Chartered
Institute of
Environmental
Health

Journal of Environmental Health Research

www.jehr-online.org

Volume 3 • Issue 1 • 2004

Journal of Environmental Health Research

ISSN: 14760932

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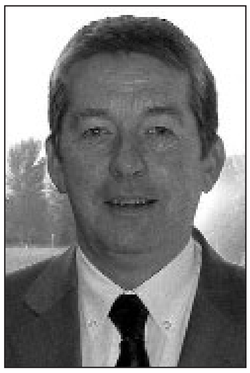

Editors: Harold Harvey (left) and Paul Fleming

Editorial

The new public health takes seriously the fact that the health of populations is affected by policy and service provision across all sectors of society and at a number of levels. In the field of environmental health, which is a core public health discipline, the way in which we address a range of key issues is driven by government policy which is often affected by resource implications. Approaches to resourcing and best practice varies internationally.

Several of the papers and review included in this edition of the Journal seek to give an international perspective on environmental health issues which many of us encounter. Thus the British experience of management of private water supplies, the control of rats and the bioaccumulation of metals can be compared with the experience in other developed countries. Such a comparison can be both affirming of local practice and also point out where we 'could do better'.

It is essential to remain vigilant to all potential threats to human health, even those which may appear to have been eliminated. In the UK much progress has been made in reducing the incidence of lead poisoning by controlling potential exposure sources but research reported here suggests that it is a health risk that should not be overlooked in especial populations.

Many attempts have been made to eliminate the common cold but it is still widespread and creates significant levels of human discomfort and economic loss each year. A consideration of the transmission routes is important. Air travel is now a common mode of travel for a substantial proportion of the population and the confined space of an aircraft cabin could increase transmission success. But does it, and what are the implications for passengers and the industry? A paper in this edition answers this question from an existing research evidence-base.

Underpinning the contribution of environmental health to the new public health (which we have recently labelled 'New Agenda Environmental Health') is the need for a more solid research base which should arise from a research culture within Environmental Health Departments. Each department, or group of collaborating departments, should have a planned and properly resourced research programme which contributes to both local, national and international debate in environmental health. Partnerships with academic departments would greatly enhance this process. However, until the need for a dynamic, credible evidence-base is accepted at the highest level, commitment and resources will remain lacking and the research effort in environmental health will remain, at best, sporadic and opportunistic.

Paul Fleming and Harold Harvey

Lead in house paints – Still a health risk that should not be overlooked

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Abstract

Much progress has been made in the UK in reducing the incidence of lead poisoning by controlling potential exposure sources. Notable in the first part of the 20th Century were controls on industrial emissions that reduced occupational exposure and local environmental pollution. Recently, more widespread environmental emissions of lead in the UK have been drastically reduced through the introduction of unleaded petrol. As a result, publicity about this common toxin has considerably diminished. However, there is still a problem from these sources in countries with less developed controls. Furthermore, there is still one source of lead in the UK regularly causing poisoning, namely old paints, on which this paper focuses.

This paper serves as a reminder that the potential for lead poisoning from old leaded paints still exists in the UK. Lead concentrations of paint samples from private housing in Greater London were determined by concentrated nitric acid digestion followed by Atomic Absorption Spectrophotometry. Concentrations over 50,000 ppm, exceeding a 'safety level' of 5,000 ppm, were recorded for a number of pre-1930 flats and houses. Concentrations are compared with those found in a previous study in which concentrations exceeding 10,000 ppm were recorded for a Greater London primary school built in the 1920s. It is hoped that the paper will stimulate further research interest in this field and that more detailed studies may follow.

Old leaded paints are an environmental hazard having the potential to poison young children exhibiting pica (chewing or eating non-food items). They also pose an occupational hazard to decorators, as well as an environmental hazard to people living in redecorated homes, who ingest or inhale contaminated dust resulting from paint stripping operations in old houses. Fatalities are now rare in the UK, although poisonings do still occur on a regular basis. The most serious effect is encephalopathy, and permanent damage to the nervous system may occur resulting in behavioural difficulties. Lead is also toxic to many organ systems including the kidneys and red blood cells.

Environmental Health Officers, medical staff and social workers should be aware of this hazard, if encountering children with pica or when investigating unexplained illness or behavioural problems in children. The potential for leaded paint contaminating house dust, food or garden soil during redecoration of older properties should also be considered. Primary preventative action to prevent exposure to lead is preferable to secondary preventative action to screen those at risk or tertiary action to treat those affected.

Key Words: Environmental health; houses; lead; paint; pica; redecoration; toxin

Introduction

Lead is a well known and widespread toxin, albeit one that has received less publicity in recent years. Its poisonous nature has been known for centuries. Several authors have referred to the fact that lead poisoning might have contributed to the decline of the Roman Empire. Evidence for this comes from high lead concentrations in some Roman skeletons, the likely sources being lead in glazes on cooking and food storage pottery and in lead water pipes. At the end of the nineteenth century there were around a thousand cases a year of factory workers poisoned by lead in the UK (Timbrell, 2002). However, legislation in the last century provided effective controls to the extent that lead poisoning in UK factory workers is now rare. Lead emissions from motor vehicles using leaded petrol became the major source of environmental lead pollution and a focus for concern. This in turn has been controlled by the introduction of unleaded petrol, although it should be borne in mind that lead cannot be broken down. Consequently, roadside lead concentrations will remain elevated for some years, only decreasing by gradual dispersion and leaching through the soil. Nevertheless, with reductions in atmospheric lead concentrations and consequent probable general reductions in human blood lead levels, concern about lead has reduced and it now rarely features in the media. However, it should not be forgotten that there are many countries with less developed lead pollution controls, where problems from these sources still exist. For example, many poorer countries are still using leaded petrol and have less effective controls on industrial emissions. Additionally, the hazard posed by lead drinking water pipes in soft water areas should not be overlooked. Houses built before the 1930's in the UK had lead water pipes, some of which are still in place. However, even more recent properties may have a problem caused by lead solder used to join copper pipes.

This paper focuses on a source of lead that has not been completely eliminated in the UK and that still poses a health hazard in some older properties. As long ago as the early 18th Century, painters were aware of the dangers from leaded paints and symptoms of occupational lead poisoning were described (Rosen,1953). Penrose (2000) provides a review of lead poisoning from paint arguing that government reluctance to prohibit the use of lead paint pigments has ensured that lead poisoning continues to be a major occupational and public health problem today. Whilst legislation in the 1970s reduced permitted levels of lead in UK paints (see, for example, Horner 1995), older paints may still be exposed in some properties. It is also possible that some high lead paints that have been stored for many years could be applied or that leaded paints intended for industrial use are misappropriated for residential use. The link between lead poisoning in children and ingestion of old paint flakes is well known and the majority of recent cases of lead poisoning in the UK have been children who have ingested paint flakes or dust contaminated by paint. Lead in paint is still recognised as a potential hazard in the USA where Regulations limiting lead in paint were also introduced in the 1970s. Relatively recently, Landrigan and Todd (1994) stated that lead poisoning is the most common disease of environmental origin in the USA today. Sutton *et al* (1995) estimated that there were approximately 1.3 million homes in California in which interior paint lead levels exceed 5,000 ppm and Kassa *et al* (2000) described lead poisoning as a significant health problem among some children living in inner-city homes in Toledo, Ohio. Kokori *et al* (1999) identified lead as remaining an important environmental health threat to children today.

In the UK, USA and other countries that have introduced legislation to control the lead content of paints, the hazard posed must be decreasing as more old paints are either covered by low lead paints or removed. However, it is important that we do not become complacent or forget about the hazard posed because it is likely to be many years before old leaded paintwork in houses has been completely eliminated. In Belgium, despite restrictions on lead in house paints dating from the 1920s, lead poisoning of children living in old inner city housing has been reported relatively recently (Limbos *et al*, 1987). Furthermore, as with other sources, it must not be forgotten that a more serious problem almost certainly exists in other countries where legislation is either less stringent or non-existent. For example, Nriagu *et al* (1996) and Shen *et al* (1996) reported childhood lead poisoning being a serious health problem in Africa and China, respectively. In both studies, leaded paints were identified as being one significant source. Paint was also reported as a source of lead exposure in Saudi Arabia and it was noted that manufactured paints were still exceeding a lead standard set in 1986 (Al-Saleh and Coate, 1995).

Leaded paints pose a hazard to young children (and to older people, with, for example, learning difficulties) who exhibit pica - a tendency to chew or consume non-food items. Consumption of just one paint flake could be enough to cause poisoning. Lead attacks the nervous system and in children the most serious effect is encephalopathy with mental retardation. There may be lifelong effects including seizures and cerebral palsy. In children, lead can cause skeletal changes. Chronic exposure can be detected by bands at the growing ends of long bones or by a lead line on the gums. Lead has also been linked with damage to kidneys and red blood cells. Children are more susceptible to poisoning than adults because gastrointestinal absorption of lead is greater in children (Timbrell, 2002). However, this could be offset to some extent by the fact that the hydrochloric acid in a young child's stomach is less concentrated than that in an adult's stomach, so less lead might be extracted by digestion. It is likely that cases of lead poisoning are not being diagnosed, especially in poorer countries. Shen *et al* (1996) report that in China most doctors are not even aware of lead poisoning. There are also sub-clinical effects that are more difficult to diagnose, for example the interference of lead with haem and porphyrin synthesis (Timbrell, 2002). Therefore the incidence of lead poisoning is much greater than published reports might suggest.

Leaded paints may also pose a hazard to people who ingest or inhale contaminated dust resulting from paint stripping during redecoration. Scholz *et al* (2002) demonstrated how residential and commercial painters can be exposed to dangerously high atmospheric lead concentrations when preparing surfaces for painting as did Johnson *et al* (2000) for construction workers renovating a bridge. In both cases this was caused by contaminated dust produced when removing old paintwork. Such dusts from redecorating operations could contaminate food, house dust and garden soil. This would pose a hazard to house occupants, especially young children who make more hand to mouth movements. Evidence to support this was provided by Mielke *et al* (2001) who reported the death of a family pet and illness of three children caused by lead poisoning resulting from power sanding and paint scraping during redecoration of a house in New Orleans.

The aim of this study is to report on levels of lead found in house paints in the UK, providing a reminder that high concentrations certainly do still exist. A 1977 EC Directive requires that all paint containing more than 5,000 ppm lead should be labelled with a warning that it must not be applied to surfaces that are likely to be chewed or sucked by children. The same concentration has been specified as an abatement action level by the US Department of Housing and Urban Development (1990). This concentration has been considered as a 'safety level' for comparison with paint sample concentrations determined in this study to assess the extent of the hazard. It could be argued that this concentration is too high - the Toys (Safety) Regulations (Home Office, 1974a) specify that paint on toys should contain no more than 2,500 ppm and the Pencils and Graphic Instruments Regulations (Home Office, 1974b) state that paint coatings on pencils, pens and brushes should contain no more than 250 ppm.

Method

Ten paint samples were collected from each of ten student private rented flats or houses. All the properties were in Greater London, and they were selected to represent a range of different decades of construction. The samples were taken with a scalpel from different surfaces, each being readily accessible to children. Several rooms in each property were sampled. All properties sampled were in Greater London and their decades of construction were determined.

Samples were ground with a pestle and mortar and then digested in concentrated nitric acid at 90°C for 1 hour. Lead concentrations were then analysed using an Atomic Absorption Spectrophotometer.

Results

As can be seen from Table 1.0, overall lead concentrations ranged from 10 to 430,000 ppm, the highest concentration being found for a sample from the oldest property. Concentrations exceeding 100,000 ppm (10%) lead, exceeding the 5,000 ppm Safety Level by more than 20 fold, were found in some paint samples from all four of the oldest properties. However, some samples from two of these properties had concentrations below the Safety Level. There was considerable variation in concentrations both between properties and between samples within properties, the latter being indicated by the large ranges and standard errors. However, generally the older the property the higher were the lead concentrations. Means for the five oldest flats all exceeded the 5,000 ppm Safety Level, whereas means for the five newest flats were all below it.

Discussion

Mean lead concentrations of paint samples from all houses built before the 2nd World War exceeded the 5,000 ppm Safety Level. Indeed mean concentrations

Table 1.0 Range of Lead Concentrations Found in the Houses Together with Means (and Standard Errors)

Flat number	Construction Decade	Lead Concentration Range	Lead Concentration Mean (Standard Error)
1	1860s	90-430,000	141,200 (37,600)
2	1900s	16,000-144,000	78,400 (10,980)
3	1900s	5,200-385,000	129,400 (27,500)
4	1910s	200-177,000	14,090 (8,350)
5	1920s	520-72,000	19,300 (7,740)
6	1950s	1,900-2,600	2,400 (70)
7	1950s	850-7,200	4,500 (690)
8	1970s	580-1,500	1,050 (90)
9	1980s	10-1,000	170 (60)
10	1990s	50-300	135 (22)

for the three oldest houses all exceeded the Safety Level by a factor of more than ten. The sample size for this study was small so no firm conclusions can be made regarding the frequency of houses likely to contain paint with excessively high lead concentrations. However, it is worth noting that results of similar unpublished experiments conducted over several years with groups of undergraduate students have regularly determined lead concentrations exceeding the safety level in paint from old houses. Based on these results, it seems clear that there is still considerable potential for lead poisoning from UK house paints in older properties. Privately rented student properties are probably a category of accommodation more likely to have poor maintenance standards with lower painting frequencies. Hence they are probably likely to have higher lead paint concentrations than average for UK housing. However, they are probably less likely to have young children as occupants, although the oldest house in this study was occupied by a mature student with two young boys.

It is interesting to compare these results with results of a recent similar study that investigated paint lead levels in the nursery classroom of a London local authority school built in the 1920s (Horner, 1994). In the school study, mean lead concentrations of four of six paint surfaces sampled exceeded the 5,000 ppm Safety Level. The highest paint surface mean lead concentration was just over 26,000 ppm with the highest sample concentration being just over 29,500 ppm. Generally, concentrations were similar to, but slightly lower than, concentrations determined in housing of a similar age. Older properties had considerably higher concentrations than the school. This is perhaps not surprising in view of the fact that local authorities have almost certainly been more aware of the hazard from old leaded paints than most private housing landlords. The higher concentrations found in the older flats, coupled with the fact that private tenants or home owners will often be unaware of the hazard, means that lead poisoning is more likely to occur from exposure to leaded paint in private homes. For this reason, the intention is to conduct further monitoring of lead in paints in older homes to estimate the extent of the potential hazard in the UK. Monitoring would also be useful in other countries, especially those with less well developed Regulations controlling the lead content of paints.

The range of paint lead concentrations found in this study is similar to the range (20-309,713 ppm) found in interior house paint samples in California (Sutton *et al*, 1995) and likewise the highest concentrations were found in the oldest homes. The authors concluded that a hazard is posed because redecoration and or behaviour of children may lead to exposures. Mean paint lead concentrations for the two houses with the highest levels are similar to the lead concentrations (c.130,000 ppm) of paint in the New Orleans house study referred to in the Introduction in which children suffered lead poisoning (Mielke *et al*, 2001). The study concluded that 'all cities should prepare plans to manage the reservoir of accumulated metals in paint, dust and soil to improve environmental conditions for families living in older homes'. They recommended that old paint should be tested for lead before major redecoration schemes commence. They suggested that power sanding which spreads contamination should be banned in New Orleans (where there are many old wooden houses) and that scraping followed by careful cleaning is a safer method for removing old paint. As Campbell and Osterhoudt (2000) point out, parents should receive more education on lead exposure pathways, hygiene and housekeeping measures to prevent ingestion of lead contaminated dust and soil (primary preventative action). They also recommended screening young children for lead in blood in a targeted manner as did Limbos *et al* (1987). It is possible to treat children with elevated blood lead levels with chelating chemicals that act to eliminate lead from the body. However, ultimately it is preferable for Environmental Health Officers and others to take primary preventative action aimed at reducing lead exposure rather than taking secondary preventative action by screening children at risk or tertiary action by treating those with elevated blood lead levels.

It is recognised that the data presented in this paper is limited in quantity. However, it does confirm findings of previous studies in that the content of lead in paint in some older UK housing is shown to greatly exceed recommended 'safety levels'. It was not an intention to provide significant new insights regarding the hazard from leaded paints, but more importantly to serve as a reminder to environmental health practitioners that lead in old paints still presents a potentially serious health threat. Therefore, it is hoped that when considering unexplained behavioural problems or illness, environmental health practitioners will not overlook the possibility that lead poisoning from old paint or paint dust could be the cause. Furthermore, it is also hoped that this work can be followed up with more detailed studies and that further research might be stimulated to investigate the risks that leaded paints pose, particularly to young children. Two projects currently being considered are firstly an investigation to determine whether lead in house paint concentrations correlate with lead in house dust and children's blood lead levels. Secondly, a study to ascertain whether the hazard posed by leaded house paints is more common in countries where controls are less developed.

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Common cold transmission in commercial aircraft: Industry and passenger implications

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Abstract:

An impression exists among frequent fliers that colds and flu are more prevalent after flying than from normal ground level exposures. A recent, well designed survey of adult passengers on 2½ hour flights established that an average of 20% self-reported colds were experienced by these travellers when questioned 5 to 7 days after the flight. We have taken the details of these survey results and compared them with the relevant frequency of colds, 2.2, or 2 to 4 colds per person year, experienced by ground level adults by converting these to common units. When the scenarios of 6 days, 24 hours, or 5 hours were taken as the relevant flight exposure times to colds, passenger transmission rates for colds of 5, 23, and 113 times the normal daily ground level transmission rate were obtained. Primarily for internal verification purposes annual infection rates were also calculated by a somewhat different method to give aircraft transmission rates of 12, 60, and 350 colds/person year for the same flight exposure scenarios. Recent published tuberculosis transmission rates are also compared and found to be substantially greater for aircraft passengers than for ground level adults. This revealed an exception for cockpit crew for whom tuberculosis transmission could not be demonstrated, which we attempt to explain.

As a result of this analysis, recirculation of aircraft air was confirmed not to be a significant factor. However, reduced resistance to infection from the usual very dry cabin air and fatigue, coupled to the small cabin air space per person, and low outside air replacement rates of newer aircraft could have contributed to the very high cold transmission rates observed.

Key words: Aircraft cabin air quality; colds; environmental health; ground level transmission; tuberculosis.

Introduction

There is a widespread public belief that commercial aircraft travel increases the risk of developing upper respiratory tract infections. Such colds also are thought to be more common in passengers today because of the greater use of recirculated cabin air for ventilation.

Interestingly, a recent survey of the subsequent cold development of 1,100 passengers, flying from San Francisco Bay, California to Denver, Colorado in aircraft using either 100 percent fresh air or some recirculated cabin air, conducted by Zitter and colleagues (Zitter *et al*, 2002), permits both of these widely held beliefs to be evaluated.

Are Aircraft Passengers More Susceptible to Colds?

The frequency of upper respiratory tract infection in non-fliers must be established before it can be determined whether, or not, flying increases susceptibility to colds. Fortunately, Reid and coworkers (1953) studied upper respiratory tract infections in 131 Greater London adult daily bus or train commuters, finding that they experienced an average of 2.2 colds per year (Table 1.0)(Reid *et al*, 1953). Similarly, Fendrick and coworkers (2003) conducted a nationwide telephone survey of 4,051 United States households, during the period November 3, 2000 to February 12, 2001, in an attempt to establish the annual incidence of colds. They concluded that the average American experiences some 2.5 colds each year (Fendrick *et al*, 2003). This figure, similar to that of London commuters, is consistent with the US National Institutes of Health's estimate that the average American adult of working age should expect to catch between 2 and 4 colds each year (NIH, 2001).

Taken together these three sources suggest that the normal adult catches 0.6 to 0.8 colds per 100 days, or roughly 1% per person day. Given this rate of

Table 1.0 Reported Transmission Rates for Colds by Ground Level Adults

Circumstances	Incidence of colds as specified	Exposure time scenarios	Infection rate, colds/person year
Normal Ground Level Experience:			
131 adults of Greater London	2.2 colds/person year all daily commuters to work by bus, rail and underground tracked for 1 year (Reid *et al*, 1953)	Bus commuters: 257 h/year (11 d/year) from ca. 70 min/day × 200 d/year ÷ 60 min/h Train commuters: 367 h/year (15 d/year) from ca. 110 min/day × 200 d/year ÷ 60 min/h	2.2 (actual experience) 2.2
Telephone survey of 4051 U.S. households in 2000-2001 for self-reported incidence of viral respiratory tract infections	Average of 2.5 colds/person year	Results correlated with absenteeism estimates from National Health Interviews Survey data (Fendrick *et al*, 2003)	2.5
Average for healthy American adults, children and the elderly excluded (IH, 2001) Winter infection rate about twice the summer rate.	2-4 colds/person year Winter: 6 months @ 4 colds/year gives 2 colds Summer: 6 months @ 2 colds/year gives 1 cold	Winter: 4 colds/person year Summer: 2 colds/person year	3.0 (year round average)

infection by the 200 or so viruses known to cause common colds, it might be expected that some 1% of working adults would become infected on any given day. It is recognized, of course, that the incidence of upper respiratory tract infection may show geographical and temporal variation, altering from place to place and throughout the year. However, there is little available data that suggests major spatial or seasonal differences in cold incidences.

Ideally, surveys of the impact of air travel on the transmission of colds should be conducted using a large sample of passengers supplying cold incidence information for several weeks prior to and after flying. Probably because such a survey would be expensive and time consuming, it has yet to be undertaken. Nevertheless, the data on subsequent colds developed by 1,100 aircraft passengers, flying between San Francisco Bay and Denver, suggests that air travel increases susceptibility to upper respiratory tract infections. The 2½ hour flight itself represented 4 to 5 hours of associated exposure to which must be added the 5 to 7 days that passed after flights were concluded but before cold data were collected (Zitter *et al*, 2002). As shown from the available information from London commuters (Reid *et al*, 1953) and Fendrick and colleagues' (2003) US nationwide telephone survey, a similar sized hypothetical control group of non-flyers would normally have experienced a 4% incidence rate for "new" colds during such a time period. This compares with the 20% incidence rate for upper respiratory tract infections experienced by those flying between San Francisco Bay and Denver. Although Zitter and coworkers (Zitter *et al*, 2002, Zitter, 2002) attempted to explain away this apparently greater susceptibility to cold infection by aircraft passengers by claiming that their survey had been conducted at the height of the cold season, their argument seems unconvincing and it is more likely that the public perception that flying promotes colds is correct.

It is possible to use Zitter and colleagues' data (Zitter *et al*, 2002) to examine in more detail the hypothesis that flying promotes cold transmission. If, for example, flight exposure is considered to be the entire 6 day period between passenger boarding and subsequent interview then the cold transmission rate can be calculated at 3.33% per day, roughly 5 times that of the normal daily non-flying transmission rate.

If, however, flight exposure time is viewed as one 24-hour day, then such aircraft travel appears to result in a 16.5% infection rate per day. To calculate this the average ground level cold transmission rate of 0.7% per day must be multiplied by 5 to represent the time elapsing after flight but before telephone survey and subtracted from the 20% cold incidence rate recorded by Zitter and colleagues (20%/day - 3.5%). Under these assumptions, the flight cold transmission rate would appear to be some 23 times that normally experienced by ground level adult commuters.

Table 2.0 Survey Measured Cold Transmission Rates by Aircraft Passengers

Circumstances	Specified incidence of colds* by passengers	Exposure time scenarios	Infection rate, colds/person year
Self Reported Incidence of Colds (least restrictive criteria)			
1100 passengers surveyed, flights during Jan-April, 1999, San Francisco & Oakland to Denver, CO, children < 18yr excluded (Zitter *et al*, 2002)	19-21%*, self reported 5-7 days after initial survey contact	i Sweeping, (0.2 colds/person 6d) ÷ 6 × 365 d/year	12.2
		ii Conservative, ((0.2 colds/person day - (5 × 0.7%/d)) × 365 d/year	60
		iii Focussed, ((0.2 colds/person 0.2 d × 5) − (6 × 0.7%d)) × 365 d/year	350

* *Colds or related symptoms (Zitter et al, 2002).*

In contrast, if it is assumed that any air travel-related increase in cold incidence stems only from the 5 hours spent boarding, deplaning, and in the aircraft, then the transmission rate for this period is 15.8%/0.2d (20%/6d − (0.7% × 6d)) for the air travel itself. Multiplying by 5 gives a daily transmission rate of 79%/day (15.8%/0.2 day × 5), which amounts to 113 times (79%/day ÷ 0.7%/day) the normal daily ground level experience. Analysis at this level of exposure clearly confirms that the colds transmission risk during travel as an aircraft passenger is very high. For internal verification of our methods, and not intended to reflect realistic yearly extrapolations, these daily estimates of transmission rates have also been calculated on an annual basis by a somewhat different method (Table 2.0). These results are entirely consistent with the calculations on a daily basis.

Even using Zitter and coworkers' (2002) most restrictive criteria to identify which passengers subsequently developed colds, flying between San Francisco Bay and Denver still appears to have been associated with an infection rate of 15 times (10.8%/day ÷ 0.7%/day) the daily ground level transmission rate, equivalent to 56 colds/person year on an annual basis.

Does Aircraft Cabin Air Recirculation Increase Cold Susceptibility?

Interestingly, the passenger survey conducted by Zitter and coworkers suggests that cabin air recirculation has little impact on the incidence of colds. Nineteen percent of passengers on aircraft that recirculated cabin air, for example, developed post-flight respiratory symptoms compared to twenty-one percent of those flying on aircraft that did not (P = 0.34). The figures for reported runny noses and colds were similarly non-significant (P = 0.70) at 10% and 11% respectively. It would appear, therefore, that the public belief that recirculating air in passenger aircraft increases the incidence of upper respiratory tract infections may be incorrect.

However, a higher than normal viral load is likely to be experienced by aircraft passengers and cabin crew as a consequence of the much lower rate of outside air ventilation per person in modern aircraft than for any other ground level or transport public space (Hocking, 1998, 2001). To illustrate, other public spaces routinely provide 7 to 14 L/s of outside air per person, while aircraft built in the 1980s and 1990s supply those flying with only an average of 4.8 L/s (Hocking, 2002). It seems inevitable that this reduced rate of provision of outside air in more modern aircraft has been associated with a decline in quality and a rise in viral load.

Support for a contribution to high colds transmission rates from low outside air flow rates in aircraft is provided by recent experiments involving occupants of an office building who were unaware of ventilation changes (Wargocki *et al*, 2000). Outside air flow rates were varied between 3, 10, and 30 L/s per person for 4.6 hour periods. At the lowest flow rates occupants had the perceptions of higher intensity of odour and of less fresh, drier air, and also found it more difficult to think. They also generally felt in poorer health at the low flow rates than at the higher levels of provision of outside air, that is they suffered the symptoms of sick building syndrome.

Possible Causes of the Elevated Incidence of Colds by Aircraft Passengers

Aircraft with full passenger loads provide the smallest volume of available air per person of any public space (Hocking, 1998). As a result, the transmission risks of microbiota between overlapping personal airspaces, and from direct person-to-person contact are substantial. Experts in aerospace medicine agree that transmission of contagious diseases like upper respiratory tract infections is facilitated by person-to-person contact in an enclosed space, such as an aircraft passenger cabin (American Medical Association, 1998; Aerospace Medical Association, 2002; Rayman, 2002). Clearly this pathway could be a contributing factor to the high cold transmission rates observed.

If the greater incidence of colds suffered by aircraft passengers were due to exposure to a generally higher than normal viral load, one might expect that there would be a statistically significant increase in colds amongst those passengers breathing recirculated cabin air, but as already described this appears not to be the case (Zitter *et al*, 2002). It seems more likely, therefore, that the higher incidence of colds reported by recent aircraft passengers, may be due to a decline in their ability to resist infection while flying. The natural human defence system against colds is known as the Mucociliary Clearance System, which consists of a layer of thin mucus that is kept in motion by beating cilia. This protective system traps viruses and bacteria and moves them from the nose and throat to destruction by acids in the stomach. However, when the air is dry, the mucus becomes too thick to be effectively moved by the cilia. This leaves more viruses and bacteria to cause upper respiratory tract infections. The typical relative humidity in aircraft cabins for flights over an hour is below 10% for most of the journey, often dropping to less than 5% on longer flights. It has been shown experimentally, using saccharin, that under these conditions the Mucociliary Clearance System either slows dramatically or stops (Barry *et al*, 1997, Salah *et al*, 1988). This would suggest that it is the low relative humidity in aircraft cabins that increases susceptibility to colds rather than a higher viral load in the air.

There is growing evidence in the literature to support the belief that bacteria and viruses are more likely to cause infection during air travel. To illustrate, tuberculosis is caused by the bacterium M. tuberculosis and an active carrier of this pathogen would be expected to infect roughly ten people a year (Shnayerson & Plotkin, 2002). However, on a flight from Paris to New York in the Fall of 1998, a Ukrainian passenger with active, drug-resistant TB infected 13 other passengers who sat in his vicinity (Shnayerson & Plotkin, 2002). In this case bacterial transmission on board an aircraft (type not identified) was evidently far higher than typical ground level experience.

Similarly, a Boeing 747-400 aircraft on a 14 hour flight carried 308 passengers, one of whom suffered from highly infectious tuberculosis (Wang, 2000). It proved possible to subsequently contact and test 277 of these passengers, 9 of whom showed conversion. In 3 of these 9 contacts the possibility of transmission from the index patient could not be ruled out (6 had one or more other risk factors). Nevertheless, flight exposure-related TB conversion in this event appears to have been some 1.3% (3/225), much higher than the normal ground level transmission.

Implications and Suggestions

Taken as a whole, the evidence appears to suggest that aircraft passengers do indeed develop colds with a higher than normal frequency in the week following their flights. However, this seems more likely to be due to the depressed humidity of cabin air or to an inadequate provision of outside air, than to its recirculation. Substantial overlap of personal air spaces causing mixing of these, and high person-to-person contact could also be factors, as explained earlier. It would be possible, although not simple, to conduct survey tests of each of these hypotheses to determine the possible significance of these air quality variables. Aircraft specially modified to increase the relative humidity of the cabin air to the normal comfort level of about 20% (Wang, 2000), both with an outside airflow of 7.1 L/s person (15 cfm/person), and with an airflow of 3.5 L/s person (7.5 cfm/person, about one-half of the office building standard) would be needed. These aircraft should be operated on a common route to that used by conventionally-equipped aircraft to minimise other variables. An attempt to correlate colds transmission with the lengths of flights of aircraft using the same amounts of outside airflow per person and humidity could also provide useful answers (Nagda and Hodgson, 2001). To be meaningful, these research projects would need to be on at least the scale of the impressive survey conducted by Zitter and colleagues (Zitter *et al*, 2002).

If one or both of the humidity or outside airflow hypotheses were found to be correct, improving these aircraft cabin air quality factors may prove to be extremely beneficial in lowering the incidence of in-flight, or post-flight infections. Promise of the potential benefit from increased humidity is seen from the anecdotal reports of the apparent effectiveness of the use of personal nasal mist dispensers such as Rhinaris, or Otrivin, or even a mist dispenser containing distilled water, or of antiseptic creams such as Secaris, in reducing the incidence of flight-related illness (Ross, 2002; Nykodym, 2002). The wearing of an appropriate, well fitted filter face mask, which became commonplace during the Severe Acute Respiratory Syndrome (SARS) outbreak of Spring 2003 (Zurer, 2003), would also have maintained a much more humid breathing micro-environment for the wearer (Hocking, 2002).

Superficially, it would appear to be relatively simple to increase the humidity of aircraft air. However, as found by British Airways during humidification experiments conducted on Boeing 747-100/200 aircraft in the 1980s, problems arose, mainly from solutes blocking water passageways and spray bars, (Bagshaw, 2003) (De Ree *et al*, 2000). Not infrequently during these tests, solutes also caused the air conditioning system to spray small white pellets along with the air supply, particularly to the flight deck. As a result of these difficulties, it was only possible in this study to maintain the mean relative humidity above 10% for three of the twelve British Airways flights (De Ree *et al*, 2000). This marginal increase meant that no conclusions could be drawn on the effectiveness of humidification from these tests.

It is possible that the humidification problems could be solved, without introducing new difficulties, by using de-ionised water. However, even using such essentially solute-free water, there could still be operational difficulties associated with the raising of cabin humidity, such as the risks of moisture condensation and freezing already occasionally observed on the very cold inner surfaces of aircraft pressure shells at cruising altitudes (Sloan, 1999). Also the potentially increased operating cost of a reduced payload equivalent to the mass of water required for the in-flight humidification process itself, would have to be considered to safely test this option.

Fuel costs for the compression of outside air to cabin pressures are estimated to be US$0.33 per hour to provide 7.2 L/s person (15 cfm/person) and US$0.22 per hour to provide 4.7 L/s person (10 cfm/person), based on a jet fuel cost of US$0.52/L (Hocking, 2002). In 1984, it was estimated that the fuel for aircraft ventilation amounts to 1 to 2% of the total operating fuel costs (Lorango & Porter, 1984). Some years ago, the Douglas and Boeing aircraft companies reported 0.0009 or 0.015 US gallons of jet fuel per hour was required for each cubic foot per minute of outside air supplied for ventilation of aircraft (NRCC, 1986). With the improved overall efficiencies now achieved by the newer fan jet engines, the present ventilation fuel consumption should have dropped to somewhat less than these figures. To provide some recent perspective to the older figures, the fleet-wide specific total fuel consumption figures of 5.2 and 6.2 L/100 passenger km have been reported recently by Lufthansa, and the Scandinavian Airlines System, respectively (Lufthansa, 2000; SAS, 2000).

Conclusions

Fendrick and coworkers recently calculated an US $80 average cost of respiratory tract infection (Fendrick *et al*, 2003). This suggests that, given the relatively low expense, increasing air humidity in passenger aircraft would have a very positive benefit to cost ratio. Clearly, the issues discussed in this article are of considerable economic significance. If, in future studies, a substantial reduction of colds transmission were observed from the resumption of increased outside air flows, and/or from an increase of the relative humidity to the 20% comfort level (Wang, 2000), then the societal cost saving from adoption of such strategies would be far higher than the societal costs of implementing these air quality improvement measures.

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The bioaccumulation of tungsten and copper by organisms inhabiting metalliferous areas in North Queensland, Australia: An evaluation of potential health implications

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Abstract

Aspects of the mining history of major metalliferous sites in North Queensland, Australia are described by reference to areas which formerly were important in the production of metals such as tungsten (wolfram) and copper. Bioaccumulation in organisms inhabiting three derelict polluted areas, within this arid open savanna region, is discussed and potential toxicological implications are described. Certain plant species are noted to possess excessively enhanced bioaccumulatory capacities and the cations within these forage plants may affect herbivorous species such as cattle; skeletons of such herbivores are found to exhibit enhanced metal concentrations. Ultimately humans may be recipients of these toxic elements and some health effects are considered.

Key words: Copper, bioaccumulation, environmental health, tungsten /wolfram, toxicology.

Introduction

Bioaccumulation has been described by various workers. Thus Bowell and Ansah (1994), working in Ghana, reported that the distribution of essential nutrients was largely affected by bedrock geology and that the geochemical dispersion of some elements was affected by soil and hydromorphic processes. Iron, manganese and cobalt were recorded as largely fixed in the soil mineral fraction whilst copper and manganese were preferentially concentrated in plants. They found copper uptake to be antagonistic to zinc, iron and molybdenum accumulation in the plants they investigated. In eastern Zimbabwe, Jonnalagadda and Nenzou (1997) studied some spoil tips and reported enhanced concentrations of arsenic in the leaves of Amaranthus hybridus.

Pyatt (1999), Pyatt and Grattan (2001) and Pyatt *et al.* (1997, 1999a/b, 2000) have demonstrated that cations including copper and lead, in areas such as arid parts of Jordan, not only bioaccumulate in organisms and through trophic levels but, additionally, show partitioning in different tissues of the same organism.

The current research programme seeks to explore the bioaccumulation of tungsten (wolfram) and copper derived from the exploitation of these elements within approximately the last 100 years in arid areas of North Queensland, Australia. Little information in this area of toxicological research has previously been published.

The Sites

Plimer (1997) noted "for some time the whole of the Cairns hinterland has been a significant producer of tin (at Irvinebank, Herberton, Mount Garnet, Ravenshoe, for example), tungsten, molybdenum and bismuth (Wolfram Camp, Mount Carbine), gold (Palmer River, Georgetown, Forsayth) and base metals (for example, Herberton, Chillagoe)".

The three sites selected for this research investigation are located within North Queensland, Australia. Mount Carbine lies approximately 140 km, by road, to the north - west of the important coastal resort of Cairns. Chillagoe lies approximately 218 km to the west-south-west of Cairns whilst Mungana is located approximately 16 km. to the west of Chillagoe. The sites, which are considered in more detail below, have an important history in terms of cation extraction; thus Mount Carbine provided tungsten (wolfram), Chillagoe was important for its copper (and lead) smelters whilst Mungana was a major site of copper mining and provided ores for the Chillagoe smelters.

Mount Carbine

Anon (2002) noted that the mine at Mount Carbine was established in the 1880's when wolframite was discovered on the hill. In 1919 the world wolframite market collapsed and production ceased to eventually recommence in 1968 when R. B Mining negotiated option agreements for the purchase of the leases. In recent times however, the mine, as a consequence of low tungsten prices, has not been operational. At its peak however, this was one of the world's major producers of high quality wolframite and generated 1500 tonnes of wolframite (a tungstate of iron and manganese) and scheelite (a tungstate of calcium) concentrate per annum. Both are essential, for example, in the steel industry for the manufacture of wear-and heat-resistant steels as well as in the tungsten carbide industry for manufacturing cutting tools (Anon, 2002). An additional use of tungsten is in the production of filaments for light bulbs.

Two sites were selected; a white tailings area and the sealed off former mining site on the hill; these sites are located approximately 0.8 km. apart. The area is dominated by dry savanna vegetation and is separated from the tropical coast by the Great Dividing Range located to the east. The tailings area is largely devoid of vegetation but there are occasional plants of Eucalyptus melanophloia (silver leaved iron bark), Eucalyptus erythrophloia (blood wood) and Triodia grassland. The tailings area is occasionally grazed by Brahman cattle; the region of earlier deposition of waste is characterized by a low biomass per unit area together with a limited biodiversity. The area (hill) around the former mining extraction activities has a greater biomass per unit area and a greater biodiversity than the tailings area as much of the richer material was formerly removed and deposited in the tailings area.

Chillagoe and Mungana

Plimer (1997) notes that various ores have been located in the area including cuprite, azurite, malachite along with calcite and massive deposits of copper sulphides. The large smelters at Chillagoe were constructed between 1900 - 1901 to service a variety of mines in the area including Mungana, Calciver and Muldiva and operated intermittently until 1943. Ore was transported from the various mines and smelting was employed for the production of copper and lead. Information boards at the abandoned site note that the smelters, and associated plant, were dismantled in the 1950's. Approximately 60% of the ore smelted was extracted from the Girofla and Lady Jane mines at Mungana; the ore contained copper, lead and sulphur as main ingredients. Bolton and Kerr (1998) noted that the Chillagoe Smelters were in pre World War 1 Queensland, major metallurgical developments. "Up to World War 1, 600,000 tons of ore were smelted from the Chillagoe and Etheridge fields for the production of 23,272 tons of copper, 31,758 tons of lead, 4,345,309 ounces of silver and 28,911 ounces of gold".

The Chillagoe and Mungana areas also lie to the west of the Great Dividing Range and are similarly characterised by dry savanna vegetation in which species of Eucalyptus are well represented. The limestone area is dominated by scrubby vegetation containing deciduous tree species which lose their leaves during June and July when the climate is extremely dry. Additional species include bats-wing coral tree (Erythrina vespertilio), and kurrajong (Brachychiton spp). Queensland Government (2000) noted that the following species are also present: native buahinia (Lysiphyllum hookeri), helicopter tree (Gyrocarpus spp), ghost gum (Eucalyptus papuana) together with various species of fig trees.

The Mungana mines are aligned along a zone extending for approximately 3km. from Mungana to the south-east and include the Girofla, Lady Jane, Griffith, Dorothy, and Magazine Face mines (De Keyser and Wolff, 1964). Broadhurst (1953) indicated that total production from these mines was 31,831 tons Pb, 7907 tons Cu and 3,228,000 ounces of Ag from 333,591 tons of ore; massive environmental effects of such activities are conceivable.

The main plant species investigated

Eucalyptus melanophloia F. Muell (silver leaved Iron bark) has been described in detail by Brooker and Kleinig (1994) and by George (1988). Trees grow to 25m and possess a rough bark coloured dark grey to black and is deeply furrowed. Brooker and Kleinig (1994) continue: "Juvenile leaves opposite, ovate to orbicular, often cordate, glaucous, concolous. Adult leaves opposite, ovate to broadly lanceolate, apiculate; lamina 5-9 cm. long, 2-3 cm. wide, glaucous; lateral veins faint, at 40°-55°; intramarginal vein up to 2 mm. from margin; petiole very short or absent. Conflorescence terminal, sometimes axillary, peniculate; umbels 7 - flowered; peduncle terete or quadrangular, 4-16 mm. long; pedicels 1-7 mm. long. Buds fusiform, glaucous; operculum conical, 3-4 mm. long, 3–5 mm. wide; hypanthium obconical, 4-6 mm. long; 3-5 mm. wide. Fruits hemispherical, ovoid or urceolate, 3-8 mm. long and wide, glaucous; disc broad; steeply descending, valves 3 or 4, level or slightly exerted.

Distribution

Occurring widely in Queensland from Brisbane to east of Charleville and northward to north of Chillagoe, occurring as a small mallee south of Mt. Isa; also widely distributed from the western slopes of the northern tablelands of NSW to north of Bourke"

Experimental Procedure

Material was obtained, in the case of the iron bark trees (Eucalyptus melanophloia), from trees of comparable size and health. Samples of wood and leaves were collected at the same height and comparable exposure. Portions adjacent to incisions with the metal scalpel (possibly contaminated by the blade) were eventually discarded and the remaining material was subsequently analysed. All material collected from the three sites was air dried in Cairns and transported to the laboratory in clean polythene bags, (double wrapped and sealed). In the laboratory, samples of Eucalyptus, Triodia, bone (from material of similar size), termites and faeces samples were washed to remove any remnant superficial contaminants using several applications of deionised water, they were then air dried in a new drying cabinet which had been thoroughly washed to be free of metalliferous contaminants. Samples were weighed and digested using nitric acid and were then analysed by ICP-AES. The results are derived from five replicates in each case and are presented in terms of parts per million.

Table 1.0 Tungsten and copper (ppm) in samples of vegetation, animals and soils from metalliferous sites in North Queensland, Australia and control data from Quarantine Bay.

Mount Carbine, North Queensland		**W**	**W^{ct}**	**Cu**	**Cu^{ct}**
Tailings					
Spoil 0 - 5 cm		59.3	N/A	1.3	N/A
			0.1		6.6
Spoil 5 - 15 cm		78.4	N/A	1.4	N/A
			0.1		9.1
Eucalyptus melanophloia	leaves	13.6	0.1	2.4	0.7
E. melanophloia	young stems	2.9	0	1.6	0.3
E. melanophloia	old stems	4.3	0.1	2.1	0.5
Triodia grassland		379.4	6.6	8.7	1.6
Termites		19.8	0.1	1.5	0.2
Cow scapula		34.3	0.2	6.5	0.3
Cow femur		28.6	0.1	6.4	0.2
Cow faeces		37.8	0.1	5.8	N/P
Kangaroo faeces		36.1	N/P	5.8	N/P
Spoil tip area					
Spoil 0 - 5 cm.		24.7	N/A	1.2	6.6
			0.1		
Spoil 5 - 15 cm.		60.0	N/A	1.4	9.1
			0.1		
E. melanophloia	leaves	6.9	0.1	2.4	0.7
E. melanophloia	young stems	1.3	0	1.5	0.3
E. melanophloia	old stems	2.7	0.1	2.0	0.5
Triodia grassland		201.1	0.6	8.6	1.6
Termites (1)		5.3	0.1	1.5	0.2
Cow scapula (1)		9.6	0.2	6.1	0.3
Cow femur (1)		9.2	0.1	6.1	0.2
Cow faeces (1)		12.7	0.1	5.6	0.1

N/A: Not appropriate – data is derived from soil
N/P: Not present
1 Not available on enclosed abandoned site; samples obtained c. 200m from site.
W^{ct} Control samples collected from non-polluted site at Quarantine Bay, North Queensland. Tungsten values.
Cu^{ct} Control samples collected from non-polluted site at Quarantine Bay, North Queensland. Copper values.

Table 2.0 Tungsten and copper (ppm) in samples of vegetation, animals and soils from metalliferous sites in North Queensland, Australia

Chillagoe, North Queensland		**W**	**Cu**
Abandoned copper smelter site			
Spoil 0 - 5 cm		0.6	9005
Spoil 5 - 15 cm		0.9	12604
Eucalyptus melanophloia	leaves	0.1	1335
E. melanophloia	young stems	0.1	987
E. melanophloia	old stems	0.1	1016
Triodia grassland[1]		9.7	7514
Termites[2]		0.6	1374
Cow scapula[3]		1.4	2415
Cow femur[3]		1.3	2111
Cow faeces[3]		1.3	2378

[1] 200 m. from main smelter site
[2] 200 m. from main smelter site
[3] 200 m. from main smelter site

For control values, see Table 1.0

Results and discussion

These results are presented in Tables 1.0, 2.0, and 3.0 and consider material from both autotrophs (e.g., Eucalyptus) and heterotrophs/herbivores (e.g. cattle).

Both soils in the Mount Carbine area and those in the Chillagoe/Mungana area, despite decades of potential weathering processes, still exhibit high quantities of the elements which were formerly mined (Tables 1.0, 2.0 and 3.0). Values are massively enhanced compared with control material obtained from the Quarantine Bay area to the north-north-east of the site.

From Table 1.0, it is apparent that whilst tungsten is well represented in the area and in the organisms selected for study, traces of copper are also present; this area is rich mineralogically. Material of Eucalyptus melanophloia (Table 1.0) contained enhanced concentrations of tungsten especially within the leaves; this pattern is mirrored, but to far lesser extent, by the copper values. However, the Triodia grassland contained massively enhanced values of tungsten (379.4 ppm) and this would be available to herbivores such as the cattle grazing this area. This is indeed reflected by the high values found in the bones of cattle which had grazed the area (cow scapula 34.3 ppm and cow femur 28.6 ppm). Faeces of both cattle and kangaroos contained a high concentration of tungsten (Table 1.0). Cattle and Triodia are acting as important sentinels of tungsten pollution. Furthermore, it should be noted that humans are likely to ultimately be recipients of material, e.g. meat with a high tungsten content and toxicological implications are conceivable. The values in the former mining area, on the hill (Table 1.0), mirror the above findings but the concentrations are markedly diminished.

Termites, which feed especially on wood, contained rather lower concentrations of tungsten than the mammal skeletons. Browning (1961) has indicated that tungsten retention is greater in bone than other tissues; for humans the following results are presented: bone retention (up to 18 mg. per cent), spleen (up to 14 mg. per cent) with much lower values in the kidneys and liver (less than 1 mg. per cent). The values in kangaroo faeces are interesting and reflect those values found in cattle faeces. Thus it may be argued that tungsten is bioaccumulating, and being excreted by, native and domesticated animals.

Material from the Chillagoe smelter also demonstrated the presence of tungsten (Table 2.0). This will have been derived from scheelite (CaW04) which has been listed as present in the excellent text of Plimer (1997). With the exception of the spoil values (Table 2.0) and the animal bone and termite values, the tungsten concentrations are not massively enhanced compared with the control values presented in Table 1.0. The high values within the bones and the termites again reflect marked bioaccumulation through trophic levels. The high value in the Triodia grassland is again worthy of attention in biomonitoring research programmes.

Tungsten is potentially a very important environmental pollutant; Klaassen *et al.* (1996) note that carbides of tungsten emanating from the manufacture of cutting tools can cause pulmonary fibrosis and related effects. De Bruin (1976) indicates that rats exposed to various metals, including tungsten, showed enhanced leucocytary phagocytic potential whilst 'inhibition may be shown in instances of toxic ingestion.' Thus when high concentrations of tungsten are exposed in the environment, the route of dispersion, fate and bioaccumulation through trophic levels, should be given thorough attention.

In this site, copper values are massively enhanced (Table 2.0) as compared with the control values; leaves had higher values than young and old stems whilst again the values in Trioidia grassland were massively enhanced. Additionally, as noted for tungsten, the values in the skeletal samples of herbivores, located in close proximity to the smelter site, are markedly enhanced.

The Mungana data is presented in Table 3.0. Tungsten (wolfram) is still present in all samples with the exception of the young stems of Eucalyptus melanophloia. The values of copper are markedly enhanced compared with those in material collected from the control site. The copper values in organisms from this site, which exhibits recovery in terms of both enhanced biomass per unit area and indeed biodiversity, are high but unsurprisingly much lower than values obtained from the vicinity of the abandoned smelters. Recovery from the former mining activities is well advanced.

Again, high values are found in Triodia grassland and, in the case of E. melanophloia, particularly in the foliage. Cattle bone and termite values reflect the fact that copper is being bioaccumulated by these organisms. The data on the faeces illustrates that, post-grazing, copper is returned via the faeces to the pedosphere where it will eventually continue to be available to other herbivores as a consequence of re-cycling together with bioaccumulation through trophic levels. Kangaroo faeces contained a higher concentration of copper (1785 ppm) than those obtained from domestic cattle (1264 ppm); regrettably kangaroo skeletons were not observed at this time to afford an opportunity to examine bioaccumulation values.

Copper, like tungsten, is potentially a very important environmental pollutant. Whilst it is essential for life, it can become toxic to organisms in high concentrations and this toxicity is enhanced by the presence of other

Table 3.0 Tungsten and copper (ppm) in samples of vegetation, animals and soils from metalliferous sites in North Queensland, Australia

Mungana (Nr. Chillagoe), North Queensland		**W**	**Cu**
Abandoned copper mining area			
Spoil 0 - 5 cm		0.01	964
Spoil 5 - 15 cm		0.01	1408
Eucalyptus melanophloia	leaves	0.02	613
E. melanophloia	young stems	0.0	407
E. melanophloia	old stems	0.01	518
Triodia grassland		3.9	1296
Termites		0.01	17.9
Cow scapula		0.4	1459
Cow femur		0.4	1283
Cow faeces		0.4	1264
Kangaroo faeces		0.3	1785

For control values, see Table 1.0

cations. Effects on humans can include nausea, diarrhoea, convulsions and coma; these are thoroughly reviewed by Scheinberg (1991). Again, in cases where high concentrations of copper, as also noted for tungsten, are available in the environment, careful monitoring of its fate is essential to safeguard plant and animal (including human) health.

Acknowledgements

Shibani Sinha of the Reference Section, Cairns City Council for her great help in obtaining literature concerning both species of Eucalyptus and mining activities in North Queensland, Australia. Colleagues at the Fletcher Botanic Gardens for valuable discussions, Daniel and Ryan Kennedy for helpful assistance, advice and laboratory support in Australia. We also thank Dale Debel at Chillagoe (Queensland Parks and Wildlife Service) and Ian Stretch (Manager of the Mount Carbine site) for helpful advice. We are indebted to WFP of Bulwell, Nottingham for the analysis of the samples by ICP-AES.

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Public health policy – can there be an economic imperative? An examination of one such issue

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Abstract

Interventions to protect public health are usually seen as both necessary and good in themselves, intrinsically worthwhile, with public expenditure self-evidently necessary. However, such interventions are increasingly subject to some assessment as to their cost effectiveness, and whether the service provided offers Best Value. Whilst pest management services have traditionally been provided on the basis of controlling vectors of disease, increasingly the service has been subject to a more commercial approach. Indeed, as no such service is required by the Prevention of Damage by Pests Act 1949 there has been some question as to whether provision of such a service is justified. For rats it has been suggested that there may be an economic justification for proper control, even if the public health argument does not persuade local authorities to invest in an effective management strategy. This paper examines whether it is possible to assess the costs of rat damage and whether those costs justify investment in improved rat control strategies.

Limited data are available, and costs to society as a whole are fragmented. Despite evidence of infection with a range of zoonoses, there is little published evidence to enable an assessment of the costs to society attributable to ill- health due to brown rats. The total costs due to infrastructure damage are also difficult to estimate. However, a model has been constructed that estimates the cost to the economy of such damage could be between £61.9m to £209m. The size of the rodent control industry indicates that the higher figure is more likely.

It is concluded that the costs to society should include the social (including health and wellbeing) costs arising from rat infestations and that there is an economic argument for local authorities having effective control strategies for rats in place. The economics of rat control must also take into account the existence of such infestations as a reflection of poor environmental quality, endured by those who are already economically disadvantaged. Thus, reducing inequalities within the economy could contribute to reduced infestations, with savings in treatment costs.

Key words: Brown rats (Rattus norvegicus); costs; damage; economics; environmental health; infrastructure; public health.

Introduction

Asserting that an intervention is to protect public health has often been sufficient to justify expenditure; sometimes even where there is little current direct evidence that public health will be enhanced by the intervention. Increasingly, unless the public health risks are seen as sufficiently immediate and important (and this may be the result of media activity) public expenditure has to be justified on economic grounds, or utility, for instance by reducing working days lost through illness. Cost benefit analysis has been used as a method of assessing the most appropriate response to a problem, but putting a value on good health can be a problem. This is similar to environmental economics where it can be difficult to evaluate the benefits and costs of environmental pollution control. Environmental protection becomes an investment project, where present costs must be compared to future benefits (Sandmo, 2000).

Local authority pest control, in particular the control of Brown rats (Rattus norvegicus), has been seen as a public health measure, as it is both vector control, and a means of alleviating public concerns. Yet, in the context of Best Value, local authorities have been discussing whether they should be charging and in some cases whether a service should be provided at all (CIEH NPAP, 2003). Reported increases in rat infestations have been said to be, in part, related to reduced funding of control, leading to a lack of coherent pest management strategies (Battersby, 2002; Colvin et. al., 1998; NPTA, 2001; NPTA 2002). The extent of duplication within the published figures for complaints and treatments is unknown, and may be the result if increased sensitivity within society as the result of media stories.

Colvin (2001) has suggested, nevertheless, that the public should be concerned about a rising rat population mainly because the presence of rats is an economic issue and reflects a degraded environment.

DEFRA (2003), without quantifying costs, suggests that the direct and indirect costs of structural damage by rats can be high. It is well known that rats cause damage to buildings and installations, with a significant risk of fire and electrocution as the result of damage to cables (Colvin, 2001; Hall and Griggs, 1990). This paper seeks to gather information as to the cost of physical damage in the built environment, which is additional to costs of damage to stored foodstuffs, and losses due to ill-health attributable to rat-borne disease.

Thirty years ago Drummond questioned why the methods available to virtually eradicate rats from towns and cities, which had been used in Germany, were not being used in Britain (Drummond, 1970). He suggested the answer was that the need for such work was by no means self–evident and that progress could not be expected until some assessment of the benefits by comparison with the costs of control had been made.

Methodology

A search of the web was made using BIDS Bibliographic service, Ingenta and EBSCO online and general search engines Yahoo, Google, Lycos. A search of Hansard was also undertaken. These searches revealed an extremely limited literature base.

Only one reference was found using Ingenta for the period 1987 to 2002; on the effects of simulated rat damage on yields of macadamia trees (Tobin *et al*., 1997). A search using the search terms "rat damage costs" "brown rats damage economic costs" and "wild rats damage economic costs" on the BIDS International Bibliography of the Social Services (IBSS) Data Service for the period 1951 to 2002 resulted in no relevant hits.

There was direct communication with businesses thought likely to be affected. These companies were asked for information on the costs to them of controlling rat infestations and the costs to them of damage caused by rats. Letters were sent to water and sewerage companies, regional environmental managers of Railtrack, train operating companies, British Telecom and other telephone companies, London Underground and cable TV companies. A letter was also sent to the Associations of British Insurers (ABI) who did not have any information, but provided a list of member companies who were contacted directly (Wright, 1999, pers.comm.).

Results

The nature of the economic impact of rat damage

Surprisingly, the ABI has not undertaken any research into the costs of rat damage (Wright, 1999, pers.comm.) even though in the post-Second World War period US insurance companies claimed that about 25% of fires for which there was no apparent cause may have been caused by rodents (Anon, in Pest Control, 1947, cited by Meehan, 1984).

Lund (1994) has suggested that in developed countries with over-production of food crops and adequate storage, commensal rodents are controlled on grounds of hygiene and public health rather than for economic reasons, whereas in the tropics and sub-tropics the opposite is true. When wild brown rats do destroy or spoil stored food they are likely also to have damaged the container or building within which the foodstuff is stored. Gnawed pieces of wood are often one of the first indications of an infestation (Meehan, 1984). In the UK food industry there can be substantial costs due to closure where rodents are present. Meehan (ibid1984) reports costs of between £7,000 and £125,000 in the 1970s for individual companies that had to close facilities. Adjusting those costs to current prices using compound interest and an average inflation rate of 5.7% since then (Economic History Resources, 2002), would give costs of between £26,500 and £473,000. However it is also estimated that £22,000 and £389,000 have the same purchasing power today as those in 1979 (McCusker, 2003). In the retail food and catering industry, there are additional unquantifiable the costs from loss of trade resulting from adverse publicity as the result of rat incidents.

Brooks (1973) suggested that the annual bill for rodent control in the USA in the early 1970's was $100million and that the costs to society in the USA due to food losses, damage to structures, and rodent borne disease, must outweigh treatment costs to make the latter justifiable, although no direct assessment was made. Nevertheless in developed countries the cost to human society of commensal rodents must be substantial.

Burrowing rats can cause landslips on embankments and the collapse of banks of canals and ditches leading to flooding (Meehan, 1984). The monetary value of the damage caused by gnawing will depend upon what is attacked, and may depend upon the function of the material damaged and cost of repair. It is likely that much damage goes un-repaired if the disrepair to a building or service is not seen to impair its function greatly. The intrinsic value of the gnawed article may be what is important; sometimes it may be the consequence of the damage that is the cost. Burrowing rats can cause landslips on embankments and the collapse of banks of canals and ditches leading to flooding and in a Meehan (1984) reported an incident in which a rat gnawed through a lead gas-pipe, the gas leaked and an elderly person asleep in bed was poisoned Meehan (1984). Rats gnawing cables in a car production plant led to an electrical fault causing £100,000 worth of damage, including cars falling off the end of the assembly line (Anon, in Oracle, Car, 1978, cited by Meehan, 1984).

There are few data on damage caused by commensal rodent infestations around farm buildings, and so it is unsurprising there are little data on the economic impacts of urban and off-farm rat infestations. Richards (1989) reported that the most significant form of economic damage on farms came from the gnawing of electrical cables, and some 50% of farm fires have been attributed to this cause. Richards estimated that at 1989 prices all sources of damage on farms in the UK amounted to £10-20m per annum. The current equivalent purchasing power would be met by £15.3m to £30.6m (McCusker 2003).

Pimental *et al* (1999) record a particularly striking view of the consequences of rat infestation Iin the USA. They note that rrats cause $19,000,000,000 worth of losses and damage annually, with the USA being the land of a billion rats (Pimental *et al*. 1999). Further, iIt was estimated that rats on poultry farms and other farms destroy grain and other goods worth $15 billion annually. In the urban and suburban areas of the US, Pimental *et al*. (1999) suggested there is roughly one rat for every human, causing fires by gnawing electric cables and polluting foodstuffs. He There are an estimated 1 billion rats on US farms, with 250 million in cities and towns Pimental (Pimental 2000, pers.comm.). Pimental *et al*., (1999) made no assessment of health costs, although it has been shown that rats are infected with a wide range of zoonoses (Battersby *et al*., 2002). Meehan (1984) reported an instance where 70% of one ton of wheat, was spoiled by 10-26 rats over a 12-28 week period, when only 4.4% was actually eaten. Pimental (2000, pers.comm.) estimated conservatively that one rat could cause $15 worth of damage per year, giving the total of $19 billion, but this is an estimate and as Pimental, and this author have found, there is a surprising lack of data on rats and damage.

The sewerage industry and infrastructure costs

Local authority officers in England and Wales believe that a substantial proportion of aboveground infestations are attributable to defects in below ground drainage (both public and private) (Battersby, 2002).

Most water and sewerage companies in England and Wales contacted indicated they suffered little from rat damage to either premises or sewer network or were unable to quantify this. There were some instances of rodent damage to cables within underground structures, but these were isolated incidents causing minimal cost.

Taking the figures from the three companies in Table 1.0 they appear to spend an average of £37,000 on controlling rat infestations within their facilities, excluding sewers. It does not follow that the greater the length of public sewer, the greater the expenditure on rat control at treatment works, pumping stations and company-occupied land. The information available points to the water and sewerage companies spending up to £0.5m per year on rat control on their sites, and damage costs must exceed this.

In 1988/89 the level of expenditure by Thames Water on sewer baiting was £410,000 over an estimated 17,000 kilometres of sewer and 120,000 baiting points (Forbes, 1990) giving a cost of £24.11 per km baited. It is estimated that the equivalent purchasing power today would be £627,000 at £36.88 per km baited (McCusker, 2003). Thames Water has in total approximately 80,000 km of public sewer (Thames Water, 2002) and for their network as a whole the 1988/89 figures would equate to £5.13 per km (or £7.85 taking the current equivalent purchasing power)(McCusker, 2003).

Table 1.0 shows a wide variation of expenditure on sewer baiting but extrapolating the figures in column 3, the annual expenditure for all ten water companies in England and Wales could be £1.75m. Figures from Table 1.0 and those for Thames Water in 1989 (Forbes, 1990) up- rated show the average spend per company could be £5.54 per km of public sewer. The network in England and Wales amounts to 305,226 km (Wise, 2002, pers. comm.), giving the potential total spent on sewer baiting as £1.691m for the ten companies.

As Forbes (1990) indicated, much of the network in England and Wales is not subject to baiting, and indeed baiting may not be justified. Expenditure on sewer

Table 1.0 Costs to Water and Sewerage Companies in England and Wales of dealing with rats

Company	Costs of damage by rats	Annual expenditure on sewer baiting (£)	Annual expenditure on controlling rats on water company land, treatment works etc (£)	Total length of public sewers in company area (km)*	Expenditure per km of public sewer on sewer baiting (£)
1	Not given	–	60,000	30,000	–
2	Not given	300,000	40,000	53,000	5.66
3	Not given	50,000	10,000	16,000	3.13

**Source: Wise, 2002, and OFWAT W2000 JR-2000-01* baiting can also be assessed utilising the proportion of Thames' sewers baited, as 21.25%. The current equivalent value for the cost to Thames in 1989 is £36.88 per km of sewer baited, and if all ten companies bait the same proportion of the national network now (64,983km), the current cost would be almost £2.4m. It has been estimated more recently that the average cost per person per annum for rodent control in sewers in the UK is 4.5p (UKWIR, 2000). For England and Wales with a population of 52.042 million (National Statistics, 2003) that would amount to £2.34m. Other figures from the UKWIR study though have indicated that sewer baiting by utilities on a reactive basis costs £2.32 per km of sewer, and is seen as more 'cost effective' than a current 'proactive' strategy at £8.65 per km or a combined strategy of £10.17 per km (UKWIR, 2000). It has been argued that the costs of separately operating combined and proactive strategies of £10.95 per km suggest that a proactive strategy only slightly reduces the need for reactive action. This assessment indicates that sewer baiting cost savings by the water industry could be substantial. The total spend, if only reactive baiting is undertaken will be £150,761, assuming the same proportion of sewers is baited as Thames in 1989. At best this represents only just over 6% of the potential expenditure if all ten companies currently operated as Thames Water did in 1989

It has been estimated that 339,000 domestic premises were treated for rat infestation in 1997/98 (Battersby, 2002). It has also been assessed that the number of infested premises may be between 373,400 (England only; Langton, *et al*., 2001) and 995,900 (England and Wales; Meyer *et al*., 1995). Up to 40% of the infestations may emanate from underground drainage (both public and private) (Battersby, 2002). This indicates between 149,360 and 398,360 drainage defects. Even where rats have not caused the initial defect, they may have exacerbated the effects by gnawing and burrowing, undermining the drains and sewers. A true figure is not known, but if this occurs in 10% of cases that implies that in 15,000 to 40,000 cases, rats may have caused or exacerbated damage to the sewerage infrastructure.

A minimum average repair cost as £150 (Davis et. al., 1997) would yield the lowest estimate for the cost of rat damage to the sewerage infrastructure in England and Wales (public and private) as between £2.24 million per year to £5.98 million. The average drain and sewer repair is more likely to cost about £500, implying an annual bill to the economy of up to £19.92 million. However, as the drains and sewers may appear to be "serviceable" for some time, many of theses defects will go un-repaired, so costs will be deferred, even though there may be infiltration, or even pollution of groundwater.

Telecommunications

Only one telecommunications company contacted had considered the problem and had an early warning system and comprehensive control plan to protect those premises that are at risk of pest infestation. That company spent approximately £10,000 per year across the UK on its pest prevention services.

The rail network and costs

None of the responding train operating companies provided information. Discussions with a representative of a regional office of Railtrack plc (Harrison, 2000, pers. comm.) made it clear that rats gnaw through cabling and have affected signalling. It was alleged that litter thrown from passing trains or from station platforms attracts rats, which then gnaw through the cabling materials. Railtrack plc incurred costs both in the control of rats, and as the result of damage caused by rat infestations but no information has been held centrally (RailtrackWhite, 2000a, pers. comm.).

Information was received from the environment manager of only one region of Railtrack plc on three contract areas within the zone (RailtrackMcMurtrie, 2000b, pers. comm.). For one contract area it was reported that in 1999 there were two significant incidents attributable to rat damage, with delays of 2,500 minutes, which at £40 per minute delay (the penalty imposed by the Rail Regulator) equated to a cost of £100,000, plus rectification costs. The usual nature of damage was reported to be 660v power cables being nibbled through, with rats "particularly fond of the more modern cable types". In another area in 1999 there were 30 rat complaints from third parties. With treatment costs of £750 a time, costs of £22,500 can be implied (RailtrackMcMurtrie, 2000b, pers. comm.). The costs given excluded complaints at signal boxes and other railway owned properties.

Rodent control is a small element of the business with activity limited to reacting to complaints (RailtrackMaggs, 2000c, pers. comm.). It was confirmed that signalling was damaged as a result of gnawing by rats. They also cause power failures by lying between, and making contact with, live terminals. It was considered that rodent damage did not represent a major problem, but individual incidents could generate substantial costs to the business (RailtrackMaggs, 2000c, pers. comm.). It was estimated that a rat gnawing a power cable might cause a major "black-out" of signalling systems, which could take several hours to identify and rectify. The cost to the business could be between £2,000 and £400,000 dependent on the severity and time of the incident. It was suggested that a typical average cost would be £60,000 recorded over 10-20 incidents, yielding a total of £600,000 to £1.2m of costs due to rat gnawing. In that zone typical annual costs of reactive rodent control were £10,000.

Table 2.0 sets out the potential costs to the operator of the railway infrastructure from the information received.

Table 2.0 An assessment of potential costs to Railtrack plc and its passengers as the result of damage caused by rats on the railways (net of repair costs)

Penalties per year (£000)	+	Delays to passengers (minimum costs in lost time) (£000)	+	Treatment costs per year (£000)	=	Total costs to Railtrack plc and the public as the result of rat damage on the railways (£000)
800 – 4,800		780		80 – 180		1,660 – 5,760

Within the overall budget of the company these figures may seem relatively small when compared to track renewal costs of about £750,000 per mile (Railtrack, 2001) and in 2001 about £500 million was spent on signalling resources.

The costs to passengers who suffer delays are not considered by Railtrack's assessments. For £60,000 worth of incidents, with penalties at £40 per minute, the average for a single year in one maintenance zone implies 1500 minutes of train delay (RailtrackMaggs, 2000c, pers. comm.). With an average of 350 passengers per train, that would equate to 8,750 passenger hours lost per year as the result of rat damage. If each hour is taken to be worth £11.16, the national average gross hourly income (Jenkins, 2001), the value of lost time for passengers is £97,650 for one zone. For the rail network (eight zones) the minimum total cost to passengers in England and Wales of delays caused by rat damage could be assessed as a minimum of £780,000.

Figures in Table 2.0 take no account of the costs where the railways are the source of an infestation but damage is caused elsewhere, nor of any social costs due to the upset of householders where rats move from railway property into adjoining houses and gardens.

Local authorities

The Audit Commission's Best Value Inspectorate's report on the pest control service for Wyre Borough Council (Audit Commission, 2001), reports the average "cost per job" for rodent control as £41.75. Currently, the service charges for commercial rodent work but does not charge domestic customers. The Borough Council deals with both rats and mice, but charges are the same. Using the figures for infested domestic premises from Meyer *et al.* (1995) as 995,000 this represents a potential cost of £41.5m. The lower figure suggested by the work of Langton *et al.* (2001) of 373,000 infested premises implies a total potential national treatment cost of domestic premises as £15.6m. These figures represent infested premises, but not all infested premises are treated. Meyer *et al* (1995) found a quarter of rat infested domestic properties were not subject to any control and in about 10% of cases the occupier exercised control measures. These sums represent the range of costs that council taxpayers potentially will face to treat rat-infested premises, if no charge is made by local authorities, or individuals will pay if local authorities charge the full cost. This is 10 times the sum it is estimated above could be spent on 'reactive only' sewer baiting.

Any economic assessment also has to take account of the value to the public of local authority activities. However, there is under-reporting of infestations (Battersby 2002), and evidence that complaints reduce when charges are introduced (Battersby, 2002; NPTA, 2002). This may indicate that for many householders their valuation of a rat free environment may be lower than expected. As one local authority has indicated, for April to September 2001 the introduction of a £25 charge for a "complete treatment" led to a 71% decrease in complaints (NPTA, 2001).

The rodent control industry

Products such as rodenticides represent about 6-7% of the value of a service contract for all rodents (Peck, 2002, pers. comm.). It has been estimated that the value of the public health rodenticide market in the UK is currently about £3m. The "on-farm" rodenticide market is about £2.5m, giving a total market of the order of £5.5m. Although the figures provided are for the control of all rodents, the largest proportion is likely to be for the control of rats, and this could be about 80% (Peck, 2002, pers comm).

If the market for rodenticides of £3m (off –farm) represents 6-7% of treatment costs (Peck, 2002, pers. comm.) and 80% of treatments are for rats, then total actual costs of off-farm rat treatments is assessed at between £34m and £40m. This compares with the potential treatment costs to local authorities assessed above of £15.6m to £41.5m.

The current total value of the whole rodent control market (including on-farms) could be of the value of about £85m for the service industry (Peck, 2002, pers. comm.). That assumes that all infestations are treated adequately, but there is evidence that infestations go unreported in domestic premises, and it is unlikely that in the UK all on-farm infestations are treated fully or comprehensively and so the true potential value of the market should be nearer £100m (Peck, 2002, pers. comm.) with perhaps

Table 3.0 Estimation of some of the costs facing society as the result of commensal rats

Infrastructure / area affected	Potential range of costs/values (£000s)			Value of rat control industry (£000s)
	Damage	Treatment	LA Treatment	
Railways	1,600 - 5,760	80 - 180		
Water industry	Not known	1,500 - 2,200		
Sewerage system (all)	2,240 - 19,920	n/a		
Surface infestations			156,000 - 415,000	
All society *	61,900 - 209,000			80,000

** Assessment of the cost of rat damage to society in England and Wales, using the methodology of Pimental for comparison with the assessment of the rat control industry, and the costs to major utilities.*

£80m attributable to the control of rats. This may seem substantial, so it is surprising that the government has not estimated the value of the rodent control industry either on the basis of the manufacture of rodenticide or the activities of the pest control servicing industry (Hansard, 2002a).

Overall assessment of total costs of rat damage

The information for England and Wales does not indicate that Pimental's assessment of a minimum cost of damage per rat at $15 per rat is excessive. Indeed he indeed suggests it is conservative (Pimental 2000, pers. comm.). If, for England and Wales, an equivalent figure of £10.4489 is used ($15 at a conversion rate of $1=£0.696595, (Universal Currency Converter, 2002) the cost of damage in rural and urban areas could be between £61.9m (using the population figures of 5.92 million rats from Harris *et al.*, 1995) and £522.4m if the rat population is of the order of 50 million which is unlikely. If the rat population in England and Wales is 20 million (Battersby, 2002), then the costs of rat damage could be £209m per year (Table 3.0).

Discussion

It is difficult to make an assessment of the true cost to the economy of rat damage. Little effort seems to have been made in recent years to do so, although there is some indication of costs for individual companies where a problem has been experienced. The government itself has no data on which to estimate the damage and losses either in agriculture or the food industry, the areas where it might be expected to have best information (Hansard, 2002b).

The response of the UK insurance industry (Wright, 1999, pers. comm.) might indicate few claims because there is relatively little damage or it is not an issue because claims are running at a manageable and consistent level. However, it appears not to be an issue because it is not an insurable risk in the first place, and costs are hidden. Indeed, one responding insurance company said that their standard policies, both personal and commercial, specifically exclude accidental damage caused by vermin. Another indicated that whilst providing optional accidental damage cover to domestic buildings, the cover excludes amongst other things "damage caused by vermin, insects, wet or dry rot, or fungus". That same company did provide accidental damage cover to domestic and commercial underground services without the restriction. If this is standard practice, then it is likely that claims are made on the basis of other causes of damage (misdiagnosis). Alternatively those affected make no claims and costs of rat damage are lost in other maintenance and repair bills.

Indications from England and Wales are that a reasonable assessment of the costs to the UK economy from rat damage is likely to be in the range of £61.9 million to £209m. Much of the damage caused may be relatively low value, but the lower figure is unlikely given that the minimum costs on the railways alone attributable to rats could be between £1.66 million and £4.16 million. Furthermore, given that local authority officers attribute a substantial proportion of aboveground infestations to defects in the underground drainage system, it has been calculated that the damage to the whole of the sewerage and drainage infrastructure could be between £7.5 million and £19.9 million. To put that in context, in 2000-01 the Water and Sewerage companies spent £467m on repairs and renovations to the sewerage system (OFWAT, 2001b), but only 271 km of sewers were renovated or replaced, of which 166km were the 'critical sewers', (out of a total of over 300,000 km).

The lower figure is also improbable given the value of the rodent control industry, as the costs of control are likely to be less than cost of damage.

In the context of other expenditure, the potential treatment costs for all infested domestic premises and potential costs from rat damage, the figures for expenditure on sewer baiting are small. For society as a whole, it would be worthwhile and economic to spend more on the control of rats in sewers where it can be shown to contribute to reduced aboveground infestations. The difficulty is that private companies will incur the direct costs, but they will not gain any direct benefits. Nor do the companies incur costs resulting from increased rat infestations above ground which are the consequence of inadequate baiting and disrepair of sewers.

Less is spent now than in 1989 and this must raise serious questions as to the adequacy of baiting programmes. These figures can only be estimates as no account has been taken of the differing relationships with local authorities. The indications are that there is a reduced level of baiting and rat control in sewers. The up-rated cost per kilometre for Thames Water baiting in 1989, substantially exceeds the actual 1999 figures from two other companies and the figures reported by UKWIR (UKWIR, 2000).

Even if it can be demonstrated that spending more on the control of rats in sewers will reduce aboveground infestations, that expenditure will not beneficially affect the performance of the company, nor influence the assessment of that company's performance by the Director General. Unless such expenditure prejudices the company's ability to "achieve a world-class service in terms of quality and value for customers in England and Wales" (OFWAT, 2001a) it will not be taken into consideration. The benefit to be gained by society is outside any current legal obligation.

The rodent control industry has been valued at between £80 million and £100 million, 80% of which was for rat control. This would be excessive and uneconomic if damage is only of the order of £61.9 million and economics were the sole issue. The cost of treatment would be far in excess of the damage caused. If, however, the total population of rats is 20 million, and each rat causes £10.4489 worth of damage per year, the total potential cost to the economy could be £209 million, approximately twice what is spent on control. This indicates that rats remain a pest as defined by Richards (1989), causing damage that is substantially greater than the economic cost of control.

The significance of these figures is that if damage costs are at the lower end, control expenditure levels are uneconomic. Increased expenditure on control may be argued for solely on the grounds of the protection public health. Yet, the costs of ill health cannot provide an economic justification as, despite health risks (Battersby et. al., 2002) there is as yet no direct evidence of such costs, as diagnosis of human ill health attributable to rats is not being made. If the cost of damage were at the higher end of the range, then increasing expenditure on improved controls on rat infestations would be justified.

Mishan (1994), in the context of disease control, reported one method of calculating the benefits of reducing or eliminating a disease, by estimating the current costs that will be averted such as costs of medical care, losses of current production and the pain and discomfort caused by disease. In the context of current rat control activity, such an approach appears to be impossible. Potential remains for direct adverse health effects that will have negative economic impact. These costs could be due to loss of time at work and loss of production, or by increasing demands on the medical services. As direct evidence is unavailable it is not possible to make an estimate of the economic impact of ill health resulting from rats. Any future assessment of the health impact of rats should take into account the psychological distress that can be caused to householders by infestations particularly from those within dwellings. Cost-effective analysis however does allow the estimation of the costs and benefits of employing alternative methods of implementing a politically desirable programme (Mishan, 1994) and it would be useful to apply that approach to strategies for controlling rats.

Richards (1989) suggested that the primary motivation for control remains human or animal health, and damage thresholds are set low by cultural distaste rather than for economic reasons. Public attitudes rather than economics may set these thresholds. If costs due to structural and infrastructure damage are hidden or held in a fragmented way, then it is difficult to see how any thresholds can be set. Without public pressure there might be even less activity on control, yet public attitudes may not lead to cost-effective control. Paradoxically, the public discards litter associated with fast food outlets also, thereby increasing the attraction for rats, and the future costs of cleaning and rat control treatments.

Thus far no assessment has been made of the social cost of rat infestations, that is, the cost of upset in seeing rats in and around the home. A method of assessing the importance and the negative value of rat infestations would be to survey householders by way of questionnaire. They could be asked to indicate the amount they would be prepared to pay to ensure that rats were not present on or adjacent to their land. Indeed this would be one way of local authorities assessing the value of the rodent control service. If service requests reduce when a charge is introduced, that may reflect that complainants do not value a rat-free environment as highly as may be supposed. Alternatively, they attempt to treat the problem themselves, with doubtful effectiveness leads to both current expenditure and increased future control costs when they turn to professional pest management. This is an issue that should be assessed further before the introduction of charges by local authorities, although charging may overcome duplication of complaints and service requests leading to more accurate information on infestation levels.

Economic injury level is that threshold below which control ceases to be economically justified (Buckle, 1994) and is based on the premise that the cost of control is less than the cost of losses incurred by the individual producer. In urban areas it is more than the loss of foodstuffs that adds to the economic impact. Here the goal is also the provision of an enjoyable environment rather than economic return. The term "aesthetic injury levels" has been suggested as the density at which the impact is such as to justify the cost of control (Flint & van den Bosch, 1981). It is argued that accurate determination and careful use of these levels is essential to the expansion of good pest management and the maintenance of environmental quality. Local authorities and the government may need therefore to better determine public expectation and valuation of the control of rats. This could be part of the development of a more strategic approach to rodent control generally as in some areas of poor housing, indoor mouse infestations are higher than reported in national surveys (Murphy & Marshall, 2003). In the circumstances it is difficult to know how the Audit Commission can decide on "Best Value". It can only compare relative costs of the service, making no assessment as to the real effectiveness, or whether expenditure is economically justified.

Any economic assessment of rat infestations should take into account the existence of such infestations as a reflection of poor environmental quality - indeed it may be more difficult to secure and retain inward investment in areas affected by high infestation levels, leading to further decline. When developing the blueprint for a green economy Pearce at al., (1989) suggested that a poor environment means more stress. This could contribute to more social unrest, and is a factor that should be taken into account when accounting for the quality of the environment, or lack of it as represented by rat infestations (Pearce *et al.*, 1989). Hutton (1995) argues that the key to personal wellbeing is not absolute but relative to position in society. Self-esteem of the poor falls the more that incomes are unequal in relative terms. In turn low self-esteem leads to little care for the environment and pride in the neighbourhood, which can lead to an increased rat population.

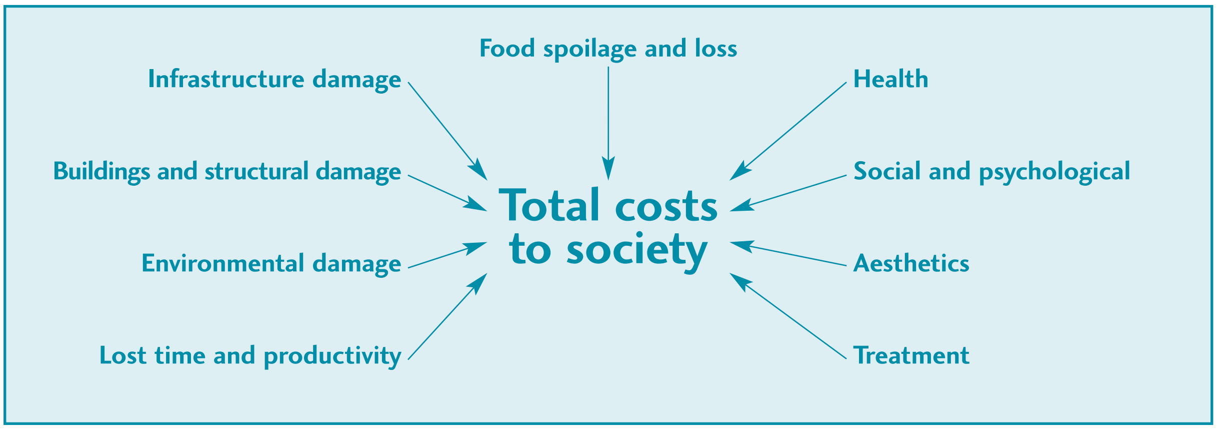
Figure 1.0 indicates how the cost to society of rat infestations can be adduced. However it is also evident that at the present time little data exists on which to evaluate the true cost in monetary terms.

Conclusion

The model for assessing the potential economic cost of rat damage suggests a figure of up to £522.4m (if there are 50 million commensal rats). This is exclusive of social costs and costs to the environment and health. It is more likely to be of the order of £200 million per year. Currently an accurate assessment is difficult because these costs are generally hidden and may be small scale on an individual basis. The effects of the damage may not be immediately apparent and are latent except in particular circumstances such as on the railways. A macro-economic argument can be made for investing in better control, including in sewers. Although increased expenditure on rodent control could be justified economically given the costs of damage, current expenditure may also be misdirected as controls are generally reactive, not based on any strategy and therefore potentially wasteful.

However, it is impossible to state whether rats are a problem that needs to be addressed solely on economic grounds. Damage is spread throughout the economy, and remains largely hidden, with no incentive to look deeper. From a governmental perspective, there is sufficient evidence to indicate that the potential exists

Figure 1.0 Rats and the cost to society



for substantial economic impact if there are inadequate controls and ineffective strategies.

Whilst this study has largely attempted to gather information as to the cost of physical damage to the built environment as the result of rodent damage, there are other costs, none of which have been measured. The social (including health and wellbeing) costs of rat infestations should be examined further whether by individual local authorities or nationally. However, it is also likely, given the linkage of rat infestations with areas of poor housing and environments (Battersby et. al. 2003), that people living in those areas would be less willing or able to pay as much as those in more affluent areas. Identification of social costs is therefore more difficult, yet the need for intervention in the poorer areas will be greater. It is concluded that reducing inequalities within the economy would also contribute to reduced infestations, with savings in treatment costs, as opportunities will be reduced for infestations to become established. It should not be forgotten that Chadwick was a utilitarian (a follower of the utilitarian philosopher Jeremy Bentham) believing that a healthier population was necessary in order to be able to work harder and cost the parishes less to support. It would seem that the control of rat infestation is a key intersectoral issue in contributing to the health of the public.

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PROFESSIONAL EVALUATION

A review of modern practices for small and private water supplies in the USA

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Abstract

This paper is a discussion on the approach to the safety of private water supplies in the United States. In February 2003 I visited the southern states as part of NSF International's Professional Sabbatical Award. The Chartered Institute of Environmental Health and the Royal Environmental Health Institute of Scotland jointly support this award. My area of study was the monitoring and control of small drinking water supplies and I was interested in comparing how such supplies were regulated and their microbiological and physico-chemical quality assured. I was aware of areas of best practice in both countries, but because private water supplies are normally small, low-key operations, information exchange concerning them is sparse.

The paper identifies and discusses five key areas of good practice:

- Chlorination as a standard on all small and private water supplies where the public have access;
- The use of the presence/absence test for total and faecal coliforms in water;
- Prior approval of all new small and private water supplies with licensed installers;
- The insistence on additional safety precautions where water supply is under the direct influence of surface water;
- Using laboratory staff to, not only carry out analyses, but also sample the water and carry out repairs to defective equipment on site.

Key Words: Borehole; chlorination; environmental health; private water supplies; USA; wells.

Introduction

Like the UK, water supplies in the United States are either public or private but the definitions are different and more complex. A public supply has to serve at least fifteen permanent connections or twenty-five people for at least sixty days. It can serve anything from a large metropolis to a small trailer park and may be provided by a city, public organisation or a private company. Public supplies are either community or non-community supplies. A community supply has to have at least fifteen permanent connections or twenty-five residents on a year round basis. A non-community supply serves at least twenty-five individuals for at least sixty days in the year. If they are the same people, e.g. at a school or factory they are a non-transient supply. If the water serves an average of twenty-five different people daily for at least six months of the year, it is a transient supply. If the supply is none of the above it is a private water supply and usually serves a single domestic property or business. Many of the community and non-community supplies in the US would therefore be classified in the UK as private water supplies.

Discussion

Between 1971 and 1985, 45 per cent of reported waterborne outbreaks in the USA were associated with non-community water systems. In 1985 for example, there were nine (60 per cent) from non-community supplies and six of those were from seasonal supplies – i.e. campsites, parks or resorts. At that time there were 180 million community, 20 million non-community and 30 million individual water supply users in the US (St Louis, 1988). A further report in 1997 (USGAO) estimated that fifteen million households obtained their water from private supplies. At that time, coliform bacteria contaminated up to 42 per cent of the private supplies and 18 per cent of them had excessive levels of nitrates.

Public supplies in the US are closely regulated and whenever water is provided to more than twenty-five people, there are clear state or federal standards and requirements (Louisiana DTE, 1985). For example, all water utilities must be licensed, with an annual inspection of the water treatment plant and a yearly report sent to all consumers detailing water quality (Watson, 2003). When a small public supply is operational, even though it would be classed as a private supply in the UK, it needs a minimum number of licensed operatives, depending on size. They must take daily measurements of free chlorine and report the results monthly. These utilities need a 'water quality monitoring plan' and a 'wellhead protection plan', which has to be updated every three years.

The regulation of private water supplies is less clearcut and several formal agencies can be involved. The US is, of course, a collection of states with their own legislation based on federal law. Like Europe, individual states have to adopt the overarching legislation and they can include tighter standards but not laxer ones. It is therefore difficult to discuss general water issues in absolutely definitive terms across the whole US. The information discussed here may not therefore apply to every single state, but generally represents the situation in most of them.

In the US, as in the UK, water sources are classified as boreholes (invariably called wells in the US), springs, hand-dug wells, rainwater collection and surface water. Most small water supplies in the US are boreholes but there are a few exceptions such as on the Southern coast of Louisiana where it borders the Gulf of Mexico. Here supplies are subject to saline intrusion and alternative sources such as surface water or rainwater harvesting have to be employed. In mountainous states the sources of water are split between wells (boreholes) and surface and spring supplies, in Tennessee, for example, this is approximately 50:50 (Foster, 2003). However, the US has another fundamental split between types of water supply and that is those that are or are not 'under the direct influence of surface water'. Groundwater in the US is normally expected to come from a deep aquifer, free from microbiological contamination and not subject to sudden changes in turbidity, conductivity, temperature or pH. They are usually protected against any contamination from the surface and can be relied upon to provide reasonably safe water. Any other supply, where a continuously good quality of water cannot be guaranteed, is considered to be 'under the direct influence of surface water'. A good definition of this is a supply characterised either by:

- A significant occurrence of insects or other macro-organisms in the water;
- The presence of algae or organic debris;
- Large diameter pathogens in the water such as Giardia lamblia; or
- A supply that is subject to significant water quality changes following precipitation (Foster, 2003).

Each public supply is normally assessed to see whether it is or is not under the influence of surface water. It should not be assumed that boreholes are never under the influence and spring supplies always are. A borehole for example, may be in a karst limestone region and easily contaminated. The supply to a spring on the other hand, may be well protected both by surrounding impermeable layers of rock and its collection chamber construction (although that is less likely). Every state has a set of guidance rules to assist engineers or health officials in deciding whether a particular supply falls within this category (TDEC, 1991). There will, for example, be a requirement to test the raw water for faecal coliforms on a regular basis for a particular period of time. There will also be an expectation that the system will be tested after heavy rain.

If a supply is not under the influence of surface water it will only require chlorination but if it is so influenced, it will need a full filtration system as well. This treatment requirement will, for example, require a 3-log removal of Giardia (reduction by 99.9 per cent). Therefore, being classed as under the direct influence of surface water brings some significant expenses to small water providers. Of course, this does not apply to individual private wells and in most states it only applies to public water supplies. In some states though, for example Michigan, they have adopted a more stringent approach to the safety of smaller water supplies and this rule applies to all supplies providing water to two or more households (Brown, 2003). It will always remains the case however that the first line of defence for the safety of small and private water supplies is protection of the source from contamination, rather than treating the water afterwards.

This appears to be a very sensible way of dealing with potential problems from small water supplies. If the supply can be relied upon to provide safe water, it only has to be chlorinated. In fact, in a few states, if the water to a small supply has proved to be free from coliform indicator organisms over a long period of time, chlorination is not strictly necessary; but this is rare and the possibility of being sued for damages tends to ensure all public and small non-community systems are chlorinated. If the source cannot be relied upon however, not only does it need to be chlorinated but it also must have a good standard of treatment and be regularly monitored, at least monthly. This will improve the water quality to an acceptable standard for many parameters, not just bacteria.

In the UK, this appreciation of the protective nature of chlorine for all water supplies, no matter how small, is usually absent and chlorination is not obligatory even when private supplies provide water to a great number of people. Therefore the protective safety features involved in the use of chlorine, both for accidental contamination of the source and subsequent problems with storage or pipework, are often absent. The UK reliance on infrequent sampling to identify contamination and then asking for treatment to be provided appears to be a much less effective approach.

As well as the general rules about supplies under the influence of surface water, the approach to the safety of individual supplies is based on a prior approval system and appears appropriate to the needs of most areas (Carlson, 2003). The prior approval systems require that:

Boreholes are only drilled by licensed operators. A newly licensed operator will be visited every time they drill a borehole until the inspecting engineer is satisfied they are competent and conscientious. Private water supplies can in fact be exempted from this requirement if the householder takes responsibility for drilling the well. They must however comply with the same strict rules and regulations as the licensed drillers and, as drilling is a skilled and technical operation, it is unlikely that many people would not use a licensed operator.

Drilling operations have to comply with a comprehensive set of rules. Most states have a manual that details everything that needs to be done, from deciding where to drill to post-completion water testing. The rules include carrying out a survey of the area to identify potential contaminating sites, details of construction, including casing, screening and filling in the annular space (between the hole and the borehole casing), post drilling chlorination and wellhead design.

All new wells are formally registered. This has been a legal requirement for many years and ensures the authorities are aware of the supplies in their area and that the water has been tested and is satisfactory. In addition when a property is purchased, the buyer can check if the well is registered. In some states there is no legal duty to register the well, but it is often done to protect the owner in case someone else tries to claim the land or the water.

Wells cannot be sited within a certain distance of a number of potential pollution sources, such as septic tanks, streams and sewers (50 feet – 15.24 metres), cesspools and outdoor privies (100 feet – 30.48 metres, but for single domestic supplies it can be 50 feet – 15.24 metres) and sanitary landfill sites, feed lots, manure piles and similar (100 feet – 30.48 metres) (Louisiana Register, 2002). Some states have a 'two for one' rule. For every extra two feet of casing, a pollution source can be one foot nearer (LaBarbera, 2003).

When the drilling is complete, the well is super-chlorinated and then tested bacteriologically. The water can only be drunk when the tests are negative.

Licensed drillers quickly become experienced in the geology of the area where they operate. In Brasos, Texas for example, they know that they must drill through one aquifer with high iron and manganese concentrations into a superior one below it (Alanzo, 2003). The borehole has to be sealed at the point it passes through the higher aquifer to stop short-circuit contamination of the lower one. When the well is being drilled, an experienced driller can tell when the aquifer has been reached as the tailings being brought to the surface usually change consistency. Boreholes are normally drilled using a rig attached to the rear of a specially adapted vehicle, although, where access is difficult or the ground is particularly wet, a separate, towed rig can be used. Some unscrupulous drillers have been known to 'deep drill' (go deeper than necessary) to raise costs. If they go too deep (to below sea-level) the water becomes saline.
When drilling is complete, the casing is added and carefully jointed. Casings are either metal (usually steel) or plastic (PVC). Depending on the use of the borehole, the backfilled grouting, filling the annular space, has to be provided to a specified depth. In private domestic boreholes this is usually ten feet (3.04 metres) below ground level. Public or community supplies need backfilling down to the screen (this is the metal grill at the bottom of the borehole, where the water enters). Vacuum pumps are usually fitted to US wells but submersible pumps are also occasionally used. Vacuum pumps have to be kept primed with water to enable them to work and the maximum depth they can operate at is about 200 feet (60.96 metres) (Ham, 2003). If it is necessary to lift water to a greater height than this, a submersible pump must be used.

Other than to ensure there are no new contamination sources in the vicinity, a regular sanitary survey is inappropriate once most boreholes are completed; they are protected from surface contamination and the weather has little impact on water quality. Of course if a major hurricane passes over and protection is ripped out of the ground, this may cause a problem. Similarly, where flooding is common, measures have to be taken to prevent floodwater getting in. In some states, private water supply treatment installers also have to be licensed. Sometimes installers over-prescribe remedial measures or install inappropriate treatment. They can make a lot of money doing this, but also risk losing their license.

Where there is a problem with a public water supply, the electronic media and local press have to be informed. If a campsite or trailer park has water problems, it would also have to post notices until the problem was corrected. However, there is no requirement to report previous sampling to new arrivals. If the problem is so bad as to require immediate action, a 'boil water advisory' can be issued. Some states issue these as a matter of course; others are more cautious and only issue them for very serious problems. An example from Tennessee involved flooding from heavy rainfall and snowmelt that caused muddy, turbid water to enter a small town's water treatment works, blocking it completely. It took three weeks to put the problem right (Foster, 2003). Occasionally a water utility is surprised that the enforcing authority does not stop them supplying water where there is a really serious problem, but because of the obvious need for water for toilet flushing and fire safety, it is usually considered to be a better idea to issue a boil water advisory.

Where water is in short supply and there are problems with over-abstraction, some states have identified areas classed as Groundwater Conservation Districts (or similar). In these control zones, water use is limited and maximum volumes are laid down for abstraction. Normally, people are not allowed to tap into water in adjoining properties, but it is interesting that in the majority of Texas this rule does not apply. This is due to case law from 1904; if someone moves next to you and drills an enormous borehole and the drawdown renders your well dry, then that is just your bad luck. This is locally known as the 'law of the biggest pump' (LaBarbera, 2003). Unlike surface water that is publicly owned, groundwater belongs to the owner of the land above it.

In the US, the usual laboratory examination for total and faecal coliforms is the 'presence absence' test. There are several different ones and they are usually known by their trade name – the most popular is the 'Colilert' system and as a rule, laboratories refer to it by this name. The membrane filtration system as used in the UK was employed in the US until the presence absence test was formally approved by the Environmental Protection Agency after several years of scrutiny. The literature comparing the two methods has indicated that presence absence is the more sensitive (Gleeson and Gray, 1997). Presence absence is also quicker, with results available in eighteen or twenty-four hours. They are equally accurate and the laboratory decides which to use depending on when the sample is received. This is to enable the result to be read during normal working hours. Presence absence analysis has to start within thirty hours of collection. In the UK, samples have to be delivered to the laboratory within six hours and analysis has to start within twelve hours, although recent research has indicated no loss of accuracy if this is extended to twenty-four hours. Where bulk analyses are being made, the cost of analysis is similar for both presence absence and membrane filtration.

Another advantage of the presence absence test is that one examination provides results for both total coliforms (a yellow colour is produced) and faecal coliforms (the sample fluoresces in the presence of ultraviolet light). This is a major step forward as membrane filtration needs two separate samples to be taken and incubated at different temperatures. In addition, the membrane filtration test is a presumptive one and for full confidence, confirmative additional tests are necessary. This whole process can take up to seventy-two hours, which is a long time to wait if the water is found to be contaminated.

Are there any advantages to the membrane filtration system? Is it better to know how many colonies there are in a water supply and thus the degree of contamination? In private supplies, water quality can change quickly over time and different parts of the system may have varying amounts of contamination. It is therefore a little naive to think that a large or small number of colonies will be truly representative of any particular water supply. The UK and US standards for coliforms are the same, i.e. nil total and faecal coliforms per 100 ml, so if any coliforms bacteria are present, the sample has failed and the water is contaminated. Thus you only strictly need a test that says whether coliforms are present. It has been argued (Sartory, 2003) that a good laboratory can tell a lot from the nature of the colonies on a filter but this only holds good for a water supply that is examined on a regular basis, such as those to large public supplies. This will not of course apply to private water supplies.

Another interesting difference between the UK and the US is the litigious approach of many American consumers. It has been suggested (Wood, 2003) that in the US, environmental legislation is often irrelevant because of the strength of the civil liability lobby. In other words, companies and individuals are more frightened of being sued by someone who has been injured by the water they supply, than they are of falling foul of the more formal legal system. Most companies take precautions to prevent themselves from being sued and this is their main driver, far outweighing any worry about the Environmental Protection Agency or state enforcement body. When properties change hands for example, the company giving the loan (the loan agent) requires a certificate of potability. This is to prevent the possibility of being sued by the new occupant, if they subsequently become ill from the water. The seller has to get the water sampled and pays for a certificate. The result is that the water supply is checked for safety whenever the property changes hand. A similar certificate is also required by employer liability insurance companies for small public or private systems at commercial premises such as restaurants or garages. They do not want to have to pay money because their client is being sued for water-related ill-health problems.

In some states chlorination is rare in single domestic borehole supplies, nevertheless bacteriological quality is usually good if the borehole has been drilled within the last fifteen to twenty years. Out of 3,319 private and public wells sampled by Texas A&M University, for example, only 7.5 per cent were contaminated with faecal material (Dozier, 2003). In more mountainous areas, where sources are a mixture of spring supplies and boreholes, the quality is more variable. In Tennessee, where 240,000 families have their own private wells, water quality ranges from good to very poor (Foster, 2003). The majority of the water from these private supplies is un-chlorinated, they are largely unregulated after drilling and are not regulated at all if the supply is not from a borehole. As pointed out to me by Hall (2003): 'If someone wants to drink out of a muddy hole and it's a private supply, they can – we still have few freedoms left!' Some of the problems encountered in Tennessee have included a cross connection with irrigation wells at a country club (to save money); raccoons and skunks being found dead in the system (with fur coming out of the tap) and a cross connection with a sewer pipe at a prison, where a third of the staff and prisoners subsequently became ill.

Chemical contamination problems in water from deep wells are comparatively rare in the Southern states, with most of the small regulatory authorities only having to deal with a handful of failures at any one time. Where there are problems they are typically from leaching (arsenic) agricultural pollution (nitrates), radiological (uranium or radon) and copper and lead from pipework. In some specific geographical regions as well as arsenic, there are other naturally occurring contaminants such as sulphur and fluoride. Iron and manganese in water supplies are also common.

Because aluminium is so ubiquitous in the earth's crust and not considered to be a health-related parameter, it is not analysed for in most laboratories.

One of the problems encountered more often in the US than the UK is chemical contamination from pollution incidents. These are usually a result of inappropriate industrial waste disposal or accidental spillage. One example is the past practice of pouring used dry cleaning fluid (trichlorethane, etc.) on the ground to get rid of it; another is leakage from defective underground gasoline storage tanks. In rural areas the herbicides atrazine and simazine can be found during the spring spraying season. In Louisiana, the Department of Agriculture has about 150 test wells around the state to monitor the groundwater. There are many 'hits' for pesticides in surface waters after the crops are sprayed and education programmes are designed to teach farmers how to use the chemicals responsibly (Carlson, 2003). Nitrates can also be a problem if supplies are near fertilizer usage areas or septic tanks. Of course, once organic chemicals contaminate an aquifer it is difficult to remove them. The wells in the area have to be abandoned and new ones drilled or expensive treatment installed to clean the aquifer. Sometimes, for minor problems, the treatment will involve increased pumping, so that the pollution is physically removed and the contaminated water run to waste. It is important that the water does not re-contaminate another part of the aquifer, so advice has to be sought on its disposal. Another remediation method involves pumping hydrogen peroxide into the well. This feeds oxygen to naturally occurring bacteria that take up some of the contaminants in order to metabolize.

In a few states, mainly Arizona or California, arsenic is a major problem in groundwater, but even in central states such as Michigan, the main driver for change at the moment is the reduction in the amount of arsenic allowed in drinking-water (Brown, 2003). The new US Environmental Protection Agency standard is 10 µg/l and many wells will fail this standard - some have up to 200 µg/l in their water. The majority have less however and it is considered by some authorities that 25 µg/l would be a more suitable standard. The reason is that at this level, there is a sufficient safety factor to prevent serious illness by raising the standard to 25 µg/l, but far fewer wells would need remedial treatment. Many systems are presently completely closed and deliver pristine groundwater, but they will now have to be opened up to put treatment in, allowing a possible entry route for contamination.

The authority for enforcing drinking-water legislation depends on whether a state or Tribal Council has formally applied for what is called 'primacy'. If it has and it meets the conditions required by the legislation, it and not the Environmental Protection Agency enforces the 'Safe Drinking Water' statutes. Enforcing authorities have wide-ranging powers to control water quality, including closing systems, seizing records, serving notices and prosecution. Most can also take action based on poor results from a sanitary survey, which is a sensible addition to the enforcer's armoury. They try to maintain a supportive relationship with the water industry and help and advise where possible. However, if there is a risk to public health they are happy to use their legal powers.

Many authorities also have education programmes for the public, license holders and regulators. The one in Tennessee for example, has been very successful, with microbiological failure rates dropping dramatically year on year (Foster, 2003). The education programme consists of simple, well-explained, graphically descriptive teaching methods that try to give an understanding of the processes and problems involved. One example is the way water operatives are told about the problems caused by falsifying records. If there is a problem with the water and they need help, operatives are informed that if they let the authorities know, they will get it, but if they lie about the results then they may lose their job or get sent to jail. Non-regulatory advice and assistance comes from the 'Farm A Syst' programme, which encourages farmers to get their wells tested annually and has access to financial support for health-related improvements. Technically independent from any state or city governance are the Rural Water Associations. Although funded by some states, they are also membership organizations that provide practical advice and advocacy to their members (LRWA, 2002). Membership is open to anyone and there is no minimum number of properties to which they will provide assistance. The Association has advisory leaflets and organizes seminars on particular topics for members. To attract participants, the associations always provide freshly cooked food at its meetings.

Some older systems have coliform and nitrate failures, usually caused by contamination from old sanitary installations. Where problems are encountered with a small village supply, the usual option is to form a local committee and ask the nearest town or city to connect it to the public supply. Very often a way can be found to achieve this, using a variety of grants and easements (Foster, 2003). The second choice is to drill another well, away from the problem. Many enforcement authorities are not keen on recommending treatment for individual boreholes and see this as a last option; they much prefer to ensure that uncontaminated ground water is used. As with arsenic removal systems, whenever microbiological treatment is put in, a potential path for contamination is introduced. In addition, many treatment systems are not maintained and if this is the case why put one in only to have it fail later on?

Sanitarians in County Environmental Health Departments often have responsibility for drinking-water safety. In many states, the owners of all non-private supplies have to send samples to them on a monthly basis (Alonzo, 2003). The samples can be posted and as long as they are received within 30 hours, have not leaked and the water is not too turbid, are examined for the presence of coliforms. Those that fail the standard are notified to the state and the responsible person. If a failure occurs, re-samples are taken and advice is given on potential causes of contamination. Sampling for a larger suite of chemical contaminants is less regular and depends for frequency on the size of the supply or the particular substance being looked for. The owners of the supply can take the water sample themselves but must have attended a training course to be allowed to do it. This does not appear to cause any major problems other than the occasional failure due to bad practice. Sampling is carried out at the source and not the kitchen tap, as is done in the UK. A sampling tap is usually incorporated in the wellhead design. Water is run for some time but the tap is not usually sterilised (Pontiff, 2003). The water is collected in specially produced small plastic bags that contain sodium thiosulphate. Sometimes chorine solution is run over the tap to prevent cross-contamination from a leaking washer. Where the owner of a property is concerned about their water, sanitarians will visit, sample the water and advise the householder about treatment and best practice. Laboratories also provide simple advice to well owners on potential reasons for contamination, what the results of water testing means and how to chlorinate and flush the system if there is a microbiological problem.

Some universities provide independent water-testing facilities for both chemical and microbiological parameters. They tend to be easier to contact for some rural people than a state regulatory department, because of worries about enforcement action, real or imaginary. University laboratories can be used by anyone and they often receive posted samples from a large geographical area. Plastic containers (such as a baby's drinking bottle) are sometimes recommended for people sending in a sample where the local water has a boron problem (Pitt and Provin, 2003). Boron can restrict plant growth, thus if a supply has a high boron content, it may have to be abandoned for irrigation purposes. As most glass contains boron, if it is leached into the sample, the laboratory result can be prejudiced and will make a borderline water supply seem worse than it is. The normal solution to the problem of high boron in water is to try and blend it with water containing lesser amounts.

In the US, Native American land is subject to a different set of rules. A good example of the way this system works is the Tohono O'odham Indian Nation, in Arizona. Water, electricity, gas and telephone services are provided by the Tohono O'odham Utility Authority and the federal Environmental Protection Agency checks that legal water responsibilities are met, rather than the Arizona state authorities. An interesting aspect of the work the Utility's water laboratory is that it is much more hands-on than equivalent positions in the UK (Natividad, 2003). As well as being responsible for a certified microbiology laboratory, the manager collects water samples, does field-testing, cleans out and disinfects water tanks and carries out minor repairs to pumps and treatment plant. To maintain this additional skill base, there are twice-monthly training sessions and some repairs are helped by mobile phone conversations with engineers back at head office. The manager believes this makes it a much more interesting job, as well as making sure that minor repairs are carried out straight away. For example, during one visit she carried out on-site testing at one village for free residual chlorine. It was too low, so the manager went back to the treatment plant, checked through the chlorination system, found a fault, repaired it and reconnected the system – all within the space of an hour. The water was re-tested the next day to ensure the repair had been carried out correctly. This appears to be a very efficient way of maintaining drinking-water safety.

There are two boreholes at each site so that supplies can be maintained if one fails. The borehole systems on the reservation are basically the same, although designs vary slightly. The water from the borehole passes through a chlorinator and then to a storage tank. The disinfection units were in waterproof cabinets and a sturdy fence surrounded the whole site, with barbed wire around the top. Most pumps were above ground but a couple were sunk in covered compartments. These are not popular with staff however, as there is a problem with illegal immigrants from Mexico on Tohono O'odham land and these underground areas have been used as hideouts. Other on-site dangers included rattlesnakes and rats. The area around the water stations is open to grazing, but the fence ensures that there is an adequate protection zone for the water supply.

One of the main drinking-water problems in rural areas is effluent from small sewage treatment facilities entering supplies. Some septic systems block up, causing a safety valve to open, allowing raw sewage to flow overland. In other areas there are septic tanks that merely discharge into shallow field drains. Where heavy clay soils do not allow the sewage to soak into the ground, it ponds on the surface and shallow wells can easily become contaminated. A community of about one hundred people in Tennessee was recently subject to a series of hepatitis A outbreaks because of this (Foster, 2003). The community was poorly educated and did not appreciate that they were making themselves ill with their own sewage. Eventually they were given federal financial assistance to sort the problem out. The emphasis of Health Departments and other enforcement authorities is normally on strict control; all septic systems should be visually checked three times a year by a licensed contractor and sampled annually. Another legal requirement for most states is that any sewage discharged onto the surface must be chlorinated. Nevertheless, it is generally accepted that there are many problem septic systems still to be found.

Abandoned wells are a particular problem in some states. There are rules for capping abandoned wells (basically a well that has not been used for more than six months) in order to prevent contamination of an aquifer by the unused borehole short-circuiting any protective overlying geology. This can cause major headaches, there are for example, approximately 800,000 uncapped abandoned wells in Texas (Mayhew, 2003). In the mountain areas of Tennessee there is also a question regarding the quality of water supplies at many rural churches. They have their own community supplies but because they are not commercial organisations there is little money for repairs or improvements. The local courts do not look favourably on state agencies taking formal action against them and the pastor is often unwilling to be told what to do by 'government bureaucrats'. If the congregation are advised about the water and still chose to use it, then it is considered that they have made an informed choice and will often be left to their own devices.

In rural areas therefore, there is often a need for effective health education to persuade people that the water they have drunk for years needs improving. One village recently had a very poor spring supply, with a filter system so old that any treatment media had been washed away years before (Foster, 2003). The village, particularly its water utility manager, were very unwilling to spend any money on the supply and considered the state's Water Supply Division an irritation. Because of the strength of this opposition, a public meeting was organised to explain the situation. Previously the Division had taken samples of the water and photographed the creatures they had found in it. At the meeting they showed large slides of these creatures, particularly the nematodes, which were 'big ugly things'. As part of the demonstration they then pointed out to the crowd where the nematode's anus and genitalia were. Some people in the audience were then physically sick. One of the people who attended the meeting on behalf of the Division said that towards the end he thought that the utility manager was going to be lynched. The water supply was quickly improved.

Conclusion

There is a great deal of good practice in the US. Five key areas of good practice which have been identified are, in no particular order:

- Chlorination as a standard on all small and private water supplies where the public have access. This is a wonderful public health measure and ensures a level of safety not apparent in UK private supplies where, as well as having very little source protection, very few have chlorination or any treatment with a residual effect. It should not be forgotten however that some people will still worry about the theoretical health effects of chlorination by-products on humans.
- The use of the presence/absence test for total and faecal coliforms in water. It is a better form of laboratory analysis and thus a way of identifying contamination. It is quicker, easier and more sensitive.
- Prior approval of all new small and private water supplies with licensed installers. This ensures a level of drinking water safety from the beginning.
- The insistence upon additional safety precautions where water supply is under the direct influence of surface water. This allows additional safety barriers for all supplies that might otherwise cause ill health, should the primary barriers of source protection and chlorination fail, and
- Using laboratory staff to not only carry out analyses but also sample the water and carry out repairs to defective equipment on site.

Acknowledgements

I would particularly like to thank the NSF International for their financial assistance to enable me to study small and private water supplies in the US.

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Book Review– People and Environment: A Global Approach

Gareth Jones

Pearson Education 0582414121 (Paperback) Dec 2003, 296 pages.

Environment is a very big word, over-used by so many people, to the point where its true meaning gets lost and diluted as a catch-all term to cover aspects of work professionals and lay people are concerned with. However many of these people are not seeing the overall picture of how changes, natural or otherwise, can impact on other aspects of environment (oops, there's that word again).

The author shows clearly that achieving any changes or improvements in any aspect of "the environment" is not just a matter of understanding the physics, chemistry and biology of our air, water and land, but also the social and political context in which we have to operate.

This book treads a fine line well, between not attempting to be an in depth reference work on all things environmental, yet giving sufficient information to encourage the reader to research further, having wetted the appetite with some good concise science and background information. The references given are comprehensive, and their content assimilated well into the theme being developed.

Recommended therefore for environmental professionals, specialising in one field to help them retain a holistic perspective on their own work. It can also be recommended for students, since its lack of depth and its presentational style make it accessible and thus readable, stimulating interest. A lot here also, for lay people to facilitate informed opinion. In conclusion therefore, a worthwhile addition to any academic or public library.

David Boland

Book Review – Industrial Safety and Health Management, 5th Edition

C. Asfahl, John Weaver

Pearson Education
0131423924 (Hardback) Sep 2003, 528 pages

Now into a fifth edition "Industrial Safety and Health Management" would in many ways be an excellent text book for those studying for a career in Health and Safety Management. However, some caution is needed as there are significant differences in approach, for example in legislative matters, terminology and standards between America and Europe and this could potentially cause some confusion for a student. The style and presentation also seemed a little dated.

The author, C Ray Asfahl, a Professor in the Department of Industrial Engineering at the University of Arkansas, has covered a wide range of topics in eighteen chapters. The text ranges from a discussion of the role of the Safety and Health Manager and the health and safety function in an organisation through to chapters dealing with specific topics such as machine guarding, ergonomics, flammable and explosive materials, welding and construction, containing considerable technical detail. A number of clear and useful illustrations are included. The book has also been expanded to take account of some more recent concerns such as blood-borne pathogens and security and safety concerns post 9-11.

The book also comes with a CD containing a searchable database on a full year of OSHA (Occupational Health and Safety Administration) enforcement statistics, again of interest but not as relevant to UK readers.

Two particularly useful facets of this textbook are the brief case studies interspersed in the text and the end of chapter study questions and research exercises. I am sure any student who worked their way through these 600 plus questions would achieve a very thorough knowledge of many of the most important aspects of industrial health and safety. Health and Safety Practitioners may also find this book of interest and value the opportunity to compare the British and American approach to the management of their chosen field.

Jane Robinson

Book review recommendations

Have you found a new book which you think would be worth reviewing by JEHR? Have you produced a book which you would like to be considered for review by JEHR? If so, please contact the Editor at hd.harvey@ulster.ac.uk for details of the review process.

Letters and comments on the Journal

The editors invite comments on any aspect of the Journal including your overall impression of JEHR, particular strengths, weaknesses and areas for improvement, letters on specific papers and topic suggestions for professional evaluations and book reviews. Correspondence on these issues should be sent to Dr Harold Harvey at hd.harvey@ulster.ac.uk.

Notes for Authors

Aims and scope of the Journal

The Journal of Environmental Health Research (JEHR) is published by the Chartered Institute of Environmental Health (CIEH). The Journal publishes original research papers, technical notes, professional evaluations and review articles covering the diverse range of topics which impact on environmental health.

Particular emphasis is placed on applied research and reviews which facilitate the improved understanding of a particular aspect of environmental health. It is intended that the Journal will help to promote improvements in the professional practice of environmental health as well as contribute to the research knowledge base.

Invitation to contributors

Contributions are invited on any of the diverse aspects of environmental health including occupational health and safety, environmental protection, health promotion, housing and health, noise and health, public health and epidemiology, environmental health education, food safety, environmental health management and policy, environmental health law and practice, sustainability and methodological issues arising from the design and conduct of studies.

Contributions should have the potential to improve practice through the dissemination of the results of research projects, reviews based on scholarly reflection and technical notes and professional evaluations which provide critical insights into practice issues. It is likely that most papers published will be based on work carried out as part of a research project or programme associated with an academic or other research institution.

Contributions are expected to be of a high standard, not only in respect of subject matter and its treatment, but also in the quality of the writing. Particular attention should be paid to clarity and conciseness of expression.

Originality

Only original articles are considered for publication. Submission of a manuscript represents certification on the part of the author(s) that the article submitted has not been published nor is being considered for publication in another journal. Contributions may, however, be based on a prior conference presentation.

Peer review

All contributions which are considered by the Editors to be within the aims and scope of the Journal are subjected to peer review by at least two reviewers. It is likely that one reviewer will have an academic research background and the other a practitioner or management background. Decisions on publication are made by the editors who are informed by the comments of the reviewers and the responses from the author(s) to the peer reviews.

Style

These notes are intended to guide authors in some details of presentation so that papers conform to a consistent Journal style. More details on style and paper preparation can be accessed at www.jehr-online.org.

Authors must comply with the style requirements in every respect. For example, manuscripts which are too long, have too many headings or tables or references which do not fully conform to the Harvard protocol will be returned to the author(s). Thus authors are encouraged to study these notes and those on-line carefully whilst preparing their manuscript.

Length

Research papers; 3,500 to 6,000 words.
Professional evaluations and literature reviews: up to 8000 words.
Technical notes, not normally more than 2000 words.

Tables, Charts and Photographs

These should be kept to a minimum consistent with the concise nature of the papers published in this Journal.

Language

Manuscripts are accepted in English only.

Layout/Sequencing

The manuscript should normally be sequenced as follows:
Title; Author(s); Abstract (300 words +/- 10%); Key words (up to 8); Introduction; main exposition (typically this section consists of the Methods and Results); Discussion; Conclusions; Acknowledgements;

References.

Further essential details on each on these is available at www.jehr-online.org and in:
Harvey, HD and Fleming, P (2003) Writing for JEHR and other peer reviewed journals. Journal of Environmental Health Research, 2 (1), pp 33-43.

Electronic submission

The submission of manuscripts will normally be by Email and word processed file attachment only, with no requirement for the submission of printed copies. The word processed document should conform to the following specification to facilitate the peer review process and editing;

- MsWord (.doc) is the preferred word processor format but WordPerfect (.wpd) and Rich Text Format (.rtf) are acceptable.
- Times New Roman, 12 point, Single spacing.
- Do not indent paragraphs, do not number the pages nor insert headers or footers.
- The Cover Page should give the title of the paper, the name(s) and affiliations of the authors plus an Email address, telephone number and postal address for the corresponding author. Add a page break at

this point and go on to the First Page.

- The First Page should repeat the Title only (not the authors details) plus the Abstract, Key Words and continue into the Introduction and the remainder of the manuscript.
- All tables and charts should be included as part of the manuscript in a single file, unless there is pressing technical reason for having separate files.
- The file should be named with the name of the first author e.g. Wilson.doc.
- Photographs should also be included in the text; if the paper is accepted for publication high quality .tif files may be requested from the author.
- Email to hd.harvey@ulster.ac.uk

Communication from the Editors will normally be by Email only.

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