alternatives were either ineffective (eg pyrethrins) or highly toxic (eg arsenicals). DDT was first discovered in 1874 but it wasn't until 1939 that Paul Müller (Geigy) found that it was highly effective in killing insects. During the Second World War, DDT was seen to be a vital addition to the armoury in defeating malaria and typhus: epidemics that could cause as many casualties as war itself. This fast-track use led to Müller being awarded the Nobel Prize in 1948. Post-war the use of DDT escalated and it was used as a widespread general-purpose insecticide in agriculture. The problems of DDT seemed to stem from over-enthusiastic use with little concern for any long-term consequences. With respect to human health effects, Carson was most concerned with cancer. DDT is slowly metabolised, with high doses causing tremors in humans, but it is a poor mutagen. To date there is poor evidence for DDT being associated with either liver or breast cancers, indicating that the threshold for any effects is far above current, even historic, exposure levels. Most concern nowadays is with potential reproductive effects as an oestrogenic compound, particularly the analogue ortho,para-DDT and its metabolite, ortho,para-DDE.

Following Carson's work, DDT was banned in the US in 1972; a gradual global ban spread over the following decades, although some use continues today for indoor residual spraying, the process of spraying indoors to control malaria. However, even in these scenarios there is ongoing controversy as to whether health effects are or are not being demonstrated. Professor Smith ended with the conclusion that overuse and poor regulation of pesticides had profound effects on the distribution of chemicals in the environment and biosphere and that *Silent Spring* brought public and political attention to this, setting in motion the control and health regulations still with us today. However, pesticides (and other chemicals) are still required and scientific risk assessment rather than risk perception should be what drives the use and regulation of these substances.

Rachel Carson's influence on US legislation: 'In pursuit of safety: 100 years of toxicological risk assessment'

Dr Joseph Rodricks (Environ) gave a wider historical perspective, taking the audience from Paracelsus identifying that dose differentiates a poison from a non-poison to Dr Alice Hamilton, a pioneering occupational physician working during Carson's lifetime, and the 1906 Pure Food and Drug Act that declared that food and drugs shall not contain adulterants that 'may cause harm'. This Act led to the use of animal studies to demonstrate that harm was possible. Other drivers that predated *Silent Spring* included the recognition of occupational diseases (the American Conference of Industrial Hygienists introduced exposure limits in the 1940s), the increase in post-war chemical production (leading to new safety requirements in the 1950s) and the identification of air and water pollution as a public health issue.

* Existing members of the RSC can be members of the Toxicology Group free of charge. Please contact Kate Jones for more information.

During the same time period, cancers were being studied and linked to chemical causes. By the 1950s there was a prevailing view that thresholds must exist for chemical toxicities, except for carcinogens, and 'allowable daily intakes' began to be derived. These became 'targets' even though they are not 'bright lines' between safe and unsafe, and there is no way to quantify whether any reduction in exposure has improved health protection. By the 1970s a no-threshold, linear dose model of cancer risk was adopted and, by and large, this system continues today.

Owing to a number of controversies, guidance was required on risk assessment and so, in 1983, the US National Academy of Sciences issued the 'Red Book', which provided a standardised framework within which to undertake risk assessment. However, risk assessment as such does not enable decision-making and so, in 2008, 'Science and Decisions' was published (again by the National Academy of Sciences) which called for a unified and consistent approach to risk assessment. In the future, high throughput in vitro testing offers the potential for a better understanding of the inherent hazards of chemicals. There is no doubt that scientific and public debate about toxic hazards and their risks to health will continue and that there is a need for greater, and improved, risk communication and public understanding of risk.

Changing profile of human exposure to persistent organic chemicals

Professor Stuart Harrad (University of Birmingham) looked at the changing profile of persistent organic chemicals. Whereas Carson was concerned with exposure to organochlorine pesticides, exposure profiles have since moved through polychlorinated biphenyls (PCBs) and dioxins and on to fluorinated and brominated compounds. Also whereas historically environmental exposures have been mostly attributed to the diet, there is growing evidence that many of the new pollutants can be found in indoor dust as well. For young children in the UK, exposure estimates indicate that average dust concentrations and intakes would be similar to the dose from diet. However, for those with high dust intake, 95th percentile dust exposures could result in exposures three orders of magnitude greater than for diet (deca-BDE estimate).

Neonicotinoids and bees – the New DDT?

After a brief first-hand account of the still widespread use of DDT as a broad spectrum agricultural pesticide in Ethiopia, Dr Keith Tyrell (Pesticide Action Network UK) made a case for how the current pesticide regulations had failed to restrict the use of neonicotinoids. He stated that there were now a number of studies demonstrating an association between the use of neonicotinoids and collapses of bee populations and outlined the situation in Italy, where bee populations have appeared to have recovered following a ban on the use of neonicotinoids. Tyrell discussed the limitations of the current regulatory requirements, primarily designed to assess spray applications of pesticides, whereas neonicotinoids are usually applied as a seed treatment resulting in a systemic pesticide. Tyrell also felt that the precautionary principle had not been applied in this case, ie although there were uncertainties in the environmental safety of neonicotinoids, there were currently no plans to restrict their use. In Tyrell's view this was counter to the precautionary principle where the onus is on the manufacturer to demonstrate unequivocal safety, not for the public to demonstrate harm.

It is relevant to note that in May 2013 the European Commission confirmed that restrictions on the use of three neonicotinoid pesticides will come into force in December 2013. The restriction will prevent the use of three neonicotinoid products – clothianidin, imidacloprid and thiametoxam – in seed treatment, soil application (granules) and foliar treatment on plants and cereals (with the exception of winter cereals) that are attractive to bees.

Balancing precaution with pragmatism

Professor Ragnar Löfstedt (King's College London) concluded the meeting with a précis of his recent paper on risk versus hazard in Europe. He outlined how there were fundamental differences between member states, and even regulatory bodies within member states, as to whether chemical regulation should be hazard or risk based. Certain areas of Europe (for example, Scandinavia) are predisposed to taking a hazard-based approach to chemicals, whereas others, such as the UK, are much more in favour of risk assessment. However, Löfstedt also noted how a member state's approach could differ depending on the circumstances, illustrating this with some examples from Sweden which has stated a desire to be 'chemical-free' by 2020 (hazard based), but has vigorously defended the eating of pickled herring, shown to be contaminated with persistent chemicals (risk based). This highlights the impact politics can have on positions: Sweden has only a very small chemical industry so, as a nation, would not be overly affected by tighter chemical regulation; however, pickled herring is an issue of cultural heritage. Löfstedt also outlined the need for greater risk communication and highlighted a number of efforts to bring about a better understanding of risk across Europe.

Conclusions

The meeting provided a diverse exploration of the areas where Rachel Carson's work has had an impact. Although it was demonstrated by a number of speakers that Carson was not instrumental in developing these ideas (much work had started before *Silent Spring*), she did 'shine a light' on the issues and generated the momentum for change which has undoubtedly had a huge impact on chemical development, regulation and environmental assessment. Her work has successfully led, for example, to the use of less persistent and less bioaccumulative pesticides uncertainties remain, such as the assessment of chemical mixtures. Perhaps the greatest challenge is better risk communication and improved public understanding of risk.

Presentations from the day are available at www.rsc.org/Membership/Networking/InterestGroups/Environmental/RachelCarson.asp

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Climate change and syndromes associated with marine algal toxins

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Introduction

Intoxication from marine organisms is a potentially increasing public health problem worldwide. There is a strong possibility that global climate change, through changes in marine temperatures and salinities, has been accompanied by a redistribution of marine species around the world with effects in waters around the UK and further afield. Amongst the millions of algal species that exist naturally in the marine environment, there are some that have been linked to human disease. This is an area of human health and disease in which new exposures are being discovered; it is thus important that unusual, new or changing distributions and patterns of disease and mortality are flagged up and appropriately investigated in a timely manner.

In the April 2011 CHaP Report, Varga and Baker[1] provided a short update on marine toxins in the UK, particularly those from organisms that can pose a danger to UK holidaymakers by direct envenomation. In addition to those marine organisms such as jelly and weever fish that can produce toxic effects through direct envenomation, marine toxins are also found in marine algae. However, while algae are a major source of marine toxins, there tends to be higher public awareness of the dangers of jelly and weever fish, a topic highlighted in both the UK Climate Change Risk Assessment[2] (CCRA) and in the National Adaptation Programme[3] which was published in July 2013. The CCRA specifically notes the potential for increased sea temperatures to affect human health through increased harmful algal blooms. A need exists for increased awareness amongst the public, healthcare workers and policy makers alike. This article presents an overview of the most noteworthy toxic poisoning syndromes associated with consuming shellfish contaminated by algal toxins and the impact of climate change on the distribution of this type of disease.

Mechanisms and classification of intoxication

People come into contact with marine algal toxins by consuming fish and shellfish species that feed on microscopic phytoplankton (algae). Toxins bioaccumulate in the tissues of shellfish and other fish that feed on the plankton, which are in turn ingested by humans. There is no visible sign of contamination of shellfish with toxins, most of which are heat stable and thus unaffected by cooking.

Figure: Algal bloom off the Devon/Cornwall coast (image courtesy of NASA)

Approximately 1% of marine phytoplankton species produce potent toxins[4]. These species exist throughout the world; toxins are specific to particular algae or groups of algae, some of which have tightly defined geographical distribution. The poisoning syndromes associated with individual toxins have thus been considered to have similar geographical distributions, although redistribution of toxin-forming algae and contamination of food stocks is occurring, possibly as a result of climate change[5,6]. Under certain conditions, phytoplankton proliferate very rapidly leading to blooms of algae which change the water colour to red, brown or green, a phenomenon known as 'red tide'[7].

This paper considers four main syndromes of shellfish poisoning: paralytic shellfish poisoning, diarrhoeic shellfish poisoning, amnesic shellfish poisoning and neurotoxic shellfish poisoning. The single-toxin syndromes ciguatera and tetrodotoxin intoxication have been described previously[1].

Paralytic shellfish poisoning (PSP)

PSP is the most common and geographically widespread of the algal toxins associated with both shellfish and other seafood poisonings. The syndrome is caused by saxitoxin and other closely related toxins produced by dinoflagellate species of algae[8]. Shellfish feed on the algae, leading to bioaccumulation of the toxin in the shellfish, particularly in the digestive glands. Human illness, as PSP, occurs when contaminated shellfish is consumed.

PSP is a severe, sometimes life threatening or fatal disease of rapid onset, often within 30 minutes to four hours of ingestion of seafood contaminated with the algal toxin. Symptoms include facial and perioral paraesthesia, headache, dizziness, muscular weakness, ataxia, nausea, vomiting and respiratory suppression. For these reasons, it has been considered as a candidate agent for use in chemical warfare.

Saxitoxin acts by blocking nerve signals, causing paralysis. It is heat stable, meaning that the toxin cannot be destroyed by cooking[7]. The toxin has been found in fish and shellfish across a wide geographical area which now includes the North Sea, Japan and the Americas. A recent outbreak in New Zealand's Bay of Plenty in December 2012 poisoned 20 people who had collected shellfish from the shoreline, 10 of whom required hospital admission[9]. A previous outbreak in Guatemala affected 187 people, hospitalising 70% and killing 26[10]. Saxitoxin (along with other PSP toxins) was detected in the mussel harvesting areas on the north and west coasts of Iceland for the first time in June 2009 at concentrations ten times in excess of the EU regulatory limit[5]. This led to extensive closures of the harvesting sites, which produce blue lipped mussels.

Diarrhoeic shellfish poisoning (DSP)

DSP is a toxic syndrome with self-limiting gastrointestinal symptoms of rapid onset. The causative toxin is most often okadaic acid, again produced by dinoflagellate algal species. Ingestion of this toxin results in severe diarrhoea and abdominal pain[8]. Symptoms generally start within 30 minutes of exposure and typically last for three to four days. Okadaic acid is a potent tumour-growth promoter[11] and immunosuppressant. It is found in shellfish in Europe, Africa and Japan. In June 2009, 11 outbreaks of DSP were reported in one week in areas of Western France. All of those affected had consumed mussels harvested from one production area over a six-day period. Fortunately, none of the 45 people affected was hospitalised. It is of note, however, that symptoms occurred after eating as little as 36 grams of mussel flesh[12].

Amnesic shellfish poisoning (ASP)

ASP is a rare toxic syndrome. In contrast to PSP and DSP which are caused by toxins from dinoflagellate algae species, ASP is caused by a toxin released by a diatom algal species known as *Pseudo-nitzchia*. This is unusual as prior to the discovery of ASP, it was thought that only dinoflagellate species were responsible for toxic shellfish poisoning. In the case of ASP, the toxin responsible is domoic acid. Symptoms vary from severe gastrointestinal disturbance to unusual neurological presentations[7]. The first described outbreak of ASP was in Canada in 1987, when 107 people became unwell after eating contaminated blue mussels, suffering neurological and gastrointestinal effects with acute memory loss, and three patients died. The most severe neurological effects, such as seizures, were reported by those aged over 65 years or those with long-term conditions such as chronic renal failure. A dose-response relationship is thought to exist; those who ingested up to 15–20 mg were unaffected, whereas ingestion of levels in excess of 135 mg caused serious illness[13]. Domoic acid has since been found in a variety of bivalve molluscs (scallops, clams, oysters, etc) as well as in crabs and lobsters. Shellfish containing domoic acid have been reported on both the east and west coasts of the US, Canada, France, the UK, Spain, Ireland and Portugal[14]. The mechanism of action, physiological and ecological roles of domoic acid is not fully understood, although 14 species of *Pseudo-nitzchia* have now been shown to be toxigenic with changes in acidity, carbon dioxide and salinity all enhancing toxin production[15].

Neurotoxic shellfish poisoning (NSP)

NSP is caused by brevetoxins which are released by dinoflagellate algal species. The toxin causes depolarisation of nerves which can be exclusively neurological or affect both muscles and nerves[16]. This leads to symptoms including paraesthesia, dizziness, diplopia and abdominal pain with diarrhoea and gait disturbances. Reversal of temperature perception has been described in victims, a very rare symptom which is shared with ciguatera poisoning.

Onset is rapid, usually within three to six hours of ingestion. In addition, aerosolisation of the toxin by wave action has been associated with asthma-like symptoms. The syndrome is associated with the waters of Western Florida, the Gulf of Mexico and the Caribbean, with the largest known outbreak reported in New Zealand in 1992–93[14]. Brevetoxin-like toxins have been found in Japan and Australia, but have not yet been associated with outbreaks of NSP.

Climate change and marine toxins in the UK

The UK Climate Change Act 2008 legislates for climate change mitigation and adaption. It sets the requirements for both the Climate Change Risk Assessment and the National Adaptation Programme.

Climate Change Risk Assessment 2012[2]

Climate change may lead to increases in marine and freshwater algal blooms, some of which may be harmful to either biodiversity or humans if the food chain is affected. Increases are projected along the north coast of Cornwall, the Firth of Clyde, the Moray Firth, and Northeast England. Changes in algal distribution have already been seen in Icelandic mussel beds.

Warmer temperatures can act to displace any cold-water species, including algae, to cooler regions. If migration is not possible then extinction of affected species may occur. A higher water temperature holds a lower volume of oxygen leading to eutrophication (a process where excess nutrients enter water bodies, stimulating waterborne organism growth); thus algal bloom incidents can increase in frequency in these waters. Blooms starve the ecosystem of oxygen causing water quality to deteriorate, impacting further on routes taken by migrating marine animals, species composition and nutrient cycling[2].

National Adaptation Programme 2013–2017[3]

The National Adaptation Programme, led by the Department for Environment, Food & Rural Affairs, aligns risks identified in the Climate Change Risk Assessment to actions being undertaken or to be undertaken with timescales for each. It examines the role of the built environment, infrastructure, healthy and resilient communities, agriculture and forestry, natural environment, and business and local government.

The Programme looks most closely at the most urgent risks facing the UK and is supported by an economic annex looking at the costs and benefits of climate change and the impact on economic activity.

The Programme sets high level objectives and actions to be taken to meet these objectives up to 2015. It has been agreed that an assessment of the response to the health objectives of the Programme will be carried out by summer 2014.

The Programme calls for the Environment Agency, Public Health England, Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Food Standards Agency (FSA) and the Marine Climate Change Impacts Partnership (MCCIP) to work together to improve understanding of the potential for increases in blooms and changes in patterns/frequency of harmful marine algae and to develop strategies to reduce the associated risks.

PHE will support efforts to prepare for and respond to our changing climate and extreme weather events.

Conclusions

This short update provides an overview of four toxic syndromes associated with consumption of fish and seafood contaminated with algal toxins. While health risks from all these syndromes have been encountered worldwide, current surveillance in the UK and Europe suggests that there is a low incidence of human disease associated with marine toxin ingestion. However, these illnesses are likely to be greatly under-reported and the species involved are often not identified. With the changing hydrological conditions and evidence that toxic algal species are increasing in their geographical location and frequency, it is important to determine the possible future public health threat in the UK. Increased distant foreign travel and global trade in fish stocks means that the health effects of marine toxins are an emerging issue of which both health professionals and the general public should remain aware.

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Citizen science – local air quality; local action

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Local air quality

Poor air quality is a significant public health issue, the effects of long-term exposure to air pollutants on mortality are well recognised, although less is known about effects on morbidity. Nitrogen oxides and particulate matter are two of the primary pollutants associated with traffic emissions.

Using figures from 2008, it was estimated that anthropogenic particulate matter had an effect on mortality equivalent to nearly 29,000 deaths and an associated loss of total population life of 340,000 life-years[1]. Effects of short-term exposure to other common air pollutants such as sulphur dioxide, nitrogen dioxide and ozone have also been identified, but the effects of long-term exposure to these pollutants is less well characterised, although evidence is developing. A recent review by the World Health Organization notes that studies have found that both day-to-day variations and long-term exposure to nitrogen dioxide are associated with mortality and morbidity. It indicates that the evidence is suggestive of a causal relationship, particularly for respiratory outcomes, but notes that nitrogen dioxide may also represent other constituents (which have adverse health effects) not represented by currently regulated metrics of particulate matter[2].

The Environment Act 1995 introduced a system of local air quality management (LAQM) because certain pollutants are best monitored and managed at a local level. Local authorities are required to review air quality within their boundary, to assess whether certain health-based national air quality objectives will be achieved and to work towards achieving those objectives. Sheffield aspires to be a city where health inequalities are eliminated and air is healthy for all to breathe; it has appointed the Director of Public Health as the overall 'Air Quality Champion' as part of their role on the city's Health and Wellbeing Board. Air pollution has recently been estimated to account for up to 500 premature deaths a year in Sheffield[3].

Community diffusion tube monitoring

Community air quality monitoring for nitrogen dioxide started in Sheffield in 1998 in backyards in Tinsley, a neighbourhood to the east of Sheffield traversed by the M1 motorway. Monitoring began because local people were concerned about the effects of air pollution on their health and quality of life. The community air quality monitoring network has been extended to cover other areas of the city, involving community partners such as local forums, environmental groups, neighbourhood watch groups and schools.

Community organisations get involved because they are well placed to know the locations in their neighbourhoods where residents are concerned about air pollution. This brings the issue of air pollution down to the local level, and empowers local communities to better articulate their concerns about poor air quality, traffic and its effects on the community's health and quality of life.

East End Quality of Life Initiative (EEQOLI) supports community groups to set up local pollution monitoring. EEQOLI is currently funded by a Sheffield City Council public health grant, and previously by NHS Sheffield (the primary care trust for Sheffield), which on 1 April 2013 became part of Sheffield City Council. The community diffusion tube scheme has been part funded by Sheffield City Council as part of its LAQM work. EEQOLI supports community groups in the monitoring of nitrogen dioxide by diffusion tube, with Sheffield City Council being responsible for managing the analysis, the quality assurance and quality control of the diffusion tubes.

Every month community volunteers change the diffusion tubes. The tube details (batch number, tube number, site, date and time of change over) are written on a log sheet and sent with the exposed tubes to the laboratory for analysis. The next batch of unexposed tubes is sent out to each community group before the changeover date. This process takes no more than about half an hour each month.

Graphs of the diffusion tube results are produced month by month each year, and graphs of adjusted annual averages are also produced using regional bias adjustment factors, and are emailed or posted to the community groups, and made available for download from the website at http://sheffieldeastend.org.uk/AQmonitoring.htm. A monthly newsletter is also emailed to community groups summarising recent research into the health effects of air pollution and noise.

Local activity

Examples of how air quality data has been used by local communities in Sheffield are listed below.

- Informed planning application concerns and environmental assessments
- Articles in community newsletters

- Supported requests for improvements to public transport
- Used to comment on the Local Transport Plan
- Used to support teaching of science in the 21st Century National Curriculum Framework in Secondary Schools
- Added to Sheffield City Council data in areas where there was no air quality monitoring
- Raised awareness that many people are living in areas with poor air quality
- Used in local media

In 2009 an existing Sainsbury's superstore in Sheffield applied for planning permission to extend the store by 44% of the floor area. At a Planning and Highway Committee meeting in August 2010 local councillors voted against a planning officer recommendation to grant planning permission, primarily because of traffic and air quality concerns.

Carter Knowle and Millhouses Community Group, working with EEQOLI, had been monitoring air pollution in the area using nitrogen dioxide diffusion tubes. The proposed development was within an existing city-wide air quality management area (AQMA) for nitrogen dioxide and results from the community monitoring scheme showed that existing concentrations of nitrogen dioxide around the proposed development were higher than the annual average national air quality objective of 40 $\mu g/m^3$. A 900 signature petition was submitted to Sheffield City Council, alongside 27 letters of objection to the development including one from the Director of Public Health at NHS Sheffield. Councillors were presented with this evidence, and considered that the proposed development could potentially have a detrimental effect on the health and wellbeing of local people.

Sainsbury's appealed the refusal to grant planning permission to the Planning Inspectorate[4]. The Inspector rejected Sainsbury's appeal in August 2011 because of concerns about air quality and health, and assumptions made in the air quality impact assessment that accompanied the planning application. The Inspector concluded that "… the potential harm I have identified with regard to the effect of the proposal on local air quality, and consequentially human health, is not outweighed by other considerations …" and "… whilst I have had regard to the conditions suggested by interested parties, it would not be possible, in my judgement, to make the proposal acceptable in planning terms through the imposition of reasonable conditions."

Sainsbury's took its appeal to the High Court, although days before the case was due to be heard in October 2012 it withdrew the appeal.

Working with Healthy Air (www.healthyair.org.uk/) EEQOLI organised a successful conference in December 2011. Presentations included speakers from Client Earth and Healthy Air, along with a presentation from NHS Sheffield Public Health on the health effects of poor air quality, and a speaker from Carter Knowle Community Group on its involvement with the 2009 Sainsbury's planning application.

The results from local air quality monitoring have led to many articles in local newspapers and radio coverage. Regional television (Look North) has run numerous stories after EEQOLI informed them of possible air quality and health news items.

EEQOLI and other community groups sit on a multidisciplinary working group with Sheffield City Council that helped develop the new air quality action plan for Sheffield 2015, which was approved by the City Council in July 2012. EEQOLI is now involved in the Air Quality Action Plan Working Group, working on the implementation of the action plan.

Conclusions

EEQOLI has demonstrated the continuing benefits of involving local people and community groups in air quality monitoring, enabling them to participate in improving their local environment and influencing planning and policy decisions. Through working with public health colleagues at Sheffield City Council, residents can help to improve and protect the health and wellbeing of all the people of Sheffield.

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Natural Hazards, Extreme Events and Climate Change

Extreme events in England – documentation of events by the HPA

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Introduction

Extreme events are defined as "any extreme weather event or other natural hazard including flooding, drought, cold, heat, earthquakes, wildfires and volcanic ash with the potential to cause adverse impacts on human health"[1]. Some extreme events are large, affecting many communities and causing major widespread disruption, such as heavy snow. Others are much smaller in scale and may not be recognised outside the immediate area, such as localised flooding.

In the UK, there is no centralised register of extreme events, although individual events may be studied with a view to identifying lessons that can be used to prevent or mitigate recurrence, or to improve future response[2]. The need to document extreme events and share them nationally and internationally in a standardised manner is increasingly important to build the evidence base. Disaster databases have the potential to provide in-depth information about the occurrence and impact of disasters and natural hazards, but rely upon human and resource input to ensure that they are comprehensive in including all relevant events, and that information is sufficiently complete. There are few such databases, and the data they contain "are often ad hoc, fragmented, and too superficial"[3], and the results may contradict each other[4]. Of the operational research based on these databases "much … lacks consistency, is of poor reliability and validity and is of limited use for establishing baselines, defining standards, making comparisons or tracking trends"[3].

Given the limitations of databases developed specifically to collect information on disasters, and the lack in the UK of a central repository[5] of information on extreme events, it is not known how many such events have occurred in England. The aim of this paper is to examine whether incident management databases, the primary purpose of which is to record the activity of front-line public health teams in responding to enquiries and incidents, can be used to estimate the frequency and describe the features of recent extreme events in England.

Methods

Three national-level databases which capture the activity of front-line teams within the Health Protection Agency (now part of Public Health England) were identified for analysis.

CHIRP

The Chemical Incidents Reporting Programme (CHIRP) is used by Centre for Radiation, Chemical and Environmental Hazards (CRCE) staff to record details of acute incidents notified to them, and the actions taken. All fields were searched using keywords (see the box), and the resulting records reviewed for relevance.

Box: Keyword search terms used to identify records that might relate to extreme events, which were then individually reviewed for further information

Flood	Ice	Gorsefire/gorse fire
Burst water main	Snow	Heathfire/heath fire
Weather	Heat	Grassfire/grass fire
Drought	Volcan*	
Heatwave	Wildfire	

NAED

The Non-Acute Enquiries Database (NAED) is also used by CRCE front-line staff, and contains details of enquiries which relate to chronic incidents. Consequently, the date on which an enquiry is initially logged may not reflect the date of the incident. NAED was searched using the keywords outlined in the box.

HPZone

This is used by health protection units (now local health protection teams) to capture and record all cases, notifications, and enquiries handled by the local team. It is primarily a case management system rather than a surveillance tool, but some fields can be queried to obtain a summary of the cases and incidents dealt with locally. Entries are classified into one of three groups:

- Cases of specific infectious diseases or chemical exposures
- Enquiries – these are requests for professional information or public health advice[6], and are classified according to the topic of the call. Topics that solely relate to extreme events are:
  - ◊ flooding
  - ◊ weather-related
  - ◊ heatwave (introduced as a new topic in 2011)

Other potentially relevant enquiry topics were reviewed to identify records relating to extreme events. These topics are:

- ◊ fire/smoke
- ◊ natural phenomena
- ◊ non-infectious environmental hazard (NIEH)
- ◊ water

- Situations, which are public health incidents or potential incidents. They can indicate that there is an ongoing problem, or that the health protection team has been informed about a local circumstance that may in future have implications for public health. Situations were searched using keywords relating to extreme events (see the box), and the resulting records reviewed

Timescales

HPZone was launched across the HPA in stages from 2009 into early 2010. This analysis includes entries on the database from the start of 2010 to the end of July 2012. CHIRP and NAED were developed more recently, and all records were included from when the databases were first used (December 2010 for CHIRP and January 2011 for NAED), until the end of July 2012.

Results

Chemical databases

The chemical incident databases (CHIRP and NAED) had 25 extreme events (Table 1) over approximately 18 months. Ten each of wildfire and flooding incidents were identified, although four of the flooding records referred to non-acute enquiries – for example, about flood defences.

Table 1: Extreme events identified in chemical incident databases, December 2010 (acute incidents) or January 2011 (non-acute incidents) to July 2012

	Acute chemical incidents	Non-acute enquiries
Wildfire	10	0
Flooding	6	4
Volcanic ash	1	1
Drought	1	0
Severe weather	1	0
Blue-green algae	1	0
Total	20	5

HPZone

A total of 241 extreme events records were identified on HPZone, at a mean rate of approximately 1.8 per week. Of these, 52 were specifically assigned to extreme event enquiry topics:

- 41 specific flooding enquiries
- 9 weather-related enquiries
- 2 heatwave enquiries

A further 52 extreme events enquiries were identified by keyword search of other enquiry topics:

- Of 123 ‘fire/smoke’ enquiries, 3 mentioned wildfires
- Of 278 ‘NIEH’ enquiries, 6 mentioned blue-green algae
- Of 1623 ‘water’ enquiries, 25 mentioned burst water main(s), 11 mentioned blue-green algae, 6 mentioned flooding and 1 mentioned frozen pipes
- None of the four ‘natural phenomena’ enquiries related to extreme events

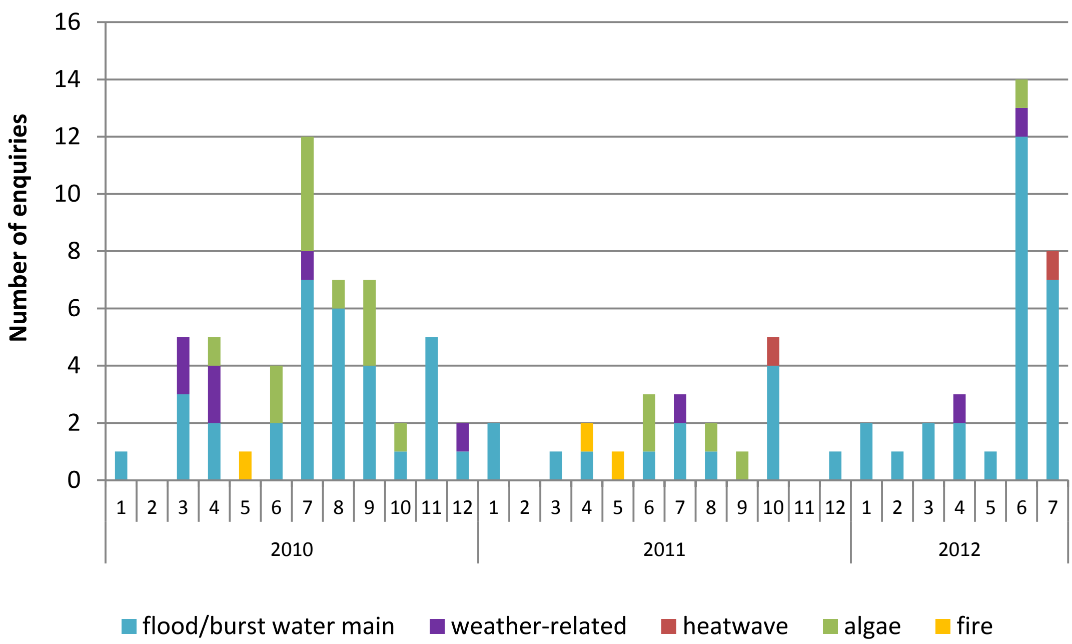

Figure 1: Enquiries received by local health protection units about extreme events: England, January 2010 – July 2012

Of the total of 104 enquiries about potential extreme events (Figure 1), 72 (69%) were about flooding, of which a third were due to burst water mains. Increases in the incidence of burst mains have been attributed to extreme weather, including extremes of both hot and cold temperatures[7]. Of flooding enquiries, 16% were about blue-green algae, the occurrence of which is linked to weather patterns. Algal blooms may become more frequent as a result of climate change[8]; the total number of enquiries showed seasonal variation, with a tendency towards more enquiries in the summer than the winter.

The organisation of the enquirer was also captured (Table 2). Most enquiries were received from water companies, which is unsurprising given the number of flood enquiries. Local authorities (including environmental health officers) were the next most common source of an enquiry about an extreme event.

Every local health protection unit had at least one potential extreme event enquiry; the maximum was 12, with a mean of 4.2 enquiries, although the units covered very different geographical areas and population sizes.

There were 137 extreme event situations identified; virtually all were recorded as an issue, which may not have required immediate public health action but could have indicated that the health protection unit was notified about a potential problem in case there was a need to act in future (Figure 2). The issues mainly related to flooding or blue-green algae. They occurred all across England, except for one local unit.

Little further information was available for most situations. On a severity rating scale of 0 to 5, where 5 is the most serious, 25 issues were assigned as either level 0 or level 1, indicating that the issue could be managed locally without wider impact. None had recorded information about the number of people affected or at risk, or whether there were any people hospitalised or any deaths as a result.

Table 2: Source organisation for extreme event enquiries

Type of organisation of enquirer	Number of enquiries
Water company	25
Local authority	20
Primary care trust	10
Public	8
Public Health England	8
Community health	6
Hospital	5
Education	4
Emergency services	3
Other	15
Total	104

Discussion

To our knowledge, this is the first time that the number of extreme events in England, dealt with by the local health protection teams, has been examined. It has shown that wildfires are more likely to be notified to chemical teams, whereas flooding is the most common extreme event which is notified to the local health protection teams. While the number of enquiries relating to extreme events is low compared to the infectious disease and chemical incident workload of the local units, enquiries are received by all local teams and mainly from existing stakeholders.

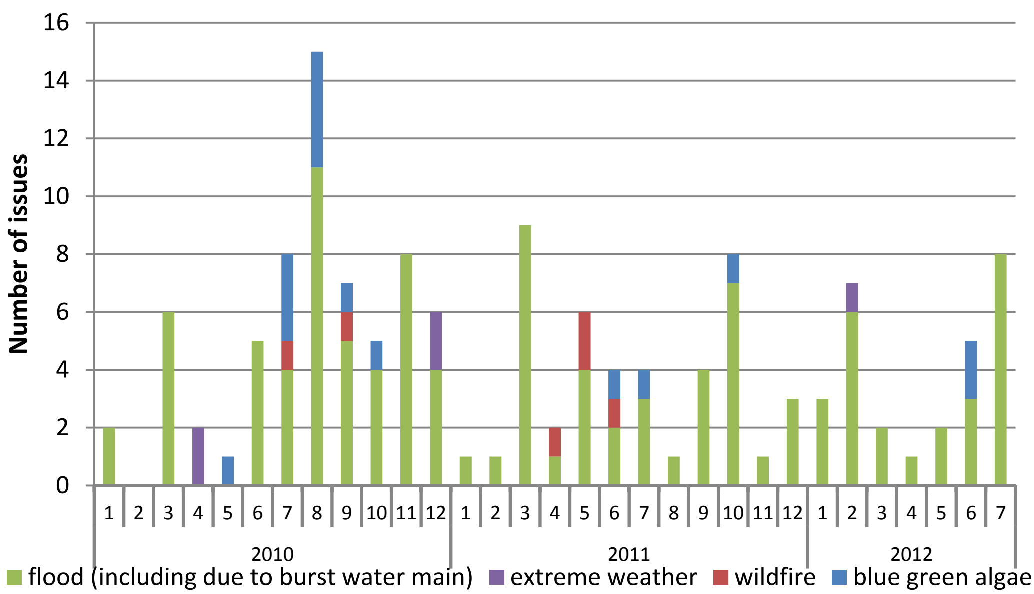

Figure 2: Local extreme events situations or issues: England, January 2010 – July 2012

Known extreme events, such as the impact of volcanic ash in April 2010 and flooding in June 2012 can be detected. However, there are other smaller scale events which still impact on local communities; this analysis shows that local teams may be notified and can consequently be a source of information about such events.

We have shown that local incident management systems can (despite not primarily being intended as surveillance tools) be used to successfully identify extreme events notified to local teams, and to describe their broad characteristics.

The number of extreme event records identified for this analysis is highly likely to be an underestimate. This is for a number of reasons, including difficulty in identifying relevant records. Only certain fields were available for analysis, and many records did not contain sufficient further information to assess whether the enquiry or situation related to an extreme event. There were also differences both within and between the local health protection units in how enquiries and incidents were routinely recorded. There was also no way to assess whether a case or outbreak of infectious disease (such as gastrointestinal illness following exposure to contaminated floodwaters), or chemical incident (eg carbon monoxide poisoning), was related to an extreme event.

This analysis looks only at enquiries and notifications of extreme events; it does not contain information on the magnitude or impact of the events on local communities or the health of its inhabitants. In order to explore ways in which this data can be captured and utilised, case studies can be used to explore selected incidents on more detail. Case studies are widely used in many disciplines including health care[9], to examine the details of the case or incident in more depth, to describe innovative or good practices and specific problems or issues, and to identify lessons for the future[10]. For extreme events, case studies can validate our understanding and encourage re-evaluation and learning, capturing the complexity of disaster risk and disaster situations[11].

Suggestions for next steps

This analysis has shown that enquiries and notifications about extreme events are already being received across PHE from a variety of sources. It is recommended that training and support materials are developed to assist front-line health protection teams and CRCE teams in responding to extreme events.

As the true number of extreme event enquiries is likely to be higher than the totals presented above, it is recommended that the databases be further developed to facilitate the recording and retrieval of these event records. Rather than duplicating effort, consideration should be given to using one database to record extreme events enquiries and developing it to improve the data collected. The production of standard operating procedures (SOP) to standardise the entry of extreme events on the databases could also be useful – for example, along the lines of the NIEH SOP currently being piloted in HPZone.

The HPA was incorporated into Public Health England in April 2013, and the new organisation has a remit that extends beyond that of the HPA. As such, this transition represents an opportunity to work proactively with both internal and external stakeholders to improve the public health response to extreme events.

Acknowledgements

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Low stratospheric ozone event over the UK – impact on UV Index

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Introduction

Public Health England's Centre for Radiation, Chemical and Environmental Hazards (CRCE), and its predecessor organisations, has been operating a solar radiation monitoring (SRM) network across the UK for the last 25 years. Triple-detector heads operate at roughly 2 degree latitude intervals (220 km) from Camborne in Cornwall to Lerwick in the Shetland Islands. Data from the heads is transmitted to CRCE Chilton from each of the measurement heads every hour[1].

Each head contains detectors that monitor the radiation level in the visible (photopic response, similar to the human eye) and ultraviolet range of the optical radiation spectrum. Monitored levels of radiation in the ultraviolet part of the spectrum are weighted for effectiveness at causing skin reddening (erythema). This latter set of results is of greatest interest for providing warnings of the need to protect themselves to those who may be outdoors when the ultraviolet radiation levels are high. One of the measurement heads from the PHE network is shown in Figure 1.

Exposure to ultraviolet radiation is beneficial for the production of vitamin D, which is linked to bone health. However, skin cancers are linked to either cumulative exposure of the skin to ultraviolet radiation or to sudden bursts of intense exposure. Therefore, it is important to balance the beneficial and detrimental implications of exposure to ultraviolet radiation from the sun.

There are a number of factors that influence the probability of getting sunburn, apart from the level of exposure incident on the skin. Skin colour is important: the fairer the skin, the more likely it is that the skin will burn. However, adaptation to sun exposure is also a factor. For this reason, many people in the UK tend to get sunburn in March or April on sunny days, even though the level of ultraviolet radiation exposure may be less than would be normally experienced in the summer.

Solar UV Index

The wavelength spectrum of ultraviolet radiation reaching the ground is different to that arriving at the Earth's atmosphere. Constituents of the atmosphere absorb parts of the incident spectrum. A typical clear-day summer spectrum at CRCE, Chilton, Oxfordshire, is shown in Figure 2.

Figure 1: Solar radiation monitoring system head unit

The structure is partially due to specific absorption mechanisms at those wavelengths. However, if this spectrum is re-plotted with a logarithmic y-axis (Figure 3), it can be seen that there is a prominent cut-off in transmission below about 320 nm. If this spectrum was measured external to the Earth's atmosphere, the plot would be almost constant on this log scale down to below 280 nm. The shorter wavelength cut-off is primarily due to stratospheric ozone.

Ultraviolet radiation is divided into three wavelength regions: UV-A (315–400 nm), UV-B (280–315 nm) and UV-C (100–280 nm). It can be seen from Figure 3 that UV-C usually does not reach the Earth's surface. However, exposure at high altitude can include some UV-C. Exposure of people to ultraviolet radiation can produce a number of positive and negative effects. The best-understood effect is erythema, or reddening of the skin. However, not all ultraviolet wavelengths are equally effective in producing erythema. The relative effectiveness as a function of incident UV radiation wavelength has been published by the International Commission on Illumination (CIE)[2]. The effectiveness as a function of wavelength is called an action spectrum. The erythema action spectrum is shown in Figure 4.

It is important to note that the y-axis is on a logarithmic scale and that UV-B is significantly more effective at generating erythema than UV-A. The action spectrum is applied by

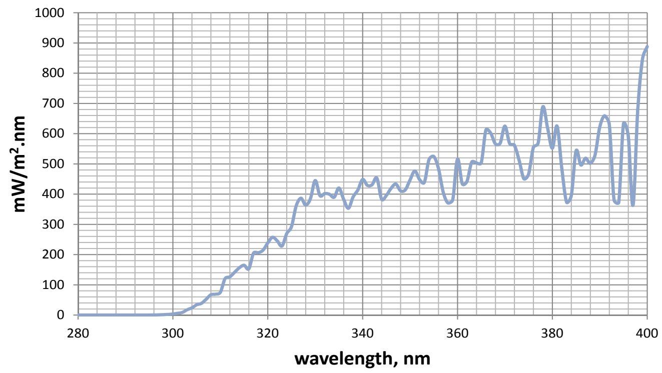

Figure 2: Ground-level solar radiation UV spectrum for Chilton (linear y-axis)

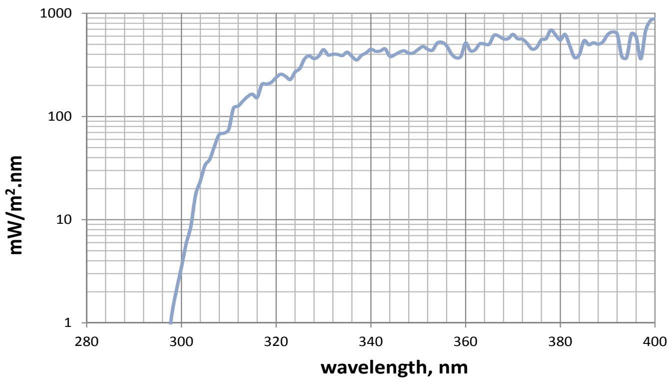

Figure 3: Ground-level solar radiation UV spectrum for Chilton (logarithmic y-axis)

multiplying the amount of UV radiation at a given wavelength by the action spectrum factor at that wavelength and then summing all of the values across the wavelength range. This then provides an erythemal irradiance or an erythemal dose if integrated over a period of exposure. One of the detectors in the PHE SRM head has a spectral response that is similar to this action spectrum. Therefore, the output is presented directly in weighted units.

The shape of the erythema action spectrum seems to be independent of skin type and degree of adaptation to solar UV. However, the absolute amounts of UV radiation required to cause erythema can be different by up to a factor of ten between very pale skin, red-haired, blue-eyed individuals early in the year and those with dark skin. Therefore, a standardised quantity is used to determine a dose for comparison across measurement systems – the standard erythema dose or SED, which is equal to 100 J/m^2. For a given person, the equivalent quantity that causes skin damage would be the minimum erythema dose or MED, but this varies throughout the year. It can range from 150 J/m^2 to over 1000 J/m^2, mainly due to differences in skin type. This complexity makes public advice very challenging because it almost has to be tailored to the individual at a specific time of the year.

In order to simplify the erythemally-weighted UV dose rate, the World Health Organization developed the Global Solar

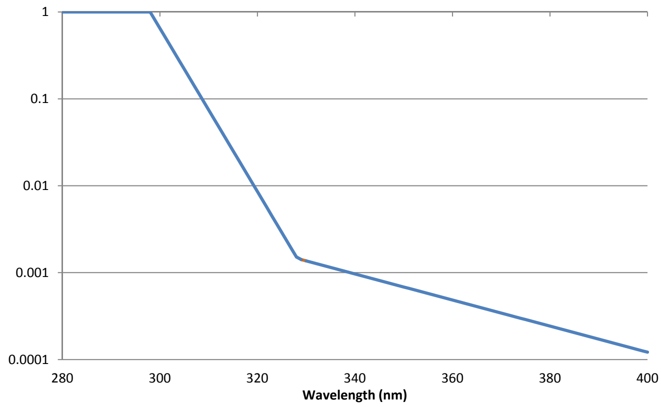

Figure 4: CIE erythema action spectrum

UV Index[3]. This figure was intended to provide guidance on the risk of sunburn and on when protection measures may be needed. The scale was first developed in Canada, with a maximum for the country set at 10. In the UK, typical peak-summer maximum values are 7 or 8, whereas more tropical areas can exceed 16.

Stratospheric ozone

The stratosphere is a layer, approximately 10–50 km above the Earth's surface. Ozone is generated in the stratosphere by exposure of oxygen molecules to UV radiation from the sun. This results in layers of molecules at different temperatures, with the highest temperatures in the upper layers. This is in contrast to the troposphere, which is the layer closest to the Earth. Here the temperature tends to be highest close to the Earth's surface.

The ozone molecules are responsible for absorbing much of the UV radiation as it traverses the stratosphere. Approximately 90% of the atmospheric ozone is in the stratosphere, with the remaining 10% in the troposphere. However, tropospheric ozone is generally related to ground level pollution. Stratospheric ozone concentration is usually measured as the quantity in a vertical column above the ground. This is then related to the thickness if compressed at standard temperature (0°C) and pressure (1 atmosphere). This thickness is measured in Dobson Units (DUs), where 1 DU is equal to a thickness of 0.01 mm. Typical average levels are about 300 DU or 3 mm thickness.

The total column ozone varies due to weather conditions in the stratosphere and it varies with season and sometimes over days. The consequence of reduced levels of ozone is that the UV spectrum reaching the Earth is enhanced in the shorter wavelength UV-B region: essentially, the edge in Figure 3 moves to the left. Since this region of the UV spectrum is very effective at causing erythema, the UV Index will increase.

The actual path length through the atmosphere that UV radiation has to travel is dependent on the solar zenith angle:

overhead sun has a shorter path than sun at the horizon, for example. This path length also results in a variation of the UV Index.

Sudden increase in ultraviolet radiation exposure levels

On Tuesday 23 April 2013, a prototype portable ultraviolet radiation spectral monitoring system was operating on the roof of the CRCE Chilton building and started to record higher-than-expected levels of UV Index. A comparison with the installed PHE SRM unit showed that both devices were reporting similar levels – approximately 2 UV Index points above that expected for the time of year (6 – high – instead of 4 – moderate).

CRCE works closely with the Defra Science and Evidence Team and contact was made with the Team to determine if the stratospheric ozone levels were reduced, which would explain the increased ground level UV radiation levels. The Defra network is operated by Manchester University. Confirmation was received that the ozone levels were below the trigger level of 302.7 DU and at that time (mid-afternoon) were 265.2 DU at the Manchester University ozone monitoring site in Reading, approximately 30 km from CRCE Chilton. Later in the day, Manchester University confirmed that the Reading average total column ozone was 265.8 DU, with its collocated UV spectroradiometer, confirming a peak UV Index of 6.4. The equivalent data for Manchester was 274.4 DU and a UV Index of 6.3.

All of the PHE SRM sites were reporting higher-than-expected levels of UV Index, suggesting that there was an ozone 'hole' extending across the UK.

The UK usually gets about five completely cloud-free days per year, and most of these tend to be in the winter. However, in May 2012, there was a rare clear day and the UV Index throughout the day is given in Figure 5, which shows that a typical peak UV Index for around this time of the year is 4.

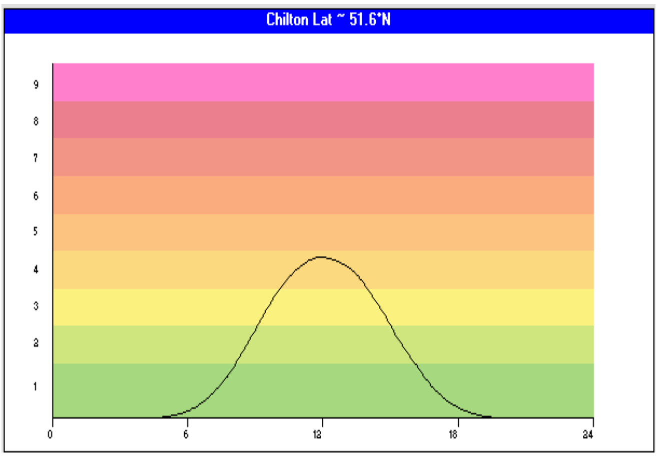

Figure 5: UV Index throughout a cloud-free day with normal column ozone levels in May 2012 at Chilton (times in UTC)

Data on total column ozone can also be obtained using satellites and ozone maps are freely available[4]. The ozone maps, alongside the UV Index at CRCE Chilton, are shown in Figures 6 and 7 for 22 and 23 April, respectively. Usually, ozone 'holes' are localised, but these maps show that this event extended over most of the country.

Monday 22 April was a relatively cloudy day, but it can be seen from the ozone map[4] that the ozone hole was already to the west of the UK.

Tuesday 23 April was generally clear and the UV Index can be seen to be considerably higher than those recorded in May the previous year (Figure 5). Ozone holes tend to be quite short lived, so it was decided that it would be inappropriate to issue any advice at this stage.

On Wednesday 24 April, it was clear from the rate of change of UV Index by mid-morning that the UV Index level at solar noon (1 pm BST or 1200 UTC) was again going to be high. Therefore, it was decided to prepare tweets for the PHE Twitter account and information for the PHE web page. Contact was also made with the Met Office because the UV Index forecasts would not be taking account of the ozone hole. Information was issued by lunchtime to ensure that anyone out of doors would be aware that the UV Index was higher than usual for the time of year. Reports were also being received of people who had been surprised at getting sunburn on the previous day.

The situation was monitored for the rest of the week. By mid-morning on Friday 26 April, the ozone levels in Reading were reported to be near normal, as was the UV Index at Chilton. Therefore, the information on the PHE home page was relegated and the Met Office removed its warning at the end of the day.

The situation from Wednesday to Friday is shown in Figures 8 to 10.

Follow-up

The CRCE does not operate its own total column ozone measuring instruments, so the direct indication of a potential ozone event is an increase in UV Index. However, the Defra monitoring network can then be used to confirm ozone events using total column measurements. Indeed, this has been routine for previous events, but these events had been during the winter months when the UV exposure level reaching the UK from the sun is weaker than during the summer. Data is also available from satellite-based instruments, including the NASA Ozone Measuring Instrument (OMI). Of interest during this ozone event was the difference in total column ozone between Reading and Chilton. The table shows a comparison between the corrected measurement data for Reading[5] with the data from the NASA OMI for Reading and Chilton. It can be seen that there is good agreement across the six days.

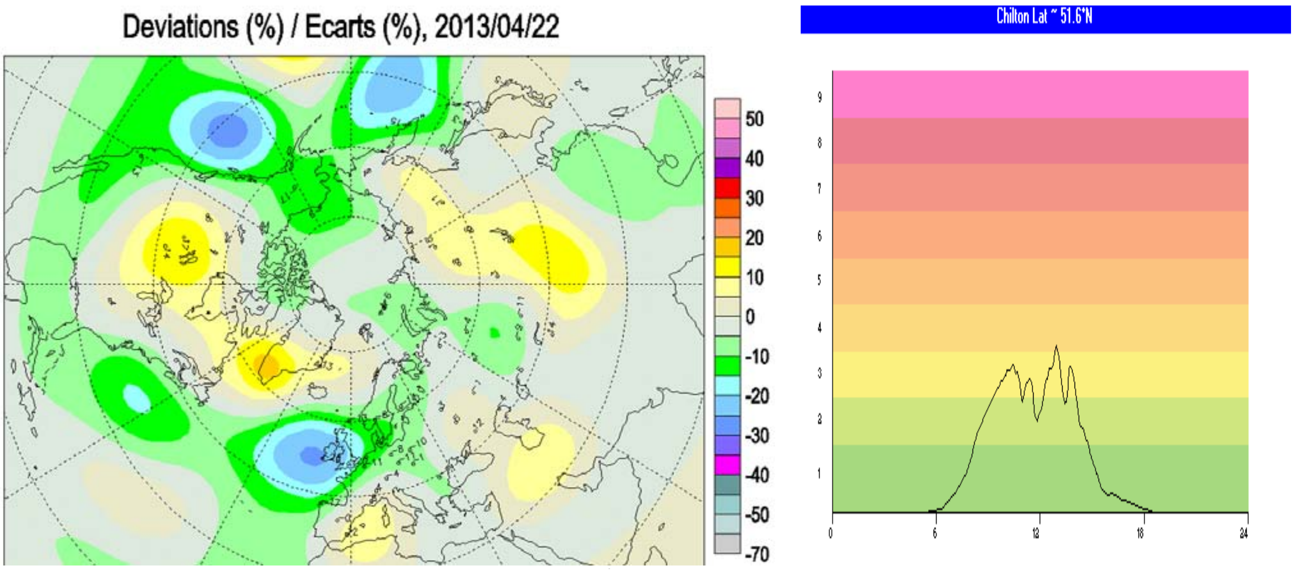

Figure 6: Ozone hole to the west of the UK on 22 April 2013[4] (left) with UV Index throughout the day at Chilton (times in UTC)

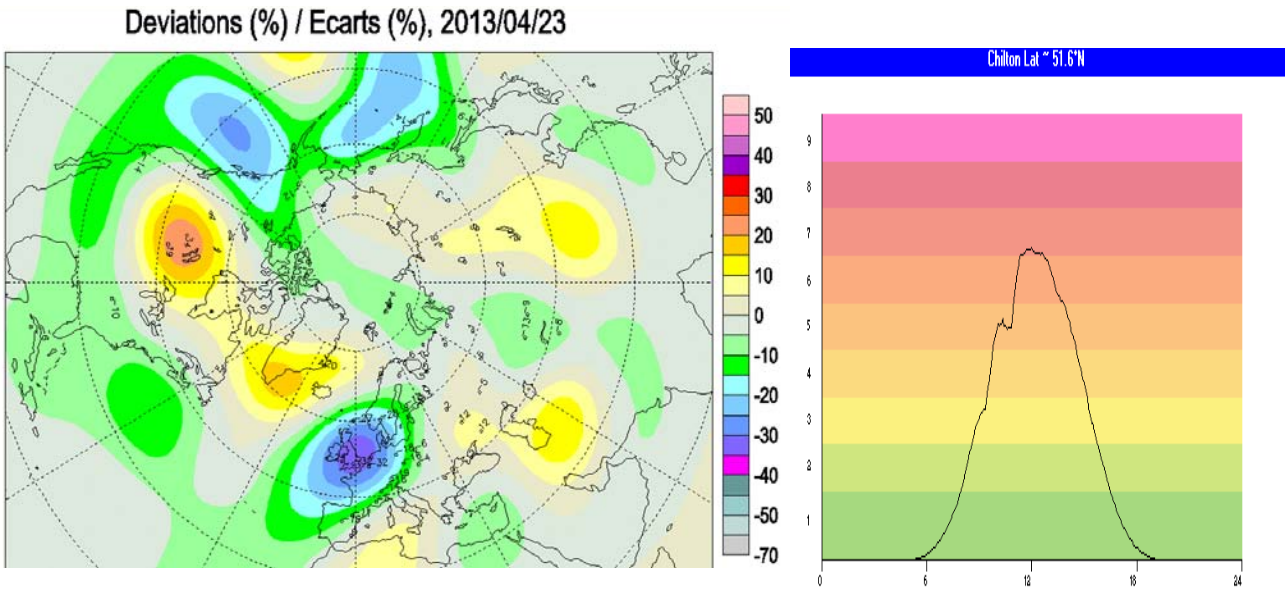

Figure 7: Ozone hole over the UK on 23 April 2013[4] (left) with UV Index throughout the day at Chilton (times in UTC)

Table: Total column ozone measured at Reading and from the NASA OMI, numbers in red correspond to periods of low column ozone layer thickness

	Stratospheric ozone (Dobson Units)		
Date	Reading (Defra)	Reading (NASA OMI)	Chilton (NASA OMI)
21/04/2013	431	441	465
22/04/2013	314	292	289
23/04/2013	267	262	264
24/04/2013	272	270	273
25/04/2013	293	290	291
26/04/2013	394	372	386

The acute adverse implication from this type of event was an increase in reports of sunburn. The risk of malignant melanoma is linked to episodes of severe sunburn, especially in childhood, though details about anyone receiving severe sunburn are not known. One positive aspect is that the increase in the UV-B level would have been sufficient to generate vitamin D in the skin after the long winter period during which diet would have been the main source. Also if people were once more out in the fresh air and moving around, this would have had benefits in terms of general health and well-being.

The ozone event happened during the week, which meant that procedures could be easily implemented and other bodies contacted. Had the event started over the weekend,

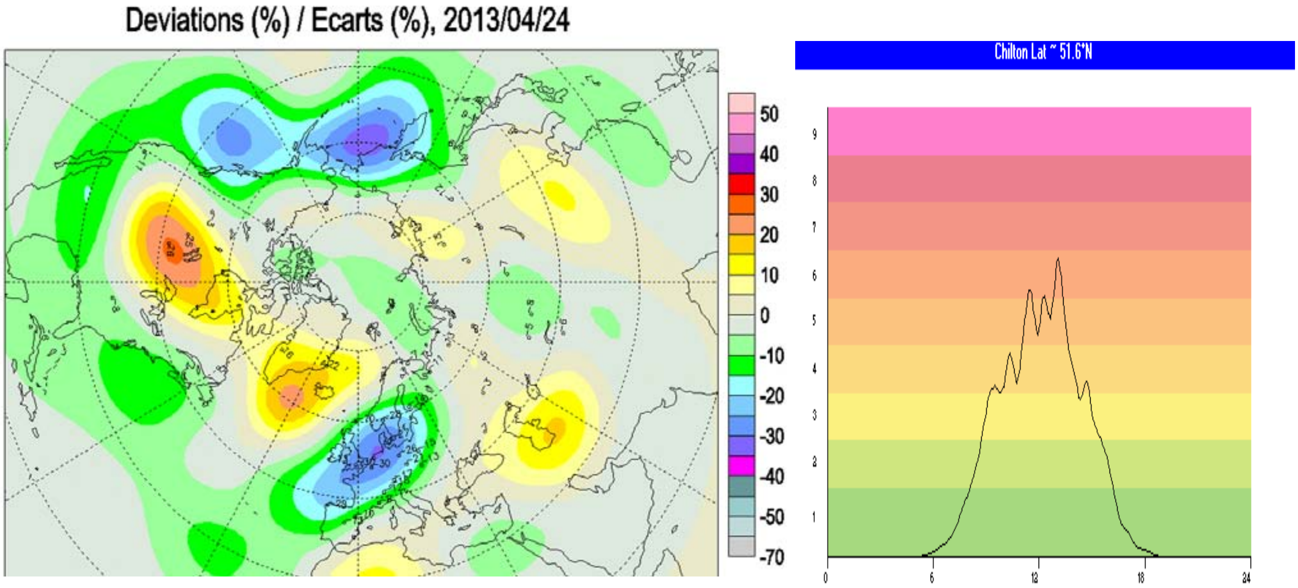

Figure 8: Ozone hole over the UK on 24 April 2013[4] (left) with UV Index throughout the day at Chilton (times in UTC)

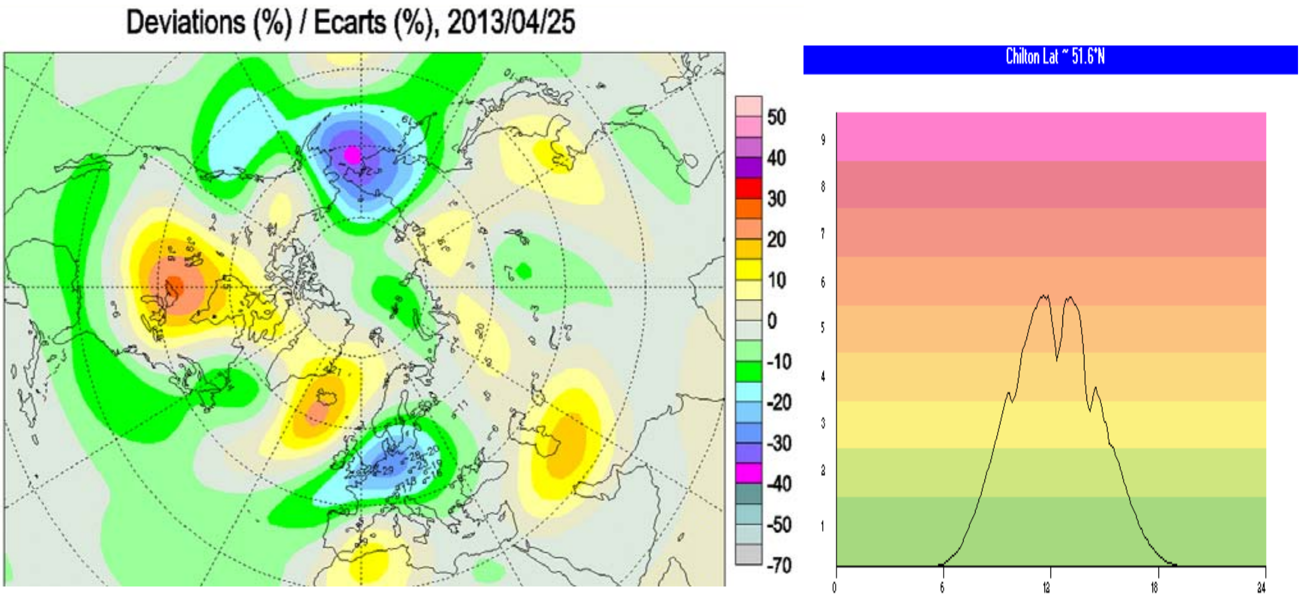

Figure 9: Ozone hole to the east of the UK on 25 April 2013[4] (left) with UV Index throughout the day at Chilton (times in UTC)

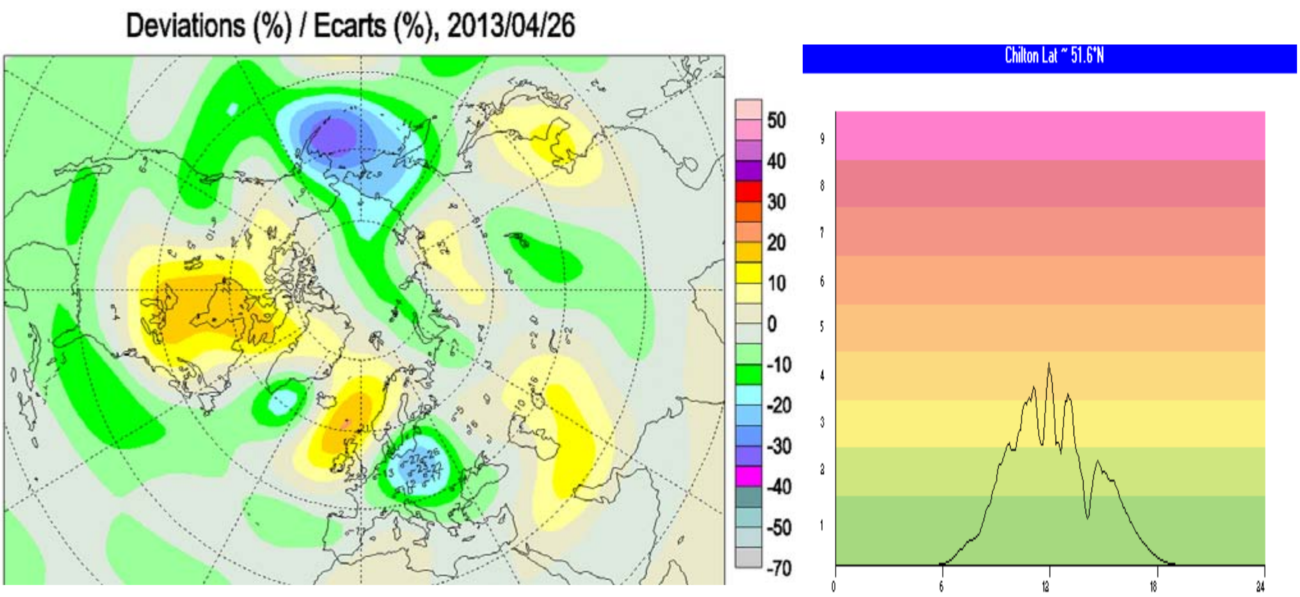

Figure 10: Ozone level over the UK on 26 April 2013[4] (left) with UV Index throughout the day at Chilton (times in UTC)

then it is unlikely it would have been picked up until the next normal working day. We are considering options for automatic notifications of unusual UV Index levels for the future.

Acknowledgements

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About Public Health England

Public Health England's mission is to protect and improve the nation's health and to address inequalities through working with national and local government, the NHS, industry and the voluntary and community sector. PHE is an operationally autonomous executive agency of the Department of Health.

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