NHS LOTHIAN

Legionnaires' Disease Outbreak in South West Edinburgh June to July 2012

Final Report of the Incident Management Team

August 2015

Acknowledgements

All members of the Incident Management Team from 2012 to 2015.

NHS Lothian
- GPs and practice staff in south west Edinburgh
- Microbiology
- Communications
- Acute Services
- Lothian Analytical Services
- NHS Lothian Health Information Unit
- Public Health and Health Policy
- Primary Care Contractor Organisation
- GP sub-committee of Lothian Medical Committee
- Edinburgh Community Health Partnership
- Medicines Information Services
- Forensic Pathology
- Finance Directorate

Edinburgh City Council
- Environmental Health
- Edinburgh Scientific Services

Health and Safety Executive

Health Protection Scotland

NHS Public Health departments across Scotland and the rest of the UK

Public Health England (formerly Health Protection Agency) Microbial Risk Assessment Unit (modelling)

Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory, Glasgow

Scottish Government Health Department

UK Meteorological Office

Members of the public, patients and relatives of those affected by this outbreak

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Summary

This is the final report of the Edinburgh Legionnaires' Disease Outbreak Incident Management Team which was convened in June 2012. Although the outbreak was declared over on 17 July 2012, the Incident Management Team has continued to meet to co-ordinate the ongoing investigations into the source of this outbreak.

There were 56 confirmed cases of Legionnaires' disease and 36 probable and possible cases linked to this outbreak. Four deaths were reported amongst the confirmed cases. The case fatality rate was 7.1% among confirmed cases and 4.3% among all cases.

An investigation by the Health and Safety Executive and Lothian and Borders Police into the circumstances of the deaths of four people from Legionnaires' disease was undertaken under the direction of the specialist Health and Safety Division of the Crown Office and Procurator Fiscal Service. As it has not been possible to identify the precise source of the Legionella bacteria that resulted in the death of four people, Crown Counsel has concluded that there is insufficient evidence to prosecute any person or organisation for the deaths.

As a result of the investigation a number of reports were submitted by the Health and Safety Executive to the Crown Office for breaches of health and safety regulations unrelated to the deaths of the four people. Crown Counsel has instructed that a number of companies be prosecuted on indictment in relation to those breaches.

This outbreak largely affected a defined population in south west Edinburgh. It had considerable impact on NHS services during June 2012. More than 1,000 patients were investigated and treated in primary care. Forty-five of the confirmed cases were admitted to acute hospitals in NHS Lothian. Twenty two patients required admission to critical care; 19 were admitted to intensive care and three to a high dependency unit. Seven of the confirmed cases, and two in the probable and possible category, were identified in people living outwith the NHS Lothian area.

Investigation of the outbreak involved close multi-agency working across Edinburgh and beyond. The investigations undertaken included: epidemiological and microbiological analysis, temporal and spatial modelling of patient and weather data and environmental sampling and analysis of potential water sources for Legionella organisms.

The Incident Management Team has concluded that the outbreak was caused by an aerosol release of *Legionella pneumophila* Sg1 Knoxville ST191 over a defined area of south west Edinburgh during May 2012. Although the Incident Management Team could not establish the specific source of the organism, it has concluded that the most likely source of this aerosol release was an industrial complex containing wet cooling towers in the north east of the affected area.

The processes followed in this investigation and the lessons learned have already been shared with colleagues in other countries that have experienced similar outbreaks. The findings in this report will also be shared across and beyond Scotland. A multi-agency debrief held soon after the outbreak recognised the considerable personal commitment to tackling the outbreak and providing high quality clinical care and highlighted important lessons to be disseminated. There is a need to ensure that the ability to respond in this manner in future is formalised and that the

resources to deliver a rapid and sustainable response across primary and secondary care, and with partners, are available on a 24/7 basis. Areas for improvement included:

- the revision of Scottish national Legionella outbreak response guidance
- a review of resources and facilities for response to be made available rapidly and for the duration of any outbreak
- additional training and exercising of joint agency plans
- additional means of communicating with the public.

Scottish Health Protection Network guidance on the management of Legionella outbreaks was updated in November 2014 and the European Centre for Disease Control has published an investigation toolbox (http://legionnaires.ecdc.europa.eu/). Members of the Incident Management Team contributed to both of these developments. There has been parallel work aimed at reducing the risk of future outbreaks across the UK. The main challenge remains to ensure that there is sufficient expertise at local level to assure surveillance, early intervention and the sustained response required to manage future outbreaks.

1 Background and Introduction

1.1 Background

Legionella was first discovered in 1976 when it was identified as being the causative pathogen in a respiratory disease outbreak among American Legion conventioneers at Philadelphia's Bellevue Stratford Hotel (Fraser 1977).

Human exposure via inhalation of Legionella bacteria (legionellosis) can lead to two illnesses that have been considered clinically and epidemiologically distinct: Legionnaires' disease is a more severe illness characterised by fever, myalgia, cough, and pneumonia; and Pontiac fever which is a milder illness with similar symptoms, but without pneumonia. The risk of severe disease is higher in older age groups, smokers, people with underlying respiratory disease and males.

The majority of cases of legionellosis are caused by *Legionella pneumophila*. There are 16 recognised serogroups of *Legionella pneumophila*, of which serogroup 1 (Sg1) is the most common. In addition there are over 50 other species of Legionella that have been shown to cause human disease. There is evidence of previous exposure to *Legionella species* in a high proportion of the population, as determined in seroprevalence studies in blood-donors. However, evidence of previous exposure to *Legionella pneumophila* Sg1 is more uncommon.

The incidence of legionellosis in Scotland is low and the majority of cases are contracted overseas.

Legionella in the environment

Legionella bacteria are distributed widely in both natural and artificial water supplies. In most cases, disease is caused by the inhalation of water containing Legionella. Sources include showers, air conditioning cooling towers, humidifiers, whirlpool spas and fountains.

Legionella bacteria are common in natural water sources such as rivers, lakes and reservoirs, but are usually found in low numbers. They may also be found in purpose-built water systems such as cooling towers, evaporative condensers and whirlpool spas. If conditions are favourable (water temperature of 20-45°C; stored and/or re-circulated water, a source of nutrients for the organism e.g. sludge, scale or fouling; creation and spreading of water droplets), the bacteria may grow increasing the risks of aerosolisation and thus human cases of legionellosis (Borella 2004; Borella 2005; Heyman 2008; Napoli 2010).

Transmission

Legionellosis can occur after inhaling an aerosol containing Legionella bacteria from contaminated water sources such as wet cooling systems e.g. cooling towers, hot water systems, showers, whirlpool spas, and similar disseminators that draw upon a water supply (Napoli 2010). There have been no reported confirmed cases of person to person transmission, so it can be presumed that the environment is the only source of the infection (Napoli 2010). The same source of infection depends on individual factors or pre-existing pathologies (Napoli 2010) and the dispersion of the aerosol from, for example, a cooling tower, the distance between the source and the affected persons (Bhopal 1991; Cameron 1991; Nguyen 2006), the dose of exposure (Brown 1999), seasonality and climatic conditions (Li 2002) and maintenance of facilities (Ordonez-Iriarte 2006).

Legionella in Europe

The European Legionnaires' Disease Surveillance Network (ELDSNet) collects data relating to Legionnaires' disease in European Union Member States, Iceland and Norway. There are over 11 cases per million population annually. This is higher than UK and Scottish rates (5-8 cases per million population) (Joseph 2010).

In 2013 there were 5851 cases diagnosed and reported by 28 EU member states and Norway. Most cases were community acquired (73%), 19% were travel-associated, and 8% were linked to healthcare facilities. People over 50 accounted for 81% of all cases. The overall male to female ratio was 2.4:1. The case-fatality ratio was 10% in 2013, similar to previous years. Most cases were confirmed by urinary antigen test (88%). *Legionella pneumophila,* particularly *Legionella pneumophila* Sg1 was the most commonly identified pathogen, accounting for 83% of culture confirmed cases respectively (European Centre for Disease Prevention and Control 2015).

Most cases are apparently sporadic (isolated) although some literature suggests single cases can be sentinels rather than truly isolated cases (Fields 2002) (Sabria 2002). Data collected on ELDSNet also includes the Europe-wide travel-related surveillance scheme. This data shows that the number of clusters reported in Europe (28 member states and Norway) has been stable between 2008 and 2013, with a decrease in the number of clusters in 2011. Ten European Union/European Economic Area countries did not report any travel-associated cases in 2013.

Figure 1 (European Centre for Disease Prevention and Control 2015) shows the largest cluster reported prior to 2012 was in Spain in 2010 with 51 cases reported (European Centre for Disease Prevention and Control 2014). The countries which reported the largest number of clusters in 2013 were UK, Netherlands, Italy and Spain (Table 1) (European Centre for Disease Prevention and Control 2015).

Figure 1: Reported clusters of Legionnaires' disease and average number of cases per cluster, by year if reporting, EU/EEA 2008-2013. (European Centre for Disease Prevention and Control 2015)

Table 1: Distribution of reported clustering of Legionnaires' disease by reporting country, EU/EEA, 2013. (European Centre for Disease Prevention and Control 2015)

Country	Clusters n	Clustered cases[a] n (%)	Sporadic cases n (%)	Unknown n (%)	Total n
Austria	5	5 (5)	89 (89)	6 (6)	100
Belgium	Unknown	7 (5)	42 (27)	106 (68)	155
Bulgaria	0	0	1 (100)	0	1
Croatia	0	0	41 (100)	0	41
Cyprus	0	0	0	6 (100)	6
Czech Republic	0	0	66 (99)	1 (1)	67
Denmark	6	12 (10)	0	103 (90)	115
Estonia	1	2 (20)	8 (80)	0	10
Finland	Unknown	0	0	15 (100)	15
France	Unknown	0	0	1 262 (100)	1 262
Germany	Unknown	85 (11)	720 (89)	1 (< 1)	806
Greece	0	0	36 (95)	2 (5)	38
Hungary	2	11 (38)	18 (62)	0	29
Ireland	2	2 (14)	12 (86)	0	14
Italy	27	37 (3)	1 308 (97)	0	1 345
Latvia	1	2 (6)	32 (94)	0	34
Lithuania	0	0	1 (100)	0	1
Luxembourg	0	0	6 86)	1 (14)	7
Malta	0	0	2 (100)	0	2
Netherlands	31	51 (17)	257 (83)	0	308
Norway	0	0	40 (100)	0	40
Poland	0	0	11 (100)	0	11
Portugal	3	4 (4)	74 (79)	16 (17)	94
Romania	0	0	1 (100)	0	1
Slovakia	0	0	6 (100)	0	6
Slovenia	0	0	77 (100)	0	77
Spain	15	81 (10)	731 (90)	1 (< 1)	813
Sweden	Unknown	0	0	122 (100)	122
United Kingdom	39	52 (16)	236 (71)	43 (13)	331
Subtotal[b]	126	332 (8)	3 732 (90)	71 (2)	4 135
Total	**132**	**351**	**3 815**	**1 685**	**5 851**

[a] *Denominator: cases with known cluster status*

[b] *Includes only countries where cluster status was known for ≥ 75% of clusters*

In the last 15 years there have been several community outbreaks of Legionnaires' disease associated with cooling towers reported in Europe. These clusters are listed in Table 1. Other sources of outdoor air pollution which have been identified as having been the source of community Legionnaires' disease outbreaks include industrial air scrubbers (Norway) (Nygård 2008); decorative ornamental fountains (Italy) (Napoli 2010); external ducting from indoor air conditioning systems (England) (Telford 2006).

1.2 Trends in Scotland prior to the outbreak 1995-2011

Prior to 2012, fewer than 50 cases of confirmed Legionnaires' disease were reported to Health Protection Scotland (HPS) each year. Of the 41 cases reported in 2009 and 2010 the majority (66%) were travel-related; 27% were community-acquired; 2% were hospital-acquired; and 5% were of unknown origin (Potts 2011).

At least half of the reported cases appeared to be sporadic and it is recognised outbreaks can be difficult to detect due to low attack rates of 0.1-5% and the long incubation period of legionellosis (Heyman 2004). When outbreaks are confirmed they are often connected to cooling towers and the use of spa pools (Fields 2002; Modi 2008; Keramarou 2010).

1.3 Notification

Legionella is a notifiable organism under the Public Health etc. (Scotland) Act 2008. This means it must be notified by microbiology laboratories to NHS public health departments in Scotland to enable them to assess any ongoing risks and to take actions to control the risk.

1.4 Clinical features

Symptoms of Legionella infection include a flu-like illness, fever, muscle aches, tiredness, headache, anorexia, breathlessness, chest pain, confusion and a dry cough which can progress to pneumonia. These symptoms are difficult to differentiate clinically from other atypical pneumonias. The incubation period is between two and 14 days but is typically between five and six days. Infection with Legionella causes a spectrum of illness and some people who seroconvert to Legionella may remain entirely asymptomatic. Infection without pneumonia is known as Pontiac fever. Men aged over 50 years, smokers, those with chronic respiratory disease, excess alcohol users and people with other chronic illnesses including those causing immunosuppression are most at risk of developing severe illness.

1.5 Diagnosis

It is not possible to distinguish patients with Legionnaires' disease from other forms of pneumonia by clinical or radiological methods so laboratory confirmation is essential for diagnosis. Whilst diagnostic methods have improved, no currently available test is able to diagnose all Legionella infections in a timely fashion, with a high degree of sensitivity and specificity. Available methods are summarised in Table 2.

Table 2: Comparison of different microbiological methods to diagnose Legionella infection

Test	Specimen	Sensitivity %	Specificity %	Laboratory turnaround time	Comments
Culture	Respiratory samples including sputum and BAL	<10-80*	100	3-7 days	Detects all species and serogroups. Species other than *L pneumophila* may be detectable only after 10 days of incubation
DFA staining	Respiratory samples including sputum and BAL	25-70*	>95	<4hours	Technically demanding. Sensitivity consistently less than for culture
Antigen detection	Urine	70-90	>95	<3hours	Only reliable for detection of *L pneumophila* serogroup 1
PCR	Respiratory samples including sputum and BAL Serum Urine	80-100 30-50 46-86	>90 >90 >90	<4hours	Detects all species and serogroups
Serology	Serum	60-80	>95	1-2 days from receipt of the sample in the Reference Laboratory	Must test both acute and convalescent samples. Interpretation of a single sample can be misleading

Source: Murdoch D 2003. Diagnosis of Legionella infection. *Clinical Infectious Diseases*;36(1):64-9.

* depends on severity of disease, BAL: bronchoalveolar lavage, DFA: direct fluorescent antibody, PCR: polymerase chain reaction

1.6 Identification of an outbreak

When potentially linked cases of Legionnaires' disease are notified to a public health department in Scotland, a problem assessment group is established to risk assess the situation and determine what action is required. Where the potential for ongoing risk to the public is identified, an Incident Management Team is established immediately.

In 2012 outbreak management in Scotland was undertaken within the Scottish Government Framework for Managing Public Health Incidents and followed the pre 2012 guidance of management of Legionella from the Health Protection Network and Scottish Government (2011).

Management of a Legionnaires' outbreak requires close multi-agency partnership working between the NHS, the Health and Safety Executive and the environmental health departments of local authorities. The Health and Safety Executive and local authorities are specialist reporting agencies with regulatory, investigative and enforcement powers in relation to Health and Safety Legislation but only local authorities have powers under the Public Health etc. (Scotland) Act 2008 which were used to conduct the sampling.

Under European Community directives, Health Protection Scotland (through Public Health England) must notify all cases of Legionnaires' disease to the European Centre for Disease Prevention and Control and alert it to any incidents or outbreaks which may cause a risk wider than the affected member state. The European Centre for Disease Prevention and Control then undertakes a risk assessment and the outcome of this assessment is then sent to member states' public health agencies.

2 Chronology of Events, Multi-agency Response and Control Measures

2.1 Immediate response

On Thursday 31 May 2012, NHS Lothian's Directorate of Public Health and Health Policy received a report of a single case of Legionnaires' disease diagnosed at the NHS Lothian microbiology laboratory, which was investigated by the NHS Lothian health protection team. As with all single cases, the team was alert to the potential for future cases to indicate a developing cluster.

On Saturday 2 June 2012, while the duty health protection nurse and consultant in public health medicine for NHS Lothian were preparing to establish a problem assessment group, they received reports of one further case, confirmed locally, and one possible case. These cases were assessed with medical microbiology and the decision was taken to investigate any links and to heighten surveillance. Relevant NHS Lothian departments including Lothian Unscheduled Care Service, the acute receiving unit at Western General Hospital, the accident and emergency department and intensive care unit at Royal Infirmary of Edinburgh and Health Protection Scotland were informed.

On Sunday 3 June 2012, the duty health protection nurse and consultant in public health medicine for NHS Lothian received reports of a further two confirmed and three possible cases, bringing the total to four confirmed cases of *Legionella pneumophila* infection and four possible cases, all resident in or linked to south west Edinburgh.

2.2 First Incident Management Team meeting

A Problem Assessment Group (PAG) was established on the afternoon of Sunday 3 June 2012 and was quickly converted into a full Incident Management Team with the first Incident Management Team meeting held that day. This first meeting included representatives from the City of Edinburgh Council, the Health and Safety Executive, Health Protection Scotland and was chaired by a consultant in public health medicine at NHS Lothian. The members of the IMT who attended the various meetings are listed in Appendix B.

2.3 Initial epidemiological investigation

Initial case definitions were agreed by the Incident Management Team. The initial cases were reviewed to identify possible links. The majority of these initial cases lived in south west Edinburgh and their home addresses were plotted on a map. Local meteorological data on wind direction was obtained and possible sources of population exposure (i.e. industrial plant or equipment capable of emitting a contaminated aerosol over a relatively wide area) were identified as a priority. Based on published evidence (Walser 2014) and past experience, these were most likely to be cooling towers which must be registered with City of Edinburgh Council, under the provisions of the Notification of Cooling Towers and Evaporative Condensers Regulations 1992 (Health and Safety at Work etc. Act 1974). Three potential sites were initially identified by environmental health officers from City of Edinburgh Council. The Incident Management Team requested these sites were visited that evening in order to obtain samples to make sure the cooling towers were chemically disinfected as a precautionary measure.

The principal clinical scientist from the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory supported the investigation of environmental and human samples with more advanced laboratory methods and the interpretation of results between June and September 2012.

Senior clinical and scientific staff from Health Protection Scotland participated in the Incident Management Team from the first day of the outbreak and provided essential support in the collation, analysis and interpretation of epidemiological data, as well as liaison with other public health agencies and the Meteorological Office.

2.4 Site visits for sampling and shot dosing

Within two hours of the Incident Management Team meeting on Sunday 3 June 2012, three officers from City of Edinburgh Council Environmental Health and Scientific Services were on site at the three identified potential sources (Premises 1, 2 and 3) to request the companies to administer high doses of chemical disinfectant shot dosing to the cooling towers as a precautionary measure.

Although it was the Sunday night of a holiday weekend two of the three sites were in operation (Premises 1 and 2). As instructed by the Incident Management Team, the opportunity to take samples in advance of shot dosing was taken that night with the first visit at 18.30 hours and the next one immediately after.

These samples were taken from the towers by the environmental health and scientific services sampling team in conjunction with the plant operators. This action was taken by City of Edinburgh Council officers using their powers under The Public Health etc. (Scotland) Act 2008 to investigate public health incidents. The third site on the cooling tower register (Premise 3) was also visited but this cooling tower was found to have been decommissioned on 7 May 2012 prior to being completely replaced. The water samples were transported that night to City of Edinburgh Council Scientific Services, a laboratory authorised by Scottish national guidance on the management of Legionella (Scottish Health Protection Network 2011) to perform accredited testing of environmental samples during an incident or outbreak.

Table 3: City of Edinburgh Council - Extract from Cooling Tower Register June 2012

Premise	Name	Address	LA/HSE Enforced	No of cooling towers
1	MacFarlan Smith	Wheatfield Road, Edinburgh, EH11 2QA	HSE	7
2	North British Distillery Company	9 Wheatfield Road, Edinburgh, EH11 2PX	HSE	3
3	Murrayfield Ice Rink	13 Riversdale Crescent, EH12 5XN	LA	1
4	Aegon UK	3 Lochside Crescent, Edinburgh, EH12 9DL	LA	3
5	Burtons Foods	34 Bankhead Place, Edinburgh, EH11 4HN	HSE	3
6	Selex	2 Crewe Road North, Edinburgh, EH5 2XS	HSE	2
7	Museum of Scotland	Chambers Street, Edinburgh, EH1 1HU	LA	5

Similar actions were taken in a series of expanding geographic concentric circles at cooling towers at two other locations (Premises 4 and 5) on Monday 4 June 2012 and two more on Wednesday 6 June 2012 (Premises 6 and 7). By this time, all registered cooling towers within six kilometres of the centre of the original cluster of cases had been both sampled and shot dosed with disinfectant as a precaution. Shot dosing* was carried out by the site operator in all cases. All these locations were then subject to a detailed audit by the appropriate authority (Health and Safety Executive or City of Edinburgh Council Environmental Health) responsible for the enforcement of the Health & Safety at Work etc. Act 1974 over the following days.

The senior environmental health officer and scientific services manager provided technical advice at all of the Incident Management Team meetings and an incident room was set up at the City of Edinburgh Council to manage the response. The register of cooling towers and evaporative condensers enabled the prompt identification, sampling and shot dosing (by the site operator) of cooling towers in the affected area.

A total of 17 City of Edinburgh Council environmental health inspectors worked throughout the outbreak to investigate a further 32 locations. Visiting was prioritised based on risk of premises emitting an aerosol containing Legionella and proximity to the area. They worked in liaison with the Health and Safety Executive specialists in occupational hygiene and 10 staff from City of Edinburgh Council Scientific Services to ensure that all the recommendations of the Incident Management Team to identify the source were implemented timeously.

A health and safety executive principal inspector represented the Health and Safety Executive at the first Incident Management Team meeting and then as part of the multidisciplinary Incident Management Team throughout the outbreak. Health and Safety Executive inspections were undertaken by a team of inspectors in collaboration with City of Edinburgh Council environmental health officers. Where required, a range of enforcement options under the Health and Safety at Work etc. Act 1974 was instituted. This included serving improvement notices requiring improvements in the management of cooling towers and hot and cold water systems, issuing of formal reports, providing advice and making recommendations.

2.5 Voluntary cessation of the operation of a number of cooling towers

Voluntary cessation of the operation of a number of cooling towers in the area was attained by the Health and Safety Executive from 7 June 2012 onwards and three improvement notices were subsequently served on premises 1 and 2 between 8 and 12 June 2012. A further three Improvement Notices were served later in the investigation on companies involved with the management of cooling towers and hot and cold water systems at premises 1 and 2. Details of improvement notices can be found at the following link: http://www.hse.gov.uk/notices/. These were all undertaken with a view to ensuring that systems and Legionella risks were being appropriately managed. The relevant duty holders complied with all the requirements of the six Improvement Notices. Follow up visits and actions were made to ensure compliance with formal requirements.

* Shot dosing: Precautionary measure whereby high doses of chemical disinfectant are used as an additional treatment to control levels of bacteria.

2.6 Communications from the Incident Management Team

Following the Incident Management Team meeting on Sunday 3 June 2012, NHS Lothian executive directors were informed and alerts were sent to clinicians in Lothian advising them of the outbreak, seeking their support to identify possible cases and to provide advice on testing and treatment. This included communication to all nursing homes, NHS Lothian clinical directors, community pharmacists, NHS 24, unscheduled care and GP practices in Lothian on the evening of Sunday 3 June 2012 (notified via Surefax). GP practices in the affected area of south west Edinburgh were also contacted by telephone on the morning of Monday 4 June 2012 with an offer of assistance.

The Scottish Government was also notified on the Sunday 3 June 2012, as is normal with any potential public health issue.

In the interest of public health a proactive media approach was adopted and shortly after the first Incident Management Team meeting, at about 20.20 hours on Sunday 3 June 2012, a media statement was issued. The priority at this point was to alert the public to the outbreak, to communicate the symptoms of Legionnaires' disease and to advise anyone who developed symptoms suggestive of Legionnaires' disease to contact NHS 24 immediately or go to their general practitioner.

On Monday 4 June 2012, alerts were also sent to all territorial NHS Board directorates of public health and to other public health agencies in the United Kingdom. The outbreak was picked up quickly by the media resulting in the initial chair of the Incident Management Team undertaking numerous interviews on Monday 4 June 2012, Tuesday 5 June 2012 and throughout the week.

The initial chair of the Incident Management Team became the lead spokesperson for the media.

2.7 Activation of Scottish Government Resilience Room

Following an increase in case numbers and the potential impact on critical care capacity beyond NHS Lothian, officials at the Scottish Government decided to activate Scottish Government Resilience Room on the evening of Tuesday 5 June 2012. It held its first meeting on Wednesday morning (chaired by the then Deputy First Minister) and included representatives from City of Edinburgh Council, Health and Safety Executive, NHS Lothian and members of the Scottish Government Resilience Room Support Team. The Scottish Government Resilience Room was able to support the Incident Management Team to establish the flow of proactive information and communication between Ministers, the Scottish Government Resilience Room, health directorate teams and external teams involved in the Incident Management Team at an early stage of the outbreak response. The Scottish Government Resilience Room continued to meet over the next few days and benefited from in-depth briefings from the NHS Lothian Incident Management Team. The Scottish Government Resilience Room was stood down on Tuesday 12 June 2012, as the incident response was firmly established.

2.8 NHS Lothian clinical capacity

There were daily NHS clinical management meetings to ensure there was capacity within all critical care and acute care sites to manage those patients that needed hospital treatment, and the microbiology services organised flexible rostering and extended hours to accommodate the large number of samples being received. A dedicated helpline for members of the public was established via NHS 24 on

Wednesday 6 June 2012. In total, 943 calls to NHS 24 and the dedicated helpline were received (up to 22.00 Monday 18 June 2012). NHS Lothian Unscheduled Care Services saw an additional 500 patients during the course of the outbreak. The Incident Management Team sent regular updates to primary care and unscheduled care services providing guidance on testing and treatment of patients. The GP sub-committee of the Local Medical Committee and the Area Medical Committee were updated formally on 11 and 13 June 2012 respectively.

2.9 Treatment of cases

More than 1,000 patients were investigated and treated in primary care. Forty five of the confirmed cases were admitted to acute hospitals in NHS Lothian during late May and June 2012. Twenty one of the cases were admitted to the Royal Infirmary and 24 to the Western General Hospital. Twenty two patients required admission to critical care; 19 were admitted to intensive care and three to a high dependency unit.

Of those patients admitted to critical care in Lothian, 17 (77%) required mechanical ventilation. In those patients who were ventilated, the mean duration of ventilation was 10.3 (±6.0) days. Three patients (18%) required prone ventilation for severe Acute Respiratory Distress Syndrome, two (12%) required treatment with inhaled nitric oxide, one (6%) required high frequency oscillatory ventilation and one (6%) required referral for extra-corporeal membrane oxygenation (ECMO). Six patients (29%) required renal replacement therapy for acute kidney injury.

Patients with severe pneumonia were treated with intravenous levofloxacin 500 mg twice daily. Intravenous clarithromycin 500 mg twice daily was added at the discretion of the treating clinician, in view of the potential small risk of cardiac electrophysiological abnormalities with quinolone/macrolide combinations (Lim et al 2009).

Information on the use of antibiotics in the treatment of Legionnaires' disease in specific patient groups was prepared by the Lothian Medicines Information Service and circulated to clinical teams. Recommended dose adjustments were made for both levofloxacin and clarithromycin when treating patients with renal impairment. No dosage adjustments were made for patients with hepatic impairment and hepatic function was monitored closely.

2.10 Ongoing Incident Management Team meetings

Each Incident Management Team was chaired by a consultant in public health medicine and all key agencies involved in the management of the outbreak attended where possible.

During the period Sunday 3 June 2012 to 17 July 2012 (when the outbreak was declared over) the Incident Management Team met fifteen times. Table 4 summarises the actions of the Incident Management Team.

Appendix C details the dates of all the Incident Management Team meetings and the members of the team.

Table 4: Actions undertaken by the Incident Management Team

Minimising risk to the public's health.

- Oversight to ensure the control measures taken in sites, identified as highest risk, were adequate to protect public health. These included shot dosing to disinfect towers thought to be possible sources of Legionella, voluntary cessation of towers thought to potentially pose a risk and the serving by Health and Safety Executive of improvement notices to ensure that risks were being appropriately managed.

The identification of cases and investigation of the population at risk.

- Through collaboration with acute and clinical services in NHS Lothian and Health Protection Scotland, the aim was to provide rapid laboratory confirmation of infection to coordinate case finding and enhanced surveillance of cases within and outwith NHS Lothian, to maintain an updated epidemic curve and to analyse patient level data.

Identification and testing of possible sources of exposure.

- Through coordination with the City of Edinburgh Council Environmental Health and the Health and Safety Executive, to identify potential sources of infection
- Through liaison with Public Health England and the UK Meteorological Office, to conduct detailed modelling of cases in relation to potential sources.
  Through coordination with the City of Edinburgh Council Scientific Services laboratory, the Scottish Haemophilus Legionella Meningococcus and Pneumococcus Reference Laboratory, Glasgow, and United Kingdom specialist laboratories at Colindale, London to test samples for potential sources.

Ensuring access to evidence based treatment.

- Collaboration with clinical service managers to monitor capacity for clinical services, and collaboration with clinicians to produce guidance for testing and treatment in critical care, unscheduled care and primary care.

Communication

- Frequent and proactive public communication using the media and direct delivery of public information to residents within the area.
- Preparation of daily Situation, Background, Assessment, Recommendations (SBAR) reports for management within NHS Lothian, partner agencies and the Scottish Government. Reports included the latest number of cases and the action being taken as a result of decisions taken by the Incident Management Team.

Planning

- Coordinated gathering of information on resource use to assist planning and evaluation of the ongoing response.

2.11 Chronology of the course of the outbreak

A summary chronology of key events and the response is provided in Figure 2

2.11.1 End of the outbreak

The outbreak was declared over on Tuesday 17 July 2012.

2.11.2 Debrief

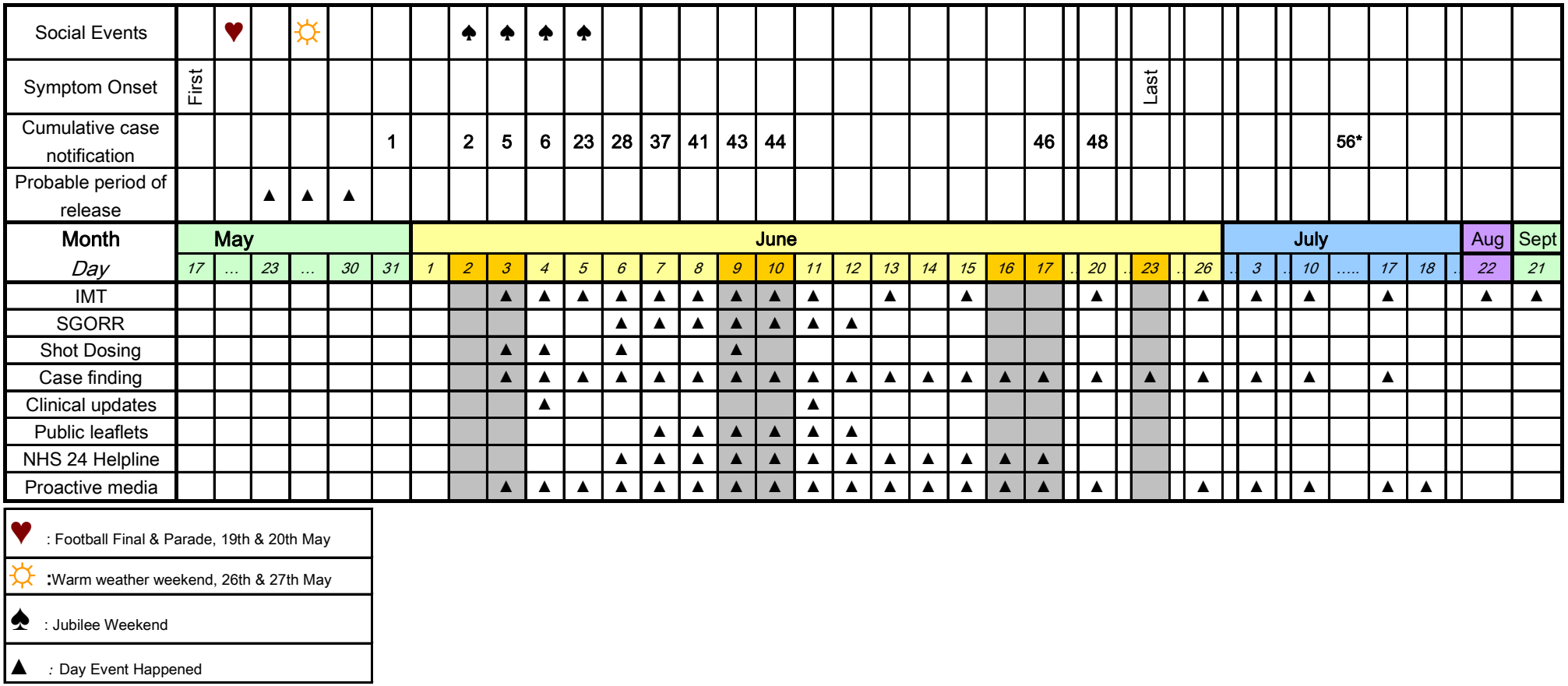
The initial incident debrief was held on 1 August 2012. A number of debriefing sessions were held following the declaration of the end of the outbreak to learn lessons. They were:

- Representatives of the Incident Management Team gave evidence at the Scottish Parliament's Health and Sport Committee on 26 June 2012. http://www.scottish.parliament.uk/newsandmediacentre/52329.aspx

- Representatives of the Incident Management Team gave presentations at a Health Protection Scotland International Legionella Seminar (closed meeting) on Tuesday 3 September 2013 at the Carlton Hotel, Edinburgh. Attendees included other Legionella experts and researchers from the rest of the UK and Europe.

- The chair of the Incident Management Team presented an update on behalf of NHS Lothian to members of the Scottish Parliament on 4 September 2012.

Figure 2: Chronology of key events and the response



*56th case reclassified as a confirmed case on 27th November, previously a suspected case of Pontiac Fever in the community,

3 Investigation of the outbreak

There were three branches of the investigation into the source of the outbreak: microbiological, epidemiological and environmental.

3.1 Microbiological investigation

The objectives of the microbiological investigation undertaken by the NHS Lothian Department of Laboratory Medicine, the Scottish Haemophilus Legionella Meningococcus and Pneumococcus Reference Laboratory and Public Health England on behalf of the Incident Management Team were to:

Investigate clinical cases potentially linked to the outbreak by testing for Legionnaires' disease (blood, urine and respiratory samples);

Test environmental samples (water, biofilm) taken from potential sources for Legionella (see previous section);

Type any organisms isolated to determine whether they were related to each other (particularly to match isolates from the environment with isolates from human cases).

3.1.1 Microbiological investigation of clinical cases

The identification of the outbreak followed the notification to public health by medical microbiology of four inpatients, admitted to critical care in NHS Lothian over a four-day period. All had severe community-acquired pneumonia and were confirmed as positive for *Legionella pneumophila* serogroup 1 urinary antigen.

Following the identification of the outbreak over the weekend of 2 and 3 June 2012, further possible cases were identified by clinical suspicion on presentation to acute care, and through active case finding by clinicians and medical microbiologists.

Advice to clinicians on microbiological testing was issued by the medical microbiologist and public health department on Monday 4 June 2012 and updated on Friday 8 June 2012. Clinicians were advised to submit urine for detection of *Legionella pneumophila* serogroup 1 urinary antigen, sputum or bronchoalveolar lavage samples for molecular testing and culture, and paired sera for specific antibody detection.

3.1.2 Methodology for medical laboratory processing of diagnostic samples

Samples for microbiological testing were processed locally according to the NHS Lothian Edinburgh and Lothians Laboratory Medicine standard operating procedures. Detection of *Legionella pneumophila* serogroup 1 urinary antigen was performed using a rapid, specific immunochromatographic assay (BinaxNOW Legionella Urinary Antigen Test: Alere). An in-house multiplex real-time polymerase chain reaction (PCR) assay was used at the Royal Infirmary of Edinburgh molecular microbiology laboratory to detect *Legionella pneumophila* and *Legionella species* in

respiratory samples. Samples positive on PCR testing were referred to the Scottish Haemophilus Legionella Meningococcus and Pneumococcus Reference Laboratory for enrichment culture and identification and typing of isolates. Legionella cultures at the local laboratory were performed on Buffered Charcoal Yeast Extract agar and were incubated for seven to ten days at 35-37 °C.

Post-mortem samples were submitted by NHS Lothian forensic pathology department. A standardised proforma was used for `chain of evidence` specimen collection and processing. Legionella isolates cultured at the Royal Infirmary of Edinburgh laboratory from post-mortem samples from the patients who died were also referred to Scottish Haemophilus Legionella Meningococcus and Pneumococcus Reference Laboratory.

Samples from hospital inpatients and cases presenting at NHS Lothian unscheduled care departments were prioritised. There was a low positivity rate in samples from patients presenting to general practitioners. Once this pattern was clear, an algorithm was developed to advise GPs on the management of less unwell patients who did not require a sample to be submitted. This was issued to Lothian Unscheduled Care Services on Friday 8 June 2012 and to GP practices on Monday 11 June 2012.

3.1.3 Medical microbiology results

Sixty-four patients with pneumonia tested positive for *Legionella pneumophila* Sg1 by urinary antigen detection, or serology, or tested positive for *Legionella pneumophila* by lower respiratory sample PCR assay or serology.

Positive cultures were obtained from 15 of these patients and the causative organism was identified at the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory as *Legionella pneumophila* serogroup 1, monoclonal subtype Knoxville, sequence based type ST 191 (6, 10, 19, 28, 19, 4, 6).

3.1.4 Report from Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory

Twenty-two isolates from the culture positive cases were whole genome sequenced at the Roslin Institute, Edinburgh in September 2012. Whole genome sequencing involves reading the entire DNA sequence of the bacteria and sequence based typing involves identifying only seven genes (only seven small parts of the whole DNA sequence). All the isolates were previously identified at the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory as *Legionella pneumophila* Sg 1 Knoxville sequence based type ST 191 between June and July 2012. One of the cases had a dual infection and was infected with *Legionella pneumophila* Sg 1 Knoxville ST 191 and *Legionella pneumophila* Sg 10 ST 1418.

Apart from the *Legionella pneumophila* Sg 10, all the patient isolates were identified as ST 191 by sequence based typing.

3.1.5 Results of further genomic sequencing work on the human isolates

Using whole genome sequencing the human isolates could be further sub divided into four groups or clades.

Using a procedure described by Sánchez-Busó *et al* in 2014, this estimated that the individual groups (clades) had evolved separately about eight months prior to the outbreak (Sánchez-Busó 2014).

In four of the patients, two or more cultures were available from each. In three of the patients, the multiple cultures all fell into the same clade. However in one patient, two isolates from separate respiratory samples fell into two distinct clades indicating that patient had been infected with multiple clades of the outbreak strain.

The identification of four clades by whole genome sequencing makes it more difficult to identify a potential source as in theory there could have been four source sites or one site with multiple clades present. All the ST191 strains had probably diversified from a single clone through mutation, recombination and horizontal gene transfer within an environmental reservoir prior to release.

In addition, some patients were infected with multiple *Legionella pneumophila* subtypes, a finding that can affect the certainty of source attribution. Variation in the type IV secretion systems encoded by the different clades correlates with virulence in a moth (*Galleria mellonella)* model of infection *(*Harding 2012, 2013*)* and revealed variation in pathogenic potential among the outbreak strains (McAdam 2014).

All of the above work including methods and results was published in Genome Biology in 2014.
http://www.ncbi.nlm.nih.gov/pubmed/25370747

3.2 Epidemiological investigation

Timely and accurate epidemiological information provides evidence to inform outbreak control measures and to monitor their impact. The purpose of the epidemiological investigation was to determine the number and distribution of cases and identify any potential sources of the outbreak.

3.2.1 Objectives of the epidemiological investigation:

- To describe the epidemiology of the outbreak, with respect to people, place and time
- To generate hypotheses for testing potential source(s) of exposure
- To test these hypotheses
- To evaluate the effectiveness of remedial action.

The epidemiological investigation was undertaken jointly by a sub group of the Incident Management Team supported by experts from NHS Lothian, Health Protection Scotland, Public Health England and the Meteorological Office. The collection and processing of epidemiological data was undertaken by the NHS Lothian health protection team with support from Health Protection Scotland for data management and analyses. Specialised temporal and spatial modelling, support meteorological data and modelling were provided by the Bioterrorism and Emerging Disease Analysis, Microbial Risk Assessment Emergency Response Department, Public Health England, Porton Down and the Meteorological Office respectively. Potential cases outwith Lothian were interviewed by the relevant health boards' health protection teams (for cases within Scotland) or Public Health England (for potential cases that had returned to England).

Key steps undertaken in the epidemiological investigation included:

- Descriptive epidemiology to determine the clinical and case status, age/sex, spatial distribution and dates of onset of illness.
- Analytical epidemiology to determine the association between cases and their likely exposure to the organism. This was carried out in the first instance by modelling of wind directions and speeds over the affected area and in-depth analysis of diaries that cases completed describing their movements.
- Follow up analytical epidemiological studies to examine the frequency and severity of illness in the community and the differences between those who became unwell and those who did not.

3.2.2 Case ascertainment

Case ascertainment depended on the prompt alerting of clinicians in hospital and primary care and asking them to refer cases from the outbreak for investigation. Health Protection Scotland sent alerts to other health boards, asking them to identify cases of pneumonia that could be linked to south west Edinburgh. Cases identified within NHS Lothian were reported to the health protection team by clinicians in primary care or from local hospitals. Reported

cases were line-listed (added to a database of cases) and shared with the microbiology team on a daily basis with updated line-lists as required.

3.2.3 Cases outwith NHS Lothian

During the course of the investigation a number of cases and potential cases were reported from elsewhere. These were people who were resident outside of Lothian, or were NHS Lothian residents who became ill whilst outwith Lothian and were subsequently treated elsewhere.

Details of such cases were reported to Health Protection Scotland by the relevant health protection team in Scotland or via Public Health England for cases outwith Scotland. Health Protection Scotland established and maintained a line listing for cases outwith NHS Lothian. This was updated daily and shared with NHS Lothian health protection team so that the master line-listing was kept up to date. Trawling questionnaires were developed to generate hypotheses about the potential source of infection. These questionnaires were completed by the relevant health protection team and emailed or faxed securely to Health Protection Scotland, who incorporated them into the trawling questionnaire database and sent a copy of the questionnaire to the NHS Lothian health protection team.

3.2.4 Case definitions

The following case definitions are based on European Centre for Disease Control definitions which were agreed by the Incident Management Team to be used in this outbreak.

Confirmed Case
An individual with clinical or radiological evidence of community acquired pneumonia, microbiologically confirmed *Legionella pneumophila* by either a positive *Legionella pneumophila* culture, *Legionella pneumophila* Sg1 urinary antigen test or fourfold rise in specific serum antibody, disease onset on or after 14 May 2012 and who has links to south west Edinburgh.

Probable Case
An individual with clinical or radiological evidence of community acquired pneumonia, a positive *Legionella pneumophila* Polymerase Chain Reaction (PCR) on respiratory secretions, disease onset on or after 14 May 2012 and who has links to south west Edinburgh.

Possible Case
An individual with clinical or radiological evidence of community acquired pneumonia, disease onset on or after 14 May 2012 and who has links to south west Edinburgh.

3.2.5 Line-listings

A line-listing (database of individual cases) of all cases of Legionnaires' disease was maintained by NHS Lothian health protection team using a password protected spreadsheet on the secure server. This line listing contained basic demographic details of all cases, case status (confirmed, probable, possible), laboratory results, hospitalisation status and ward, some

details of symptoms, occupation and whether the case had a history of exposure to south west Edinburgh. The line-listing was updated on a daily basis and shared with Health Protection Scotland for the production of epidemic curves throughout the outbreak investigation. Not all data items were initially available for all cases. Prior to data from the trawling questionnaires becoming available, an anonymised extract from the line listing was shared with the Microbial Risk Assessment Emergency Response Group at Porton Down for the generation of preliminary spatial models.

3.2.6 Interviews

A member of NHS Lothian health protection team (or other nurses co-opted into the investigation) conducted detailed interviews and completed a trawling questionnaire with each case, or with a family member of any cases who were too ill to be interviewed. The trawling questionnaire had been developed by Health Protection Scotland for use in an earlier outbreak of Legionnaires' disease. This questionnaire captured information on demographics, onset, symptoms, hospitalisation, underlying medical conditions, occupation, work location(s), usual mode of transport and route to work and exposures to potential sources of infection including spas, showers and fountains. It also included a 14-day diary of places visited, routes and journeys in the fourteen days before onset, with each day divided into morning, afternoon and evening.

Completed trawling questionnaires were sent electronically by secure email to Health Protection Scotland. The postcodes were added for all locations mentioned in the questionnaires and entered in to a password protected database to provide baseline data for spatial analysis. Data validation was conducted on a number of levels:

- **Database design**
  The formats were set to match the nature of the data being recorded (for instance, text, number, date).
- **Data capture**
  Dropdown menus were used to limit input to permitted pre-defined values.
- **Post-capture**
  A compulsory data validation process was incorporated. Errors were displayed on a general validation screen and as part of the individual record maintenance facility. The list of validation checks was designed to strike a balance between identifying obvious errors (for instance date inconsistencies) and the need to record accurately what was on the questionnaire.

Anonymised datasets comprising demographics, onset, hospitalisation dates and locations recorded in the 14-day diaries were extracted from the database and shared with the Microbial Risk Assessment Group at Public Health England, Porton Down.

3.2.7 Results of descriptive and analytical epidemiology and modelling

Case numbers

In total, 92 cases were identified in the outbreak; 56 confirmed cases and 36 probable and possible cases. Seven of the confirmed cases and two in the probable and possible category were identified outwith NHS Lothian.

Table 5: Total number of confirmed, probable and possible cases, by location

	Confirmed	Probable	Possible	Totals
Lothian	**49**	**9**	**25**	**83**
Out of board	**7**	**1**	**1**	**9**
Total	**56**	**10**	**26**	**92**

Clear and concise case definitions are essential for the categorisation of cases. However, determining the final case status can require additional microbiological typing and epidemiological information, both of which take time to obtain and analyse. Once such data becomes available, this can result in the re-classification of some individuals. These final figures differ, therefore, from some of those reported during the outbreak investigation. This reflects the additional clinical and microbiological information that became available subsequent to the earlier reports.

More than 1,000 symptomatic people were tested and treated in primary care practices in the affected area between 14 May 2012 and the end of June 2012. It is likely some of these cases in the community had the non-pneumonic form of legionellosis. A post outbreak serosurveillance study investigated this hypothesis.

Deaths

Four deaths were reported among confirmed cases. The case fatality rate was 7.1% among confirmed cases and 4.3% amongst all cases. The fourth death has been classified as confirmed based on microbiological analysis by expert advisers to the Incident Management Team. The evidence from the specialist investigation (sequence based typing using a nested PCR) is consistent with the patient having been infected with the same strain of *Legionella pneumophila* as the other culture confirmed cases in this outbreak.

Dates of onset

The onset dates for the confirmed cases ranged from 17 May 2012 to 23 June 2012. It was difficult to get an accurate history of the onset of symptoms from the patient with the last date of onset so this date may not be precise.

Age and sex of cases

Among the 56 confirmed cases, 41 (73.2%) were male and 15 (26.8%) female. Their ages ranged from 32 to 85 years, mean 57.1 years, median 58.0 years. The mean age for males was 56.0 years and 60.1 years for females. This difference was not significant ($p = 0.269$). Probable and

possible cases were aged 20 to 88 years, mean 55.2 years, median 54.5 years.

Underlying medical conditions

Among the confirmed cases, 70% (39/56) had a serious underlying medical condition, 16% (9/56) were diabetic and 25% (14/56) had a condition or were on treatment that was likely to result in immunosuppression. Of the 56 confirmed cases, 44 (79%) were reported to be current smokers compared with 19% in the overall Lothian population and 9% (5/56) were reported to have excess alcohol consumption (based on a clinical assessment of alcohol consumption greater than 21 units per week for males and 14 units for females).

Figure 3: Onset date for confirmed cases of Legionnaires' disease.

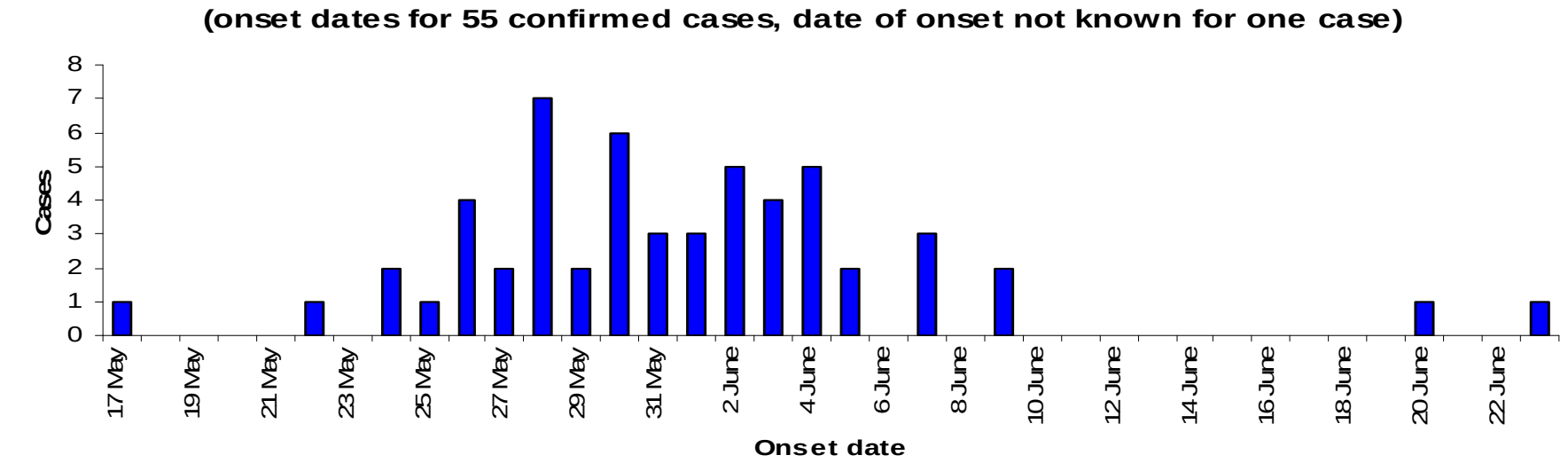


Figure 4: Age band and sex of confirmed cases of Legionnaires' disease.

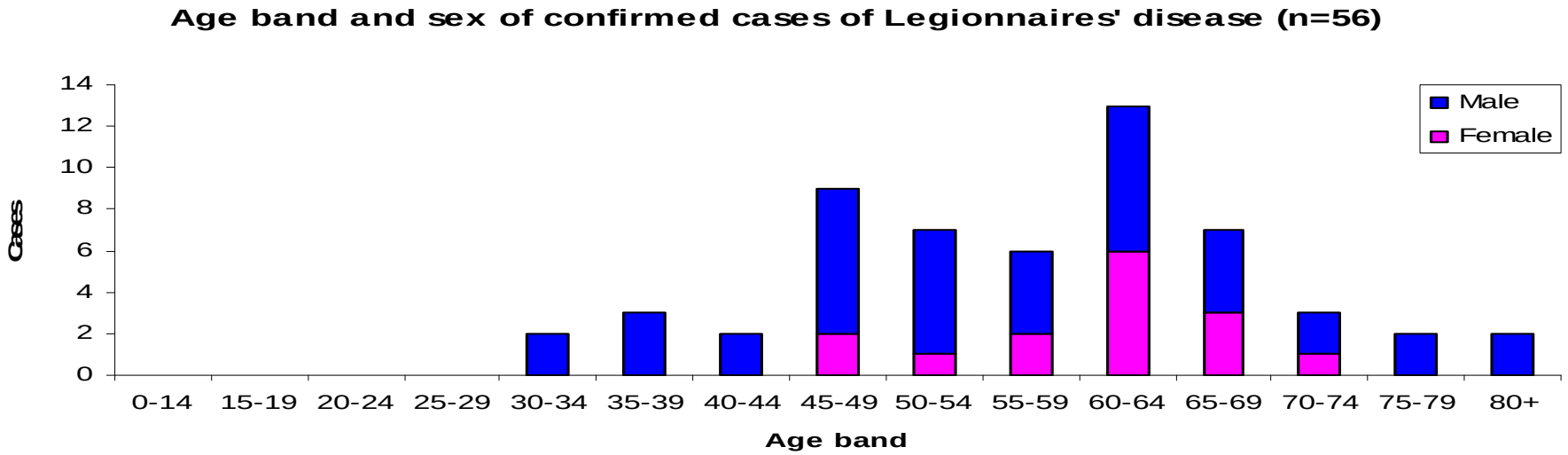
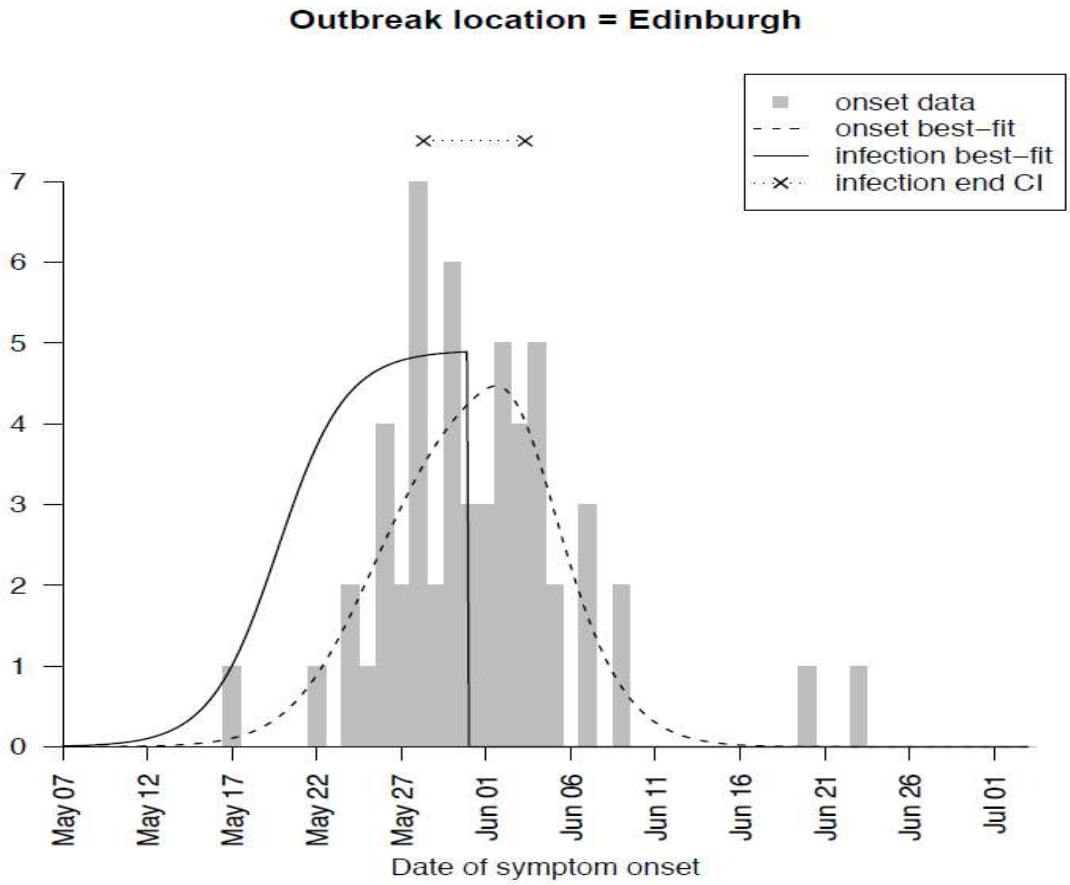


Figure 5: Modelling of date of onset of symptoms



3.3 Temporal and spatial modelling

A modelling group was established as a sub-group of the Incident Management Team. The group was chaired by Health Protection Scotland. It comprised NHS Lothian health protection team, Bioterrorism and the Emerging Disease Analysis Microbial Risk Assessment Emergency Response Group, Public Health England, Porton Down and the United Kingdom Meteorological Office.

The group met for the first time on Thursday 7 June 2012 and met on three further occasions with the final meeting on 26 June 2012.

Two data extracts from the line-listing and four data extracts from the trawling questionnaire database were sent to the Microbial Risk Assessment Emergency Response Group, Porton Down. The group has specialist expertise in the statistical modelling techniques used to help determine the likely release period and location of the source of the outbreak. The analysis included:

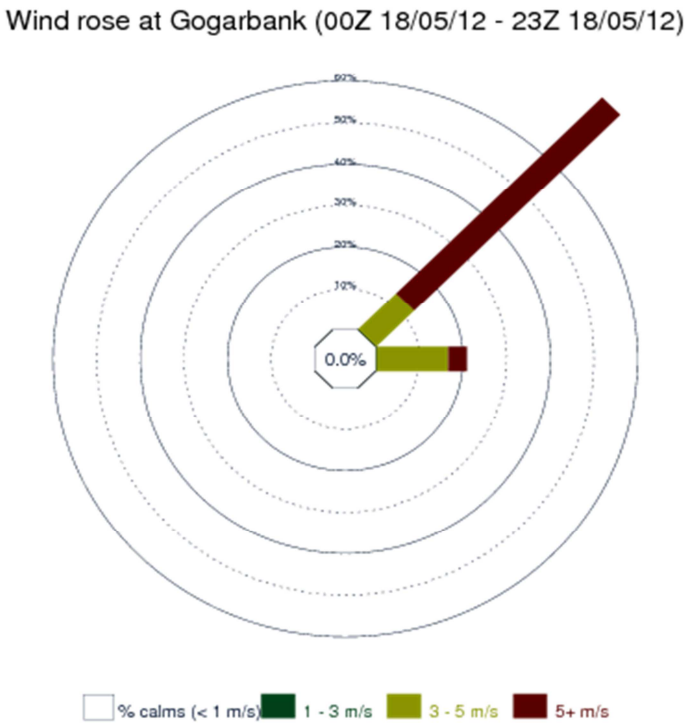
- Statistical calculation of the release window based on the epidemic curve
- Cluster analysis
- Attack ratio analysis

The Meteorological Office provided data on meteorological conditions including wind speed and direction for the affected area. Wind roses were generated using numerical weather prediction data for the coordinates of cooling tower locations in the

affected area. A wind rose (see Figure 6) is the usual way of showing the wind, direction and speed, over a period of time at a specific location. Wind direction is given as the direction from which the wind is coming (hence a south-westerly wind will transport airborne substances in a north-easterly direction). These wind roses were provided for cooling tower locations by day and by week for the likely exposure period.

The Meteorological Office used the Lagrangian dispersion model Numerical Atmospheric-dispersion Modelling Environment (NAME) driven by meteorology from the Meteorological Office's 1.5km resolution limited area Numerical Weather Predication model. They took the Microbial Risk Assessment Emergency Response Group's modelling work and used the Numerical Atmospheric-dispersion Modelling Environment model to investigate the geographical areas which contributed most significantly to the air that arrived at two separate areas which were identified as potential regions of infection.

Figure 6: Wind speed and direction



3.4 Results of temporal and spatial modelling

The release end date based on all cases submitted to the modelling group was estimated to be 30 May 2012 (confidence intervals 28 May 2012 to 2 June 2012). When the model was repeated using only confirmed cases of Legionnaires' disease the release end date was estimated to be 28 May 2012 (confidence intervals 25 May 2012 to 30 May 2012).

The cluster analysis was conducted using onset date, hospitalisation date, including and excluding unconfirmed cases. All the results suggested a single cluster of cases.

The attack ratio analysis using postcode geography is illustrated in Figure 7. The results suggest a source near or in the EH11 2 postcode sector in the Gorgie area of Edinburgh. The attack ratios appear to drop three orders of magnitude from zone A (which includes the putative source) radiating out to zone E, which is further away from the putative source (Figure 7).

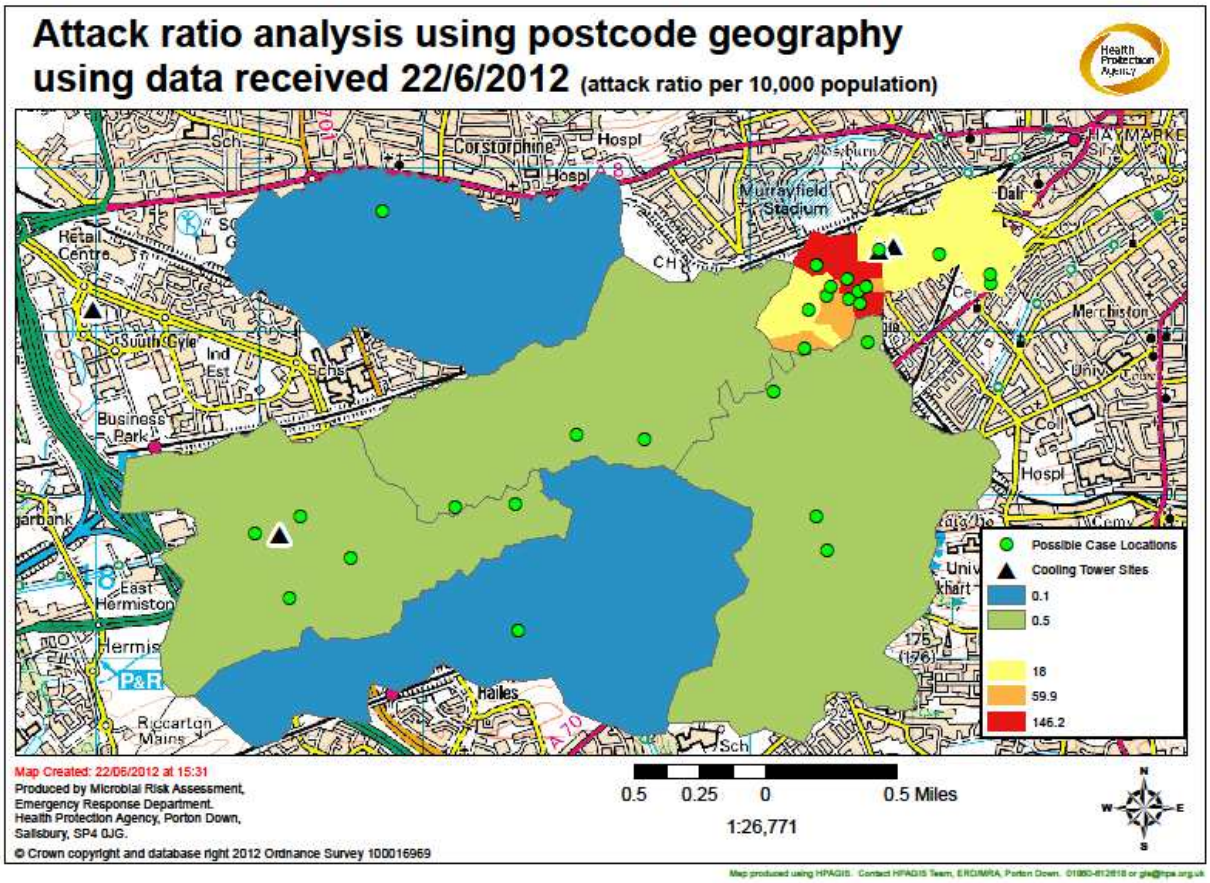
The Microbial Risk Assessment Response Group noted while such ‘radial’ attack analysis had been used elsewhere to consider Legionnaires’ disease outbreaks, this technique has not previously been applied to postcode geography.

The denominator populations for these models were taken from the National Population Database created by the Health and Safety Laboratory estimation of residential population. This will not reflect the true daytime population of the area, but is indicative for this purpose and a reasonable estimate.

The United Kingdom Meteorological Office modelling data supported the possibility that cooling towers in south west Edinburgh could be the source of Legionella in this outbreak.

Epidemiological evidence obtained through mapping of cases, analysis of travel diaries and complex meteorological analysis of wind speed and direction suggests a common outdoor airborne exposure occurred over south west Edinburgh with an estimated release end date of 30 May 2012 (confidence intervals - 28 May to 2 June 2012). This is consistent with the putative source of the airborne bacteria being from cooling towers located in south west Edinburgh.

Figure 7: Attack ratio analysis using postcode geography.



The NAME modelling was conducted separately for each infection region of interest. Each 'by day' plot represents the geographical areas that contributed to the air arriving at one of the infection regions on one day. The eight days of infection, 23 May to 30 May 2012, inclusive, were modelled. The black box (receptor area) represented, in each case, the area enclosing one of the infection regions of interest. The contours show the areas that contributed, to varying degrees, to the air that reached the receptor area on that day. For example in the plot for 23 May 2012 (covering the period BST 01.00 BST 23 May 2012 to 01.00 BST 24 May 2012), the area to the north east of the receptor area made the largest contribution to the air that passed through the receptor area on the 23 May 2015 (Figure 8).

This is entirely consistent with the wind rose information already presented. The plots presented here are a different way to visualise the wind rose data, combining both the wind speed and wind direction information. In addition they include a modelled estimate of the effect of the atmospheric turbulence, i.e. how a release from a source would be diluted as it travels and mixes downwind. The contours used denote the same level of contribution for different days for the same infection region.

Figure 9 represents the geographical area that contributed to the air arriving at each of the infection regions of interest over the total eight-day period (23 May 2012 to 30 May 2012, inclusive). This is a composite of the 'by day' plots showing the geographical region which had the highest contribution of air to the infection region.

In conclusion, the modelling shows that geographical regions that contributed to the air arriving at two infection regions. Any location within these geographical regions cannot be ruled out as a potential source. However, geographical regions which have a higher contribution can be thought of as being more likely. The modelling cannot prove a causal link between source and infection but may be helpful for other parts of the investigation.

Figure 8: An example of each of the 8 day air arrival impact in the area

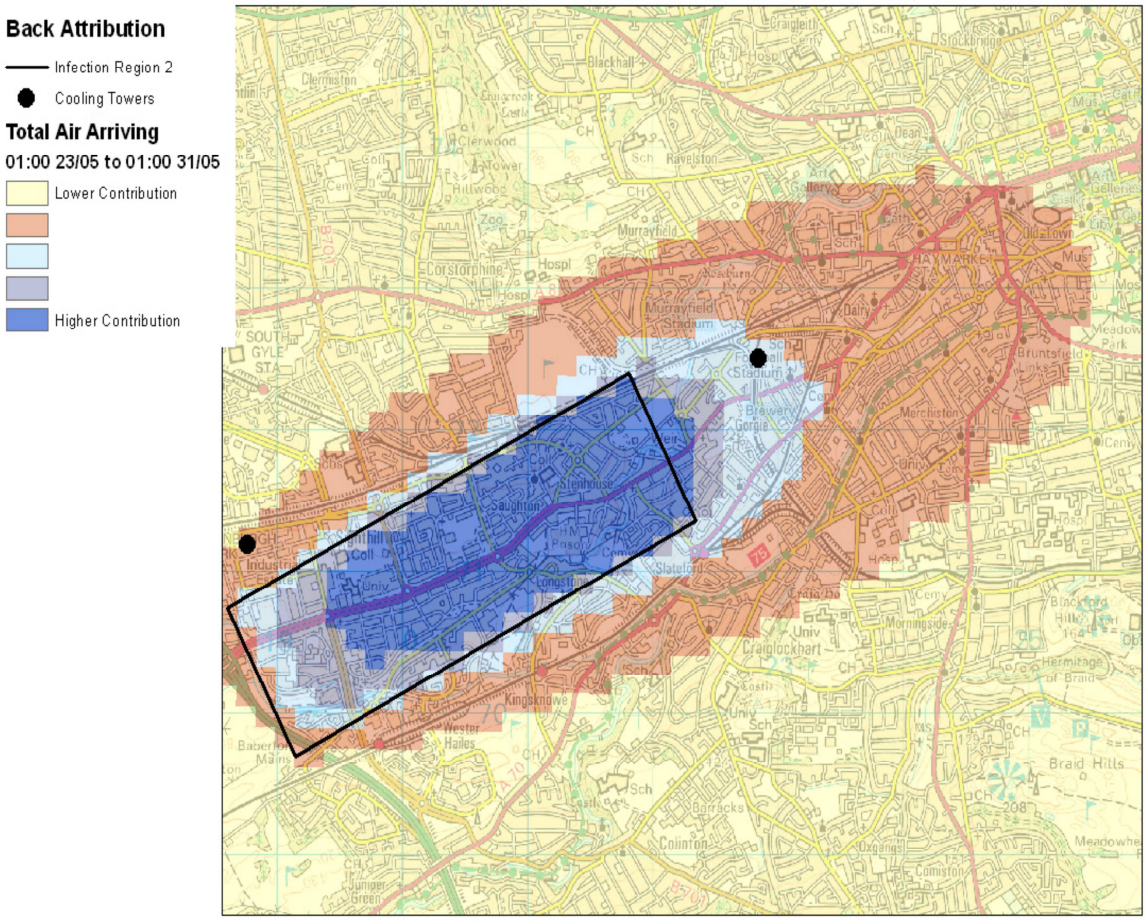
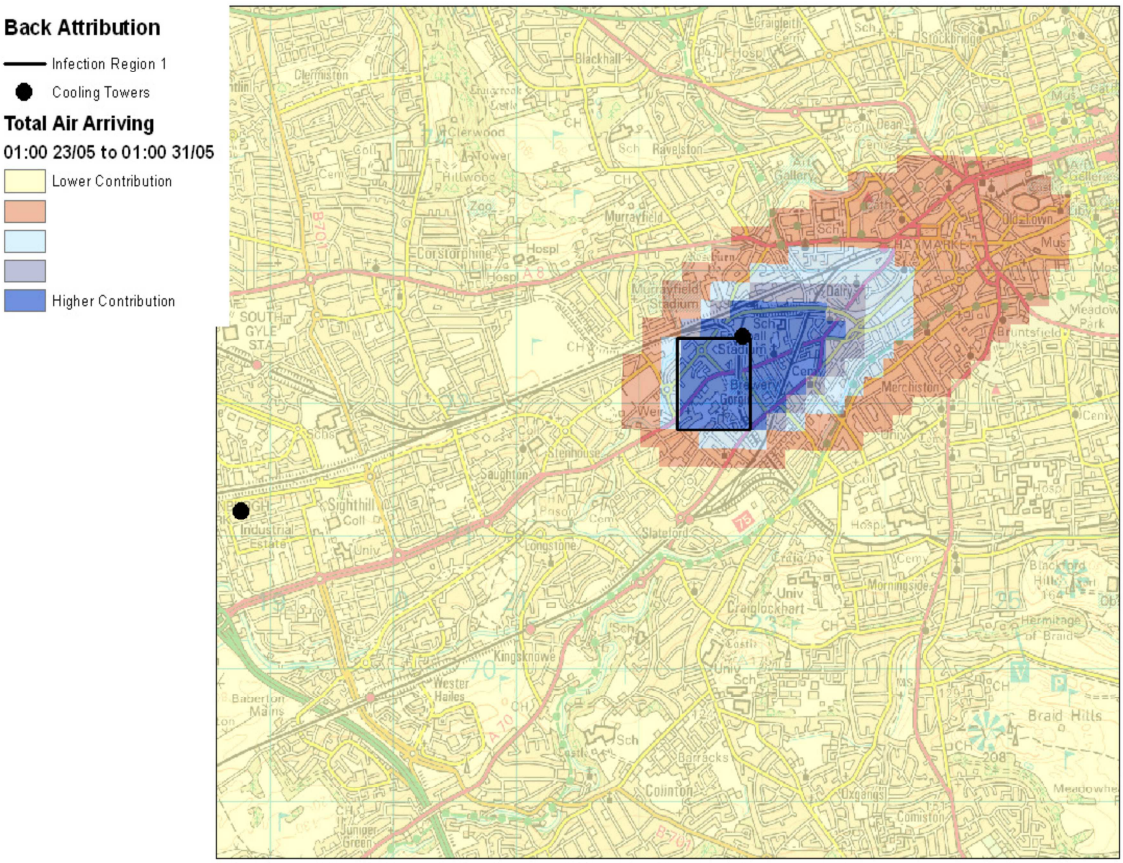


Figure 9: The composite of 8 day period air impact/infection in the area



3.5 Modelling the impact of the control measures

The impact of control measures is usually evaluated by considering cases with an onset date one incubation period after the implementation of control measures (i.e. cases likely to have been exposed after the control measures were implemented). There are uncertainties in this evaluation (Figure 10): the incubation period can be considered to be seven, 14 or 19 days and dates of onset for the first and last cases may not be accurate because the patients did not give a reliable history.

Taking the final release dates as the first control measures (Figure 11), the first shot dosing of the cooling towers by the site operators in the area was conducted on the night of 3 June 2012. When the incubation period for Legionnaires' disease is considered to be either seven, 14 or 19 days long, cases could be expected to occur up to 11, 18 and 23 June 2012 respectively.

Taking the final release dates from the calculation by the modelling group, 30 May 2012 would be the final release date (Figure 12). Applying incubations periods of seven, 14 and 19 days, cases could be expected to occur up to 6, 13 and 18 June 2012 respectively.

On reviewing case onset dates all but two of the cases have onset dates up to or before 9 June 2012, which falls within seven days after the impact of the first control measures would have been apparent and within 14 days of the estimated end of the release period from the modelling.

The latest date of onset for two confirmed cases was 20 and 23 June 2012. These fall within the 19 days after the first control measures were introduced but outside the 19-day limit if the modelled 30 May 2012 end release date is used.

The late onset of the two final cases makes it difficult to be sure of the impact of the control measures. It may be that the continuing release from the source(s) was controlled by a combination of the control measures put in place by the Incident Management Team and another unspecified event around 30 May 2012.

Overall, epidemiological analysis indicates that the locally coordinated public health, environmental and clinical response helped to prevent ongoing exposure of the population and mitigated associated mortality and morbidity.

Figure 10: Incubation periods of 7, 14 and 19 days after implementation of first control measures.

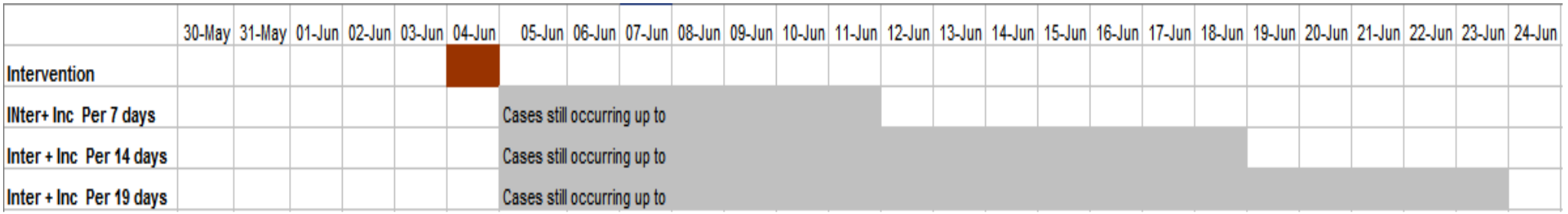


Figure 11: Incubation periods of 7, 14 and 19 days after implementation of first control measures.

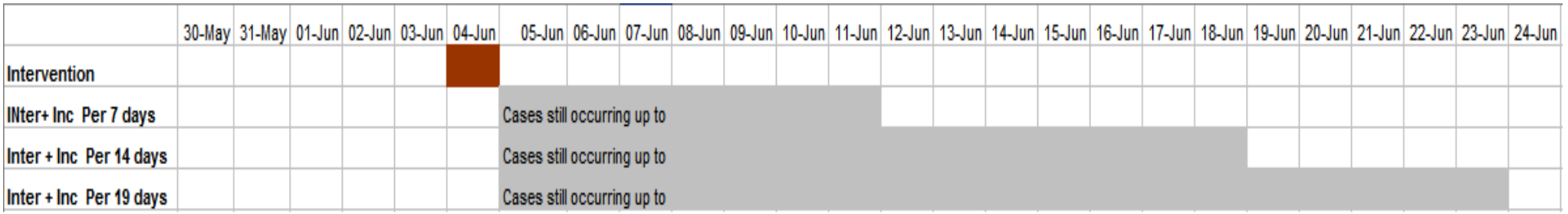
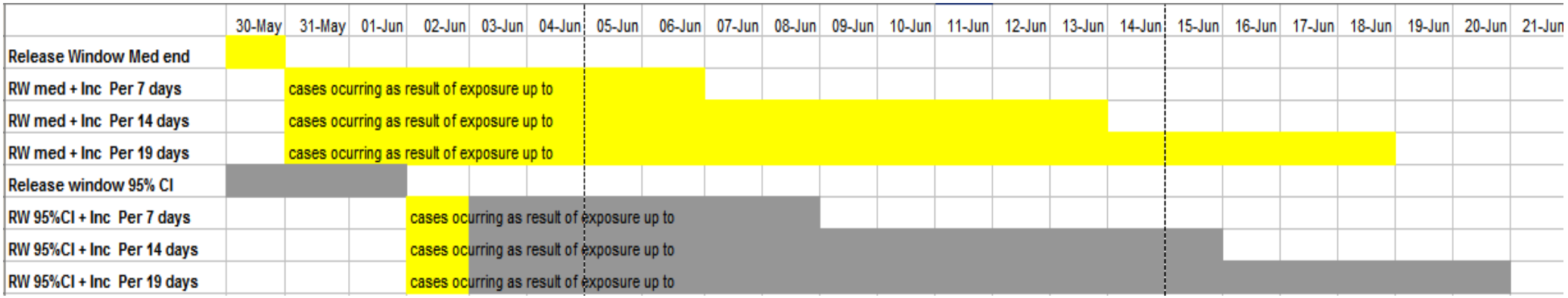


Figure 12: Incubation periods of 7, 14 and 19 days after estimated end of release period based on modelling for all cases, and the 95% confidence intervals for the end of the release period.



3.6 Environmental investigation

The purpose of the environmental investigation was:

- to trace the likely source of the outbreak as quickly as possible
- to identify how exposure could have taken place (especially with regard to Legionella growth and release of an aerosol);
- to identify if any implicated organisms were present at the source;
- to evaluate if control measures, for example disinfection (such as the shot dosing undertaken on the 3 June 2012 on a precautionary basis), had been elective in reducing bacterial content below medicated levels;
- to determine whether any breach of legal statute had taken place (especially the Health and Safety at Work etc. Act).

These processes were undertaken by the City of Edinburgh Council and the Health and Safety Executive. The Health and Safety Executive was able to provide input from its specialist inspectors and biological agents unit who had experience of other UK outbreaks including a recent major outbreak in Wales.

From the outset, the City of Edinburgh Council provided a comprehensive and timely response. The senior environmental health manager, and scientific services manager , both members of the Incident Management Team, provided technical advice at all the Incident Management Team meetings and an incident room was set up to manage the response. Close collaboration with the team was essential to ensure prompt action to control potential sources as soon as the outbreak was detected, and to conduct precautionary investigations into potential sources as the outbreak progressed. During the investigation, duty holders at all the sites under investigation cooperated with council officers at all times.

Environmental investigations included collection and testing of environmental samples and inspections by City of Edinburgh Council Environmental Health and Scientific Services officers and by specialist occupational hygiene Inspectors of the Health and Safety Executive. The aim was to identify the source of the outbreak strain of Legionella in order to direct and evaluate control measures.

All investigatory sampling was carried out by City of Edinburgh Council Environmental Health and Scientific Services staff as directed by the Incident Management Team. Environmental samples were submitted for examination and testing to the City of Edinburgh Council Scientific Services laboratory. Further testing and confirmation was performed by the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory and by Public Health England’s Legionella Reference Laboratory at Colindale, London. The Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory had clinical pathology accreditation only at the time of the outbreak and were not accredited for environmental testing but offered technical assistance in this outbreak.

The City of Edinburgh Council Scientific Services laboratory is authorised by Scottish Health Protection Network to perform accredited testing of environmental samples during a Legionella incident or outbreak. The laboratory is accredited to ISO 17025:2005 by the United Kingdom Accreditation Service (UKAS) for the isolation and identification of Legionella from water samples using culture.

3.6.1 Methods of Microbiological sampling and testing of premises

During the investigation a total of 96 samples from nine premises identified as potential external sources of Legionella were examined microbiologically. A range of chemical testing was also carried out to determine if cooling tower disinfection regimes were satisfactory. The following documents were used to guide sampling policy: The determination of Legionella bacteria in waters and other environmental samples (2005) Part 1 Rationale of surveying and sampling, BS 7592:2008; Sampling for Legionella Bacteria in Water Systems Approved Code of Practice; and Health Protection Agency Sampling of households for *Legionella species*.

On the evening of Sunday 3 June 2012, three officers from the City of Edinburgh Council Environmental Health and Scientific Services visited three premises in south west Edinburgh listed on the cooling tower register (see Table 6 Premise 1, 2,&3). Although it was a Sunday night, two of the sites were in operation (Premise 1, 2). As instructed by the Incident Management Team, the opportunity to take samples in advance of shot dosing was taken. These samples were taken from the operational towers by the Environmental Health and Scientific Services sampling team in conjunction with the plant operators. This action was taken by City of Edinburgh Council officers using their powers under The Public Health etc. (Scotland) Act 2008 to investigate public health incidents. A total of 16 samples were taken from the two operational premises (Premise 1 & 2) and transported that same night to the City of Edinburgh Council Scientific Services for examination. No samples were taken from Premise 3 as the cooling tower had been decommissioned on 7 May 2012.

On Monday 4 June 2012, a further two premises with cooling towers were visited. (Premise 4 & 5) These premises were at a greater distance from the centre of the outbreak and six samples were taken for examination.

Information from plume modelling suggested that under optimum conditions Legionella might be able to disperse over a distance of six kilometres. As a precaution, on Wednesday 6 June 2012, two further premises (Premise 6 &7) located upwind of the affected area were visited and three samples were taken. Two more premises (Premise 8 & 9) which did not have cooling towers, but which might theoretically have been able to generate a small external plume containing Legionella were visited on 7 and 14 June 2012.

Of the nine premises considered potential sources of the Legionella plume, six required additional visits to take samples to ensure the water systems were under adequate control to prevent seeding or reseeding of the cooling tower by Legionella in case any source was still active. Three premises were visited at least three times or more to take additional samples. This was due to failures of some test parameters to meet the Health and Safety Executive Approved Code of Practice L8.

In addition to the source investigation, sampling of the four homes used by the three patients with Legionella who died, and who were initially linked to the outbreak, was carried out at the request of the police. A total of 14 water and swab samples were taken.

3.6.2 Testing

The City of Edinburgh Council Scientific Services used Real Time PCR (RT-PCR) to test water samples from sites under investigation.

Between June and September 2012, the Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory received water and biofilm samples from Edinburgh Scientific Services. These samples had been taken from the sites in south west Edinburgh.

The Reference Laboratory also conducted 16S rDNA PCR ELISA to detect Legionella and *Legionella pneumophila* specific DNA in environmental samples. However, the instructions for use indicate that this assay was only validated by the manufacturer for clinical samples not environmental samples. The samples were also cultured onto Oxoid™ GVPC and MWY pre-poured media formulated for use on environmental samples.

Extracts of DNA isolated from water samples were also sent to Public Health England's Legionella Reference Laboratory at Colindale, London for further evaluation.

The technique of amoebal co-cultivation was utilised by colleagues at the University of Strathclyde to determine if any viable (living) Legionella were present in some of the water samples which had given positive Legionella DNA results even if Legionella could not be cultured on the best culture media available.

3.6.3 Results: Detection of *Legionella species*

By 8pm on Monday 4 June 2012 Real Time PCR (RT-PCR) data was available from the City of Edinburgh Council Scientific Services. This and other data is summarised in Table 6.

<u>Premise 1</u>

One cooling tower water sample (CT2) taken on 3 June 2012 was weakly positive for *Legionella species* by RT-PCR. The Scottish Haemophilus, Legionella, Meningococcus and Pneumococcus Reference Laboratory used nested Sequence Based Typing PCR

(nested SBT) to confirm the presence of DNA consistent with *Legionella pneumophila.*

A sequence based type partial profile of (6,0,0,28,0,0,0) was found for the sample from a cooling tower (CT2) taken on 3 June 2012. When comparing the partial profile with the clinical DNA isolated from patients, which had a SBT profile ST191 (6,10,19,28,19,4,6), only two positions (Position 1&4) were the same as from the patients' DNA.

A further two samples (including a biofilm sample) gave partial nested SBT profiles of ST(6,0,0,0,0,0,0) and direct SBT(0,0,0,0,0,4,0). An environmental swab from a tower gave a *Legionella pneumophila* SBT profile ST (7,0,0,0,0,4,3). Separately a water sample taken on 20 June 2012 from a cooling tower was found to contain 840 cfu per litre *Legionella pneumophila* Sg6. The Reference Laboratory confirmed the isolate to be *Legionella pneumophila* Sg 6 ST 114 (3,6,1,6,14,11,9), which was not the same as the outbreak strain. Nested sequence based typing is normally only used on clinical samples, but was utilised on environmental samples in this exceptional instance to determine if a link could be made with clinical samples from patients. No link was made during this testing. It is not unusual to find DNA in water systems and it was not detected by culture in any of the 3 June samples.

Premises 2 & 5

One tower in Premise 2 and one tower in Premise 5 gave positive results for *Legionella pneumophila* DNA using nested sequence based typing with profile ST (3,0,0,0,0,0,0).

Remaining premises

There were no positive DNA results for *Legionella species* in the other premises tested.

Home samples

Samples were taken from the homes of the deceased and City of Edinburgh Council homes for older people. Legionella was not detected in any of the 16 samples taken from the four homes used by the three patients with Legionella who died and who were initially linked to the outbreak (later confirmed as four deaths), nor in any City of Edinburgh Council homes for elderly people that were tested for reassurance purposes.

3.6.4 Assessment of disinfection levels

Six of the nine sites required follow up visits to ensure adequate management of the Legionella risk. After re-inspection visits, a number of samples were taken to test whether sites were using the recommended levels of disinfection as set out by the Health and Safety Executive. Samples were taken when towers were active and at random times during the disinfectant dosing cycle to ensure compliance and to trace the source.

Samples from four of the nine potential source sites (Premises 1,2,4 &5) were suspected to have levels of disinfectant below that expected when compared to the requirements of the Health and Safety Executive (The control of Legionella bacteria in water systems Approved Code of Practice and guidance L8).

Potential reasons for the suspected disinfectant test failures included corroded water system tanks, manual top up dosing of cooling towers and broken disinfectant dosing solenoids which may have resulted in inadequate control of the disinfectant dosing. Two of the cooling towers (Premise 1) which had previously been cleaned by contractors and had been reported to be ready for reinstatement were found to contain rust, metal fragments and biofilm in hard to reach areas. One premise was visited on nine occasions to check control measures were adequate to ensure biofilm removal from the inside of the cooling towers had been effective.

3.6.5 Summary

The investigation was not able to verify through culture or PCR the presence of the strain of Legionella associated with this outbreak in any of the environmental samples collected from the nine potential source sites, the homes of the initial three deceased cases or the sampled City of Edinburgh Council homes for elderly people.

However, samples from four of the nine potential source sites were found to have levels of disinfectant below that expected when compared to the requirements of the Health and Safety Executive guidance document ‘Legionnaires’ Disease: The control of Legionella bacteria in water systems. Approved Code of Practice and guidance. Third edition 2000.

Table 6: Summary of Environmental sampling test data

Premises	Name and address	Visits	Samples Taken	Edinburgh Scientific Services Comments	Scottish Legionella Reference Laboratory, Department of Microbiology
1	**Macfarlan Smith Ltd.** 10 Wheatfield Road, Edinburgh, EH11 2QA	9	49	Dates of site visits 3 June 2012 6 June 2012 8 June 2012 10 June 2012 20 June 2012 28 June 2012 5 July 2012 24 August 2012 7 September 2012 15 of 30 samples taken suspected of being below ACOP L8 recommended levels for appropriate disinfection. One sample (CT2) had slightly elevated ACCs and Legionella DNA was detected by RT-PCR. This was confirmed by the reference laboratory. Further site visits due to unsatisfactory disinfectant levels were required to check compliance with ACOP L8. Legionella not detected by culture method in any samples taken on 3 or 6 June 2012. Premises operator took some towers off line to allow cleaning. *Legionella pneumophila* Sg 2-14 was cultured from a sample taken from one tower on 20 June 2012. This was confirmed as *Legionella pneumophila sg6* by reference laboratory – not the outbreak strain. Legionella was not detected by culture method in any biofilm samples taken. Samples of biofilm and rust from the sumps were recovered in August and September. No Legionella was cultured.	Water from three towers sampled on 3 June 2012 were positive for Lp DNA using nested SBT with profiles ST (6,0,0,28,0,0,0) ST (6,0,0,0,0,0,0) ST (0,0,0,28,0,0,0) Swab from one tower sampled 3 June 2012 gave nested SBT profile ST (7,0,0,0,0,4,3). Water from one tower sampled 20 June 2012 gave positive for Lp Sg6 DNA with profile ST(3,6,1,6,14,11,9) Biofilm from one tower sampled 7 Sept 2012 gave direct SBT profile ST (0,0,0,0,0,4,0)
2	**North British Distillery** 9 Wheatfield Road, Edinburgh EH11 2PX	4	15	Date of site visits 3 June 2012 7 June 2012 20 June 2012 5 July 2012 6 of 13 samples taken were suspected of being below ACOP L8 recommended levels for appropriate disinfection. ACCs were elevated in 2 of 13 samples. Premises operator took some towers off line to allow cleaning. Legionella was not detected by culture or RT-PCR in two swab samples or 7 water samples.	Positive in one tower for (CT1) for Lp DNA using nested SBT with profile ST (3,0,0,0,0,0,0)
3	**Murrayfield Ice Rink** Riversdale Crescent, Edinburgh EH12 5XN	1	0	Date of site visit 3 June 2012. Closed for refurbishment.	-

4	**Aegon** Edinburgh Park, Edinburgh, EH12 9SE	2	6	Date of site visits 4 June 2012 6 June 2012 3 of 6 samples taken were suspected of being below ACOP L8 recommended levels for appropriate disinfection. ACCs results were satisfactory.	-
5	**Burton's Biscuits** 34 Bankhead Place, Edinburgh, Midlothian EH11 4HN	5	13	Dates of site visits 4 June 2012 6 June 2012 8 June 2012 20 June 2012 28 June 2012 9 of 13 samples taken were suspected of being below ACOP L8 recommended levels for appropriate disinfection. ACCs were elevated in 5 of 13 samples. Premises operator took towers off line to allow cleaning. Sample taken 20 June 2012 had 0.1mg/L free chlorine	Positive in one tower for Lp DNA using nested SBT with profile ST (3,0,0,0,0,0,0)
6	**Selex** Crewe Toll, 2 Crew Road North, Edinburgh EH5 2XS	1	3	Date of site visit 6 June 2012 2 samples taken with all test parameters satisfactory to ACOP L8.	-
7	**National Museum of Scotland** Chambers Street, Edinburgh EH1 1JF	2	8	Dates of site visit 6 June 2012 11 June 2012 8 samples taken with all test parameters satisfactory to ACOP L8. Revisit required due to discovery of potential additional sampling points	-
8	**Tynecastle** McLeod Street, Edinburgh EH11 2NL	2	4	Dates of site visits 7 June 2012 11 June 2012 4 samples taken with all test parameters satisfactory to ACOP L8. Revisit required due to discovery of additional water tank and sampling points which resulted in enforcement action being taken.	-
9	**Trainwash** Haymarket LMD EH11 2JD	1	6	Date of site visit 14 June 2014 Sump wash water had elevated ACCs and wash brushes had algal growth. Legionella not detected by culture method.	-

Key to abbreviations used in this table

ACC =aerobic colony counts
ACOP L8 =Legionnaires' Disease. The control of Legionella bacteria in water systems. Health and Safety Executive
Lp =*Legionella pneumophila*
Sg =serogroup
mg/L =milligrammes per litre
RT-PCR =Real Time Polymerase Chain Reaction
ST =Sequence type
SBT=Sequence based typing

3.6.6 Report from City of Edinburgh Council Environmental Health and Scientific Services

At the first Incident Management Team meeting, it was noted that while enforcement of occupational health and safety legislation could be undertaken by either the Health and Safety Executive or City of Edinburgh Council, depending on the nature of the premises listed on the cooling towers register. The meeting agreed that environmental health personnel were to use their powers under the Public Health etc. (Scotland) Act 2008 to carry out public health investigations. The priority was to visit the two premises (Premises 1 and 2) closest to the known cases of Legionnaires' disease in the community. Between these two premises there were 10 cooling towers and/or evaporative condensers registered with the City of Edinburgh Council. A further location was visited that evening (Premise 3) where it was found the cooling tower had been fully decommissioned. This decommissioning was subsequently confirmed as having taken place on 7 May 2012.

Following the Incident Management Team meeting of 3 June 2012, environmental health officers and Edinburgh Scientific Services staff visited both premises and obtained water samples for chemical and microbiological analysis from within the sumps of the towers. This was done prior to shot dosing with chemical disinfectant. The following day, two further locations in West Edinburgh (Premises 4 and 5), containing a total of six cooling towers were visited. Water samples were obtained and the towers subsequently shot dosed. On the 6 June 2012 another two locations (Premises 6 and 7), which were both within the 6 kilometres distance from the centre of the cluster of Legionnaires' disease cases in south west Edinburgh were visited, samples were obtained and the cooling towers were shot dosed (note: six kilometres is the postulated maximum distance of plume spread) (HPN 2014). Table 6 shows the nine locations where samples were taken.

At the request of the Incident Management Team, a number of repeat visits were made by environmental health officers and staff from Edinburgh scientific services to five of the six premises on the cooling towers and evaporative condensers register in the area of investigation. Premises 1, 2 and 5 received several repeat visits to obtain further samples for microbiological and chemical testing until the Incident Management Team was satisfied the Legionella risks at each of the three sites were under control. At one location (Premise 1) these visits continued after the outbreak was considered over on 17 July 2012.

Depending on enforcement responsibility, either the Health and Safety Executive or The City of Edinburgh Council inspectors (often accompanied by Health and Safety Executive specialist inspectors in occupational hygiene) sought detailed additional information from duty holders at each of the six locations on such issues as the maintenance regime, system design, testing, training etc. These visits were undertaken to establish whether the duty holders were meeting their obligations under The Control of Legionella Bacteria in Water Systems. Approved Code of Practice and Guidance (L8 Third edition Health and Safety Executive 2000). The duty holders at all locations were fully cooperative.

At Premise 8 where a sprinkler system was in use, the City of Edinburgh Council served five improvement notices and several additional visits were

made by environmental health staff, accompanied by a Health and Safety Executive occupational hygiene specialist. These visits were undertaken to ensure risks associated with water distribution systems at the location were adequately controlled.

At Premise 7 an improvement notice was served requiring responsible persons to be trained. All of the improvement notices served by City of Edinburgh Council environmental health were subsequently complied with by the duty holders.

As part of the outbreak investigation a further 32 locations were visited. These premises were identified from the Environmental Health database and were those where there was an actual or potential risk of water being aerosolised into the external environment. These included golf courses, car washes, bowling greens, playing fields, other recreational facilities etc. Following assessment of the risks with the duty holders at all of the 32 locations, no further samples were taken as in each case officers were satisfied that there were no risks or that the risks were adequately controlled.

3.6.7 Report from the Health and Safety Executive

A principal inspector from the Health and Safety Executive joined the first Incident Management Team meeting and the Health and Safety Executive worked as part of the multidisciplinary Incident Management Team throughout the outbreak. There was close collaboration between the Health and Safety Executive and City of Edinburgh Council Environmental Health and Scientific Services. This was essential to ensure reliable and comprehensive information was collected and it was presented to the Incident Management Team in such a way it could readily be interpreted and used as the basis for action, advice and risk assessment. The Health and Safety Executive has national expertise on Legionnaires' outbreaks throughout Great Britain. The Health and Safety Executive inspectors, both generalist and specialist, were involved in the Incident Management Team from the outset, and were able to contribute their experiences from recent outbreaks in Wales and the Midlands, to assist the Incident Management Team in its decision making. In particular, the Health and Safety Executive was able to advise the Incident Management Team from the outset that it may not be possible to prove the source of the outbreak. Both the Incident Management Team and the Cabinet Secretary for Health made it clear to the media and public that the source of the outbreak may not be found.

This was a major investigation by the Health and Safety Executive involving multiple sites and duty holders, water treatment companies, contractors and sub-contractors. It has proven to be one of the most complex Legionnaires' disease outbreaks the Health and Safety Executive has investigated to date, and required the Health and Safety Executive to draw on specialist staff from across the Health and Safety Executive as well as bringing in an independent external world Legionella expert.

The Health and Safety Executive also fed findings into its Legionella Committee, which was at that time considering a report by the Health and Safety Laboratory reviewing the causes of outbreaks in the UK over the

previous 10 years. As a result two industry-wide safety alerts were issued by the Health and Safety Executive.

Health and Safety Executive inspections were undertaken by a team of inspectors, supported by specialist colleagues to provide advice on technical issues. Details of what was assessed at these inspections are set out in Box 1. The Health and Safety Executive assessed compliance with the Health and Safety etc. at Work Act 1974 and its associated regulations to determine whether adequate arrangements were in place for the management of Legionella risks. Compliance was assessed against the requirements of the Control of Substances Hazardous to Health (COSHH) Regulations 2002 and the practical guidance given in the Approved Code of Practice 'The control of Legionella bacteria in water systems. Approved code of practice & guidance'.

This was supported by enforcement action under the Health and Safety at Work etc. Act 1974 as determined by Health and Safety Executive's Enforcement Policy Statement and Enforcement Management Model.

Advice was given by the Health and Safety Executive where corrective action was required to decontaminate water systems and to achieve adequate control. Formal reports were issued, providing advice and making recommendations to a number of duty holders. Voluntary cessation of the operation of a number of cooling towers in the area was attained by the Health and Safety Executive from 7 June 2012. Three improvement notices were served between 8 and 12 June 2012 requiring improvements in the management of cooling towers and hot and cold water systems at Premises 1 and 2. A further three notices were served later in the investigation on companies involved with the management of cooling towers and hot and cold water systems at Premises 1 and 2. The relevant duty holders complied with all the requirements of the six improvement notices. All such actions and responses by the Health and Safety Executive were undertaken with a view to ensuring systems and Legionella risks were being appropriately managed. Follow up visits and actions were made to ensure compliance with formal requirements.

Information on enforcement notices issued by the Health and Safety Executive can be viewed at http://www.hse.gov.uk/notices/ .

Table 7: Summary details of the Health and Safety Executive Inspections

The inspections included checks of the following against the relevant standards:

- The overall adequacy of the written risk assessment
- Management responsibilities and arrangements, including training and competencies of responsible person(s)
- The schematic of the water system to ensure the whole system e.g. pipe work, pumps, machinery etc. was included
- Routine cleaning and disinfection regimes
- Water treatment procedures and water monitoring results
- Responsibilities of the site occupier/duty holder and the water treatment contractor and their communication arrangements
- An initial assessment of the competence of the water treatment contractor;
- Maintenance schedules and procedures
- Routine system monitoring and inspection procedures plus results
- Start-up and shut-down procedures

All inspections included a physical examination of the cooling system plus its associated pipe work and any other relevant equipment.

Health and Safety Executive inspectors and City of Edinburgh Council Environmental Health and Scientific Services officers inspected around 60 premises in and around south west Edinburgh. One site enforced by the Office of the Rail Regulator was also visited. Health and Safety Executive specialist inspectors provided technical advice. The sites selected were prioritised on the basis of emerging epidemiological evidence and the risk ranking contained in the Guidelines on Management of Legionella Outbreaks and Clusters in the Community. Inspections focused first on premises with registered cooling towers and evaporative condensers, as potentially being the highest risk. No unregistered towers or condensers were found. Staff then visited medium risk sites with hot and cold water systems.

An investigation by the Health and Safety Executive and Lothian and Borders Police (now Police Scotland) into the circumstances of the four deaths from Legionnaires' disease was undertaken under the direction of the specialist Health and Safety Division of the Crown Office and Procurator Fiscal Service. As it has not been possible to identify the source of the Legionella bacteria which resulted in the death of four people, Crown Counsel has concluded that there is insufficient evidence to prosecute any person or organisation for the deaths.

As a result of the Health and Safety Executive and Lothian and Borders Police investigation, a number of reports were submitted by the Health and Safety Executive to the Crown Office for breaches of health and safety regulations unrelated to the deaths of the four people. Crown Counsel has instructed a number of companies be prosecuted on indictment in relation to those breaches.

Prior to this outbreak, in September 2011, the Health and Safety Executive's Legionella Committee asked the Health & Safety Laboratory to carry out a review of the causes of outbreaks in Great Britain over the last ten years. The Health and Safety Laboratory report identified common failings in control (http://www.hse.gov.uk/research/hsl_pdf/2012/hex1207.pdf).
Two safety notices were issued alerting companies to the key aspects of the proper management of the risks from Legionella; none of the advice contained in these safety notices is new.
http://www.hse.gov.uk/safetybulletins/coolingtowers.htm
http://www.hse.gov.uk/safetybulletins/legionella2.htm

The Health and Safety Executive in Scotland successfully piloted the national cooling tower inspection initiative in Glasgow with City of Glasgow Council environmental health officers in December 2012, which resulted in the initiative being rolled out across Great Britain in April 2013.

Based on the Health & Safety Laboratory analysis, and following the successful pilot initiative, the Health and Safety Executive, in consultation with UK councils, developed a cooling tower inspection initiative to address Legionella risks. The inspection initiative included compliance checks focused on sites, prioritised by population density, where the water system (i.e. cooling towers/evaporative condensers, spa pools and hot and cold water systems) posed a significant Legionella risk if not properly managed. In addition there was work with sector stakeholders and water treatment companies with the aim of driving up standards in the industry.

Between April 2013 and March 2014, the Health and Safety Executive undertook 1,906 proactive inspections at sites operating cooling towers and local authorities undertook 576 proactive inspections. The Health and Safety Executive identified significant issues at 625 sites and served 400 improvement notices and 11 prohibition notices. Local authorities throughout the UK identified significant issues at 112 sites and served 11 improvement notices. The full details of the inspection initiative are at the following link:
http://www.hse.gov.uk/aboutus/meetings/hseboard/2015/250315/pmarb1527.pdf.

4 Follow up Analytical Epidemiological investigations

4.1 Prevalence studies

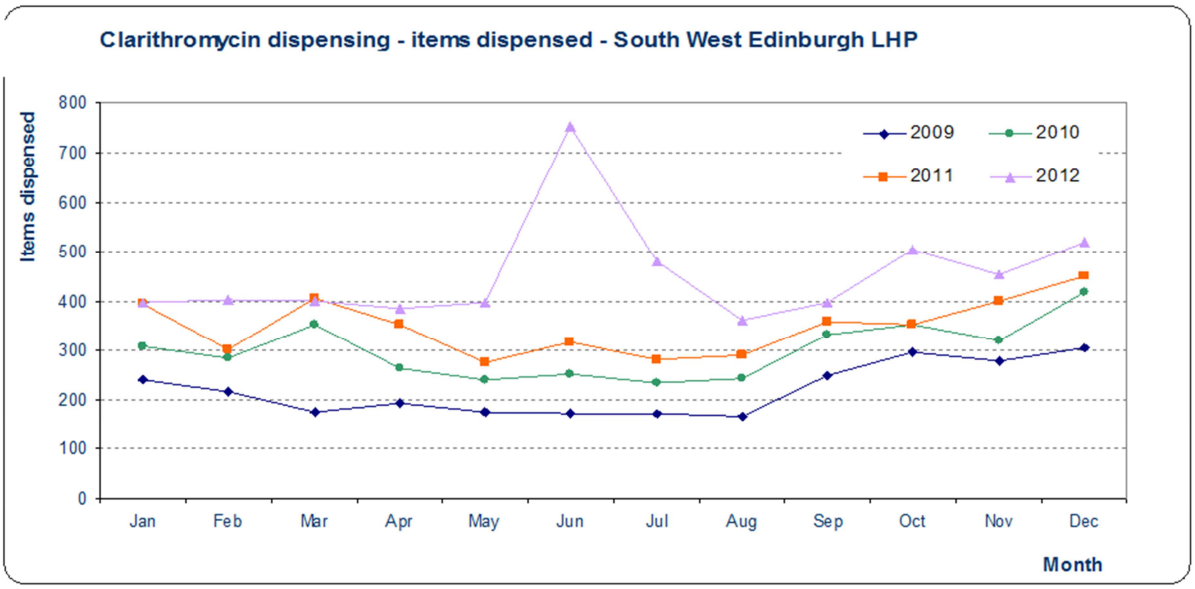
Symptoms and prescribing

Human exposure to aerosolised Legionella bacteria can lead to a spectrum from mild to severe illness. Symptomatic infection without pneumonia is known as Pontiac fever. During the outbreak more than 1,000 people in south west Edinburgh sought medical attention with a range of symptoms suggestive of Pontiac fever. Where clinically appropriate, their GP prescribed a four day course of the antibiotic clarithromycin.

Primary care data on these cases was reviewed. Clarithromycin prescribing was used as a preliminary proxy measure to ascertain the extent of healthcare sought for symptoms of legionellosis. Primary care prescribing data was extracted from the Prescribing Information System for Scotland (PRISMS). It showed that whilst there is normally a seasonal dip in clarithromycin prescribing over the summer months, this was not the case in 2012. Figure 13 shows a peak in clarithromycin prescribing in June 2012. Other areas of Lothian did not experience such peaks (data not shown) indicating that the increase was likely to be a direct result of the Legionnaires' outbreak.

Figure 13: Clarithromycin dispensing, items dispensed in south west Edinburgh practices, calendar month, 2009-2012

LHP = Lothian Health Partnership area



Source: PRISMS

4.2 Seroprevalence study

A retrospective cohort study was conducted among residents of the affected area of south west Edinburgh who sought medical attention during the outbreak for non-pneumonic presentations of legionellosis including Pontiac fever. The study aimed to:

- Quantify the extent of non-pneumonic legionellosis amongst those who developed symptoms and sought healthcare between 14 May and 27 June 2012 and were diagnosed, at the time of presentation, as potentially having non-pneumonic legionellosis.
- To determine the nature of, and the personal, behavioural and residential risk factors associated with non-pneumonic legionellosis.

Data from GPs, accident and emergency department, primary care out of hours, NHS24 helpline and microbiology, identified 915 individuals who met the inclusion criteria and who were invited to participate. Of the 915, 266 (29.1%) participated and were included in the analysis.

A clinical case definition for Pontiac fever of '*fever and either cough, headache or muscle aches*' was fulfilled by 48.1% (n=128) of participants. The clinical case definition was more likely to be fulfilled by younger participants and by those who also reported dizziness, fatigue, malaise and vomiting. Among participants, sex, deprivation category, smoking status, presence of underlying medical conditions or the distance they lived from the cluster of cooling towers did not significantly increase the likelihood of fulfilling the clinical case definition.

Serology was obtained from all participants and tested for an immunological response to *Legionella pneumophila* serogroup 1. Only eight (3.0%) participants had any raised titre and only three at a level of 1:64 or greater. While the seropositivity rates in other outbreaks of Pontiac fever have been variable, they have generally been higher than those detected here. A median delay of 50 days from onset to serology sample may have contributed to the low seropositivity rate. An increase in healthcare seeking behaviour for non-legionellosis conditions with similar symptoms may also have resulted from the intense media coverage of the outbreak.

The study demonstrated the considerable strain non-pneumonic illness placed on health care services particularly general practice. Unfortunately it was not possible to determine the proportion of illness due to Pontiac fever and what proportion was due to increased healthcare seeking behaviour.

The report recommends modification of treatment algorithms to help identify those most likely cases of Pontiac fever in order to raise the threshold for prescribing clarithromycin, but cautions that this must be balanced against the risk of missing early presentations of Legionnaires' disease.

4.3 Case-control study

A retrospective case-control study was undertaken to a) quantify the relationship between wet cooling systems as a potential source of aerosolised *Legionella pneumophila* and cases of Legionnaires' disease and b) identify the characteristics and risk factors associated with Legionnaires' disease.

This outbreak had several characteristics which made it amenable to further analysis: the affected population was relatively well circumscribed to a wedge shaped area of

south west Edinburgh; evidence at the time suggested a small cluster of cooling towers to the north east of the population being the source; the prevailing North Easterly wind during the probable period of emission remained in a singular direction probably contributing to clustering of cases and facilitating early identification of the possible source. These factors facilitated study design and implementation. Participation rates were also high giving greater confidence in the results.

The study population comprised only residents in NHS Lothian, or with links to the south west Edinburgh area between 14 May 2012 (based on 14 days prior to the estimated date of disease onset of the first case) and June 6 2012. Cases comprised all confirmed, probable and possible cases.

Fifty nine cases and 202 controls were eligible, 63% (37/59) and 42% (85/202) respectively participated. The predominant symptom profile of cases was malaise (95%), fatigue (95%), fever (84%) and confusion (68%). Confusion was a striking symptom (diaries were insufficiently complete for analysis). Established risk factors – being male, older, a smoker and having an underlying condition – increased the likelihood of contracting Legionnaires' disease. Additionally, unemployed or retired people had an increased risk compared to employed people. However, of those who were employed, those who worked outdoors had a greater risk than those who worked indoors. Living in an area of greater deprivation was also found to increase risk.

There was no difference in the average distance from the cluster of cooling towers. Quantification of exposure levels in residents found that cumulative exposure to contaminated aerosol was significantly higher in cases.

This study confirmed the importance of previously reported risk factors such as age, gender, smoking and underlying medical conditions. It identified that neurological and cognitive symptoms occur frequently and should be given greater prominence in risk assessment. The study also identified an increased risk associated with being an economically inactive resident in the area and with increasing exposure to aerosol release.

5 Discussion

This outbreak was caused by an aerosol release of *Legionella pneumophila* Sg1 Knoxville ST191 over a defined area of south west Edinburgh. The outbreak had considerable impact on local NHS services during June 2012. A total of 92 cases of Legionnaires' disease were reported. Four people died. Hundreds of local residents sought medical care for respiratory symptoms.

The case fatality rate in this outbreak was 4.3% which is low compared to 10-20% in other countries and a European average of 12%. Differences in strain virulence, host factors or case ascertainment may account for this difference in mortality (Barry et al, 2002). Another possibility is that access to health services, diagnostic and antibiotic treatment practices also have an important role.

From human samples, the organism identified as causing illness in cases was *Legionella pneumophila* Sg1 Knoxville ST191. After extensive environmental testing and the use of standard and novel genetic laboratory methods, there was no current microbiological evidence to confirm the presence of live *Legionella pneumophila* Sg1 Knoxville ST191 in any of the specimens taken from any of the potential environmental sources. Further genetic sub-typing to try to establish a match between environmental and clinical isolates was undertaken.

During the investigation, some fragments of Legionella DNA were recovered from some of the samples tested. However, the detection of Legionella from an environmental site does not by itself constitute proof of the source of the outbreak unless it can be linked to the organism identified in the human cases. In this outbreak, standard microbiological investigations were inconclusive. A link between the human and environmental isolates or DNA samples was not found. This is not uncommon and has occurred in other community outbreaks of Legionnaires' disease.

The results from the whole genome sequencing of the human isolates identified that the isolates were made up of four different groups (or clades). It was concluded that all the ST191 strains had probably diversified from a single clone through mutation, recombination and horizontal gene transfer within an environmental reservoir prior to release. This makes it even more difficult to identify a potential environmental source site using current microbiological methods as in theory there could have been four discrete source sites or one site with multiple clades present. In addition, some patients were infected with multiple *Legionella pneumophila* subtypes, a finding that can affect the certainty of source attribution (McAdam et al, 2014).

From the epidemiological and meteorological evidence, a common outdoor aerosol exposure of *Legionella pneumophila* Sg1 Knoxville ST191 occurred over south west Edinburgh, most probably emanating from an industrial complex containing wet cooling towers in the north east of the affected area. The modelling data indicates that the aerosol release probably started around 23 May 2012 and ended on 30 May 2012. The north easterly wind direction and high population density of the area probably contributed to the clustering of cases and this facilitated an early identification of the outbreak and identification and prompt disinfection of possible sources of the aerosol. It may be that the continuing release from the source(s) was controlled by a combination of the control measures put in place by the Incident Management Team and another unspecified event around 30 May 2012.

Any Legionnaires' disease outbreak has the potential to cause public concern or even alarm. The most important lesson from this outbreak was the speed and skill with which the different professionals from partner agencies and NHS Lothian investigated the outbreak and the potential environmental sources. Daily communication throughout the outbreak gave local healthcare staff and residents the most current information about the disease and how to access healthcare. Local healthcare professionals were updated on the investigation. They were also provided with information on the type of samples and tests to be taken. In addition, they were informed who they should contact if they identified potential cases.

The investigation of this outbreak involved close multi-agency working across Edinburgh and beyond. The purpose of the investigation was to identify the source of the outbreak and to take action to stop further transmission of the disease. This involved carrying out epidemiological, microbiological, meteorological and spatial-temporal studies in order to identify mechanisms of aerosol generation that could have allowed population exposure to occur.

Once the initial cluster had been identified, the Incident Management Team ensured that appropriate environmental samples were taken and that definitive actions to protect public health were taken promptly.

Epidemiological analysis indicates that this locally coordinated public health, environmental and clinical response helped to prevent ongoing exposure of the population and mitigated associated mortality and morbidity. The rapid investigation and knowledge from other outbreaks, clear communication and the early recognition of the initial cluster was critical to preventing more illness and protecting the public's health.

Investigation by the Health and Safety Executive and Lothian and Borders Police into the circumstances of the four Legionnaires' deaths was undertaken under the direction of the specialist Health and Safety Division of the Crown Office and Procurator Fiscal Service. As it has not been possible to identify the precise source of the Legionella bacteria which resulted in the death of four people, Crown Counsel has concluded that there is insufficient evidence to prosecute any person or organisation for the deaths.

6 Measures to prevent and mitigate similar outbreaks in the UK and beyond

6.1 The role of companies as duty holders

The first assessment must be whether it is necessary to use a wet cooling system or other process that runs the risk of allowing Legionella bacteria to multiply and aerosolise. All companies who currently use wet cooling systems in densely populated areas should undertake a formal risk versus cost benefit analysis to determine whether their wet cooling systems could be replaced. Some Lothian companies have already replaced their wet cooling system with other processes; others report that existing alternatives are not feasible. For these companies, and other organisations responsible for sites with water systems and cooling towers, sustained compliance with the updated Approved Code of Practice (ACOP) "Legionnaires' Disease: The Control of Legionella Bacteria in Water Systems (L8)"is essential to prevent outbreaks.

Prevention of future Legionnaires' disease outbreaks is dependent, therefore, on duty holders and any specialist water treatment companies they employ following existing guidance and legislation on how to maintain cooling towers and other risk sites safely.

6.2 Action undertaken by the Health and Safety Executive

Prior to this outbreak in September 2011, the Health and Safety Executive's Legionella Committee asked the Health and Safety Laboratory to carry out a review of the causes of outbreaks in Great Britain over the last ten years. The Health & Safety Laboratory report (http://www.hse.gov.uk/research/hsl_pdf/2012/hex1207.pdf) indicated common failings in control. While none of the risk factors for outbreaks were new, the Health and Safety Executive aimed to highlight the responsibilities of companies to control and mitigate risk by issuing safety notices and undertaking a focused programme of interventions and compliance checks in consultation with UK local authorities.

In November 2013, the Health and Safety Executive issued a new edition of Legionnaires' disease. 'The control of Legionella bacteria in water systems. Approved Code of Practice and Guidance. L8 (Fourth edition) 2013'. http://www.hse.gov.uk/pubns/books/l8.htm

This 2013 edition of the Approved Code of Practice and Technical Guidance provides greater clarity for site duty holders on what constitutes a legal requirement and what is just guidance. Terminology has been simplified and places greater emphasis on proportionality in low risk scenarios.

The review also enabled the Health and Safety Executive to update technical guidance to duty holders to incorporate the latest technological advancements. The technical guidance was removed from Part 2 of the Approved Code of Practice and is now published separately online as HSG274.
http://www.hse.gov.uk/pubns/books/hsg274.htm

6.3 Action undertaken by City of Edinburgh Council

Following this outbreak of Legionnaires' disease in 2012, the City of Edinburgh Council's Food Health and Safety Service has enhanced its ability to inspect risk systems and its capability to respond to Legionella outbreaks. This work continues

and includes appointing key personnel for Legionella control within workplaces in the city, establishing a group within Environmental Health and Scientific Services to maintain focus on Legionella related issues and raising competency levels of officers in the control of Legionella in systems. It has also involved writing to approximately 500 operators of systems regarding the importance of controlling the risks of Legionella in water systems.

6.4 Mitigation and management of future outbreaks

Significant community outbreaks of Legionnaires' disease associated with cooling towers and other sources have been reported across Europe (see Table 1). There is an expectation that countries will share their experience in dealing with large Legionnaires' disease outbreaks. Representatives from this Incident Management Team had the opportunity to present this Legionnaires' outbreak to key representatives from Public Health England and the European Centre for Disease Prevention and Control in Edinburgh on 3 September 2012. In addition, members of the Incident Management Team have presented the findings from this outbreak at specialist conferences.

Members of the Directorate of Public Health and Health Policy and City of Edinburgh Council Environmental Health and Scientific Services also contributed to the review of the Health Protection Network's *Guideline on Management of Legionella Incidents, Outbreaks and Clusters in the Community* (Health Protection Scotland, 2014). http://www.documents.hps.scot.nhs.uk/about-hps/hpn/legionella-guidelines-2014-2.pdf

The investigations undertaken during the management of this outbreak, and the learning that resulted, have contributed to the content of the European Centre for Disease Prevention and Control Legionella toolkit, which is now in use across Europe (http://legionnaires.ecdc.europa.eu/). Prior to the development of the toolkit, advice was also given to experts managing Legionnaires' disease outbreaks in other countries including Canada and Australia.

7 Evaluation of incident management

The following areas were recognised by the partner agencies as having worked well in this outbreak:-

Organisational Arrangements

- There was a rapid multidisciplinary response to the initial cluster out-of-hours over a holiday weekend.
- The Incident Management Team was formed speedily and prompt action was taken in relation to the most likely source.
- There was good multi-agency team working and cooperation from the outset.
- Local NHS services including critical care, acute medicine, out of hours and primary care services showed resilience when large numbers of patients presented.

Investigation

- This outbreak happened in Edinburgh, and all the key players were used to working together and the suspected source sites were nearby.
- There was good communication between health protection and laboratory medicine staff.
- There was good collaboration between diagnostic microbiology laboratory, Edinburgh Scientific Services and Reference Laboratories.
- There had been major advances in investigation techniques since 1994 when there was another similar outbreak in south west Edinburgh involving cooling towers.

Control Measures

- Appropriate control measures were applied quickly out-of-hours.
- The observed lower mortality in this outbreak compared to other outbreaks may have been due to excellent clinical management and the availability of new antimicrobials.

Communications

- The use of a single spokesperson helped to build trust with the media.
- There was good inter-agency collaboration and communication.
- A single daily update made media management easier.
- Proactive key messages to the public regarding the expected course of events were helpful.

8 Actions following the Interim Report 2013

Since the interim report, the agencies involved in the Incident Management Team have taken forward the following actions:

- Revision of the Health Protection Network guidance to reflect current best practice and organisational arrangements. This includes the responsibilities of regulators, other agencies and expert bodies to advise and/or address issues such as sampling (techniques and reporting results) and processes to be followed whether there is a potential for future investigation of the attribution of corporate responsibility, including homicide.

  Lead: Health Protection Advisory to advise Chief Medical Officer and Scottish Directors of Public Health Group on recommendations.

  Update: Updated guidance on the management of Legionella cases, incidents, outbreaks and clusters in the community was issued by the Scottish Health Protection Network in November 2014.

- Rehearsal of the local multi-agency major outbreak plan on an annual basis and review of the roles and tasks within and across agencies.

  Lead: NHS Lothian and all partner agencies

  Update: NHS Lothian has revised its major incident arrangements, updated communication arrangements and reviewed medical leadership roles.

- Development of a suite of templates/procedures to support the rapid distribution of information to patients, public and professionals by all appropriate means.

  Lead: NHS Lothian in line with health protection risk communication and Scottish Government guidance

  Update: Improved processes have been introduced by NHS Lothian to ensure rapid distribution of information to patients, public and professionals including a new public health alert system replacing the previous fax system, a revised process for updating the NHS Lothian website and better use of, and access to, social media.

- Review of the resources and facilities required for emergency planning and resilience to ensure all agencies involved in the management of a major outbreak can respond formally to a major outbreak in a timely manner and maintain their response as required.

  Lead: All agencies involved to review against updated Scottish Government and United Kingdom guidance

Update: A suite of current guidance is available at http://www.readyscotland.org/ready-government/preparing-scotland/. Resilience of specialist capacity remains a concern and will be considered and tested during pandemic flu planning in 2015/16.

- Development of a common approach for the recording of complex microbiological and environmental information across agencies such as the Health and Safety Executive, local authority Environmental Health and Scientific Services and national Reference Laboratories.

  Lead: Health Protection Oversight Group to advise Chief Medical Officer and Scottish Directors of Public Health on recommendations.

  Update: Advisory groups are currently being established.

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10 APPENDIX A: Glossary

Acute: e.g. acute disease An adjective commonly applied to diseases with a short time course.

Aerosolisation: Dispersal of liquid, in the form of mist, through air.

Analytical Epidemiology: The design, execution and analysis of studies that evaluate the potential association between exposures and outcomes in groups.

Anti-microbial: An agent that inhibits the growth of or kills microorganisms.

Antigen: any substance that may be specifically bound by an antibody molecule

Assay: A laboratory procedure used to qualitatively assess or quantitatively measure functional activity of the target entity.

Attack Ratio: The attack rate (percentage of the population that becomes ill in the population being studied) divided by the attack rate in a comparison population.

Biofilm: A thin viscous layer containing a community of microorganisms adhering to a solid surface.

Buffered Charcoal Yeast Extract Agar: selective agar used in culture of Legionella bacteria.

Case Control Study: A type of observational epidemiological study, where cases are matched and compared with control subjects (those who do not have the outcome) in order to determine a possible causal factor.

Case Definition: A list of criteria that must be fulfilled in order to identify a person as a case of a particular disease. It is used in outbreaks of illness to identify who should be included on a list of cases. The criteria can include the symptoms of the illness, laboratory test results, the time and place of illness.

Cluster: An aggregation of relatively uncommon events in space and/or time believed or perceived to be greater than could be expected by chance.

Communicable Disease: Any disease that can be passed from one person to another.

Consultant in Public Health Medicine: A doctor in a medical specialty that includes responsibility for the prevention and control of communicable disease and environmental hazards in the population. In Lothian, Consultants in Public Health from a professional background other than medicine were previously described as specialists.

Control Measure: Actions brought in to eliminate or minimise an exposure.

Cooling Tower: An apparatus through which warm water is discharged against an air stream; in doing so part of the water is evaporated to saturate the air and this cools the water. The cooler water is usually pumped to a heat exchanger to be reheated and recycled through the tower.

Culture: Laboratory methods used to grow microorganisms in order to identify them

Descriptive Epidemiology: Describing the characteristics of cases i.e. time, place or person characteristics such as date of onset of illness, place of residence, age or sex.

DNA Deoxyribonucleic acid

DNA-Sequence Based Typing (SBT): A method of distinguishing organisms based on differences in their genetic sequence

Drift Eliminator: More correctly referred to as drift reducers or minimisers - equipment containing a complex system of baffles designed to remove water droplets from **cooling tower** air passing through it.

ELISA: Enzyme linked immunosorbent assay

Environmental Health Officer (EHO): An individual fully trained in environmental health issues such as housing, sanitation, food, health & safety, clean air, noise and water supplies. Responsibilities include the enforcement of food and health & safety legislation in commercial businesses, and the investigation of food and waterborne disease.

Epidemiological link: Cases linked by close proximity to a plausible source.

Epidemiology: The study of the patterns, causes, and control of disease in groups of people.

Evaporative Condenser: A heat exchanger in which refrigerant is condensed by a combination of air movement and water sprays over its surface.

GVPC: Glycine Vancomycin hydrochloride Polymyxin B sulphate

Incident Management Team (IMT): A team of people from different, usually public bodies, brought together, according to official guidance primarily to control the spread of disease during an outbreak. This is done through assessing the range and extent of the outbreak; identifying the source of the problem if possible, implementing prevention and control measures and communicating with relevant parties and the public.

Line List: A table summarising the relevant information about cases involved in an outbreak.

Microbiological Sampling: Taking a sample e.g. sputum or water sample and examining it to see if an infectious agent is present.

Microbiologist: A doctor, mainly laboratory based, who specialises in the diagnosis, treatment and control of infectious agents such as parasites, bacteria, viruses and fungi.

Mortality: the death experience of the population, including causes of death and variation according to the dimensions of person, place and time

Morbidity: The health or illness experience of the population including prevalence and incidence of disease

Plume Modelling: The retrospectively determining the spread of plumes in relation to environmental conditions just prior to and during the outbreak.

Onset: The first date a person experiences symptoms associated with the disease of interest.

Outbreak: An increase in the number of people with an illness or disease that is above what you would normally expect in the population at that particular time, or two or more linked cases with the same illness.

Polymerase chain reaction (PCR): A molecular method used to amplify nucleic acid sequences enabling the detection of small amounts of 'organism' or more precisely, its genetic material, without the need to actually grow the organism.

Pond/Sump: Collection of cooling water at the base of a cooling tower.

Sensitivity: The proportion of people with disease who have a positive test result.

Sequence Based Typing (SBT): A technique in which a very sensitive PCR method is used to determine a type directly on the clinical samples as opposed to on genetic material from the cultured isolate e.g. Nested direct sequence based typing

Sequence Type: this refers to the finding from sequencing being brought together to determine types which are distinguishable from one another.

Seroprevalence Study: The proportion of individuals in a population that are blood positive for the pathogen of interest.

Shot Dosing: Precautionary measure whereby high doses of chemical disinfectant are used as an additional treatment to control levels of bacteria

Source: Point of origin of infection.

Specificity: The proportion of people without disease who have a negative test result.

Surveillance: The systematic and continuous collection, analysis and interpretation of data, integrated with the timely and coherent dissemination of the results and assessment to those who have a right to know so action can be taken.

Windrose: A diagram showing the direction wind originates from and the speed of the wind for a particular location and specified time period.

11 APPENDIX B: Members of the Incident Management Team (IMT)

Alison McCallum
Director of Public Health and
Health Policy
NHS Lothian

Alison Potts
Epidemiologist
Health Protection Scotland

Alison Smith-Palmer
Epidemiologist
Health Protection Scotland

Alistair McNab
Head of Operations
Health and Safety Executive

Andrew Campbell
Environmental Health Officer
City of Edinburgh Council

Carol Harris
Communications Manager
NHS Lothian

Christine Evans
Consultant in Public Health Medicine
NHS Lothian

Colin Sibbald
Food Health and Safety Manager
City of Edinburgh Council

Diane Lindsay
Principal Clinical Scientist
Scottish Haemophilus, Legionella, Meningococcus
Pneumococcus Reference Laboratory

Dona Milne
Specialist in Public Health
NHS Lothian

Duncan McCormick
Consultant in Public Health Medicine
NHS Lothian

Fatim Lakha
Specialist Registrar,
Public Health Medicine
NHS Lothian

Garry Stimpson
HM Principal Inspector
Health and Safety Executive

Giles Edwards
Consultant Microbiologist
Scottish Haemophilus, Legionella, Meningococcus
Pneumococcus Reference Laboratory

Janet Stevenson
Consultant in Public Health Medicine
NHS Lothian

Jennifer Irvine
Personal Assistant
NHS Lothian

Jim McMenamin
Consultant Epidemiologist
Health Protection Scotland

John Healy
Team Leader, Occupational Hygeine Team
Health and Safety Executive

Jonathan Mills
Specialty Registrar, Medical Microbiology
NHS Lothian

Louise Wellington
Health Protection Nurse
NHS Lothian

Lynn Cree
Environmental Health Adviser
Health Protection Scotland

Martin Donaghy
Medical Director
Health Protection Scotland

Mary Hanson
Consultant Microbiologist
NHS Lothian

Michael Gillies
Clinical Director of Critical Care
NHS Lothian

Richard Othieno
Consultant in Public Health Medicine
NHS Lothian

Robbie Beattie
Scientific and Environmental Services Manager
City of Edinburgh Council

Sian Tucker
Acting Clinical Director, Lothian Unscheduled
Care Service (LUCS)
NHS Lothian

Steve Harvey
Emergency Planning Officer
NHS Lothian

Stuart Wilson
Director of Communications
NHS Lothian

Sue Payne
Consultant in Public Health Medicine
NHS Lothian

12 APPENDIX C: Dates of the Incident Management Team meetings and the members of the team

Meeting	Chair	Date
Incident Management Team	Dr Duncan McCormick, NHS Lothian	Sunday 3 June 2012
Incident Management Team	Dr Duncan McCormick, NHS Lothian	Monday 4 June 2012
Incident Management Team	Dr Duncan McCormick, NHS Lothian	Tuesday 5 June 2012
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Wednesday 6 June 2012
Surveillance Meeting	Dr Janet Stevenson, NHS Lothian	Thursday 7 June 2012
Spatial Analysis Meeting	Dr Jim McMenamin, HPS	Thursday 7 June 2012
Incident Management Team	Dr Duncan McCormick, NHS Lothian	Friday 8 June 2012
Clinical Guidance Meeting	Dr Mary Hanson, NHS Lothian	Friday 8 June 2012
Incident Management Team	Dr Sue Payne, NHS Lothian	Saturday 9 June 2012
Incident Management Team	Dr Sue Payne, NHS Lothian	Sunday 10 June 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Monday 11 June 2012
Laboratories Meeting	Dr Martin Donaghy, HPS	Tuesday 12 June 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Wednesday 13 June 2012
Spatial Analysis Meeting	Dr Jim McMenamin, HPS	Thursday 14 June 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Friday 15 June 2012
Surveillance Meeting	Dr Janet Stevenson	Monday 18 June 2012
Spatial Analysis Meeting	Dr Jim McMenamin, HPS	Monday 18 June 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Wednesday 20 June 2012
Spatial Analysis meeting	Dr Alison Smith-Palmer, HPS	Tuesday 26 June 2012
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Tuesday 26 June 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Tuesday 3 July 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Tuesday 10 July 2012
Incident Management Team	Dr Richard Othieno, NHS Lothian	Tuesday 17 July 2012
Incident Debrief	Steve Harvey, NHS Lothian	Wednesday 1 August 2012
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Wednesday 22 August 2012
Incident Management Team	Dr Richard Othieno/Dr Duncan McCormick, NHS Lothian	Friday 21 September 2012
Incident Management Team	Dr Duncan McCormick, NHS Lothian	Wednesday 20 February 2013
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Wednesday 11 December 2014
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Thursday 26 March 2015
Incident Management Team	Dr Janet Stevenson, NHS Lothian	Thursday 18 June 2015