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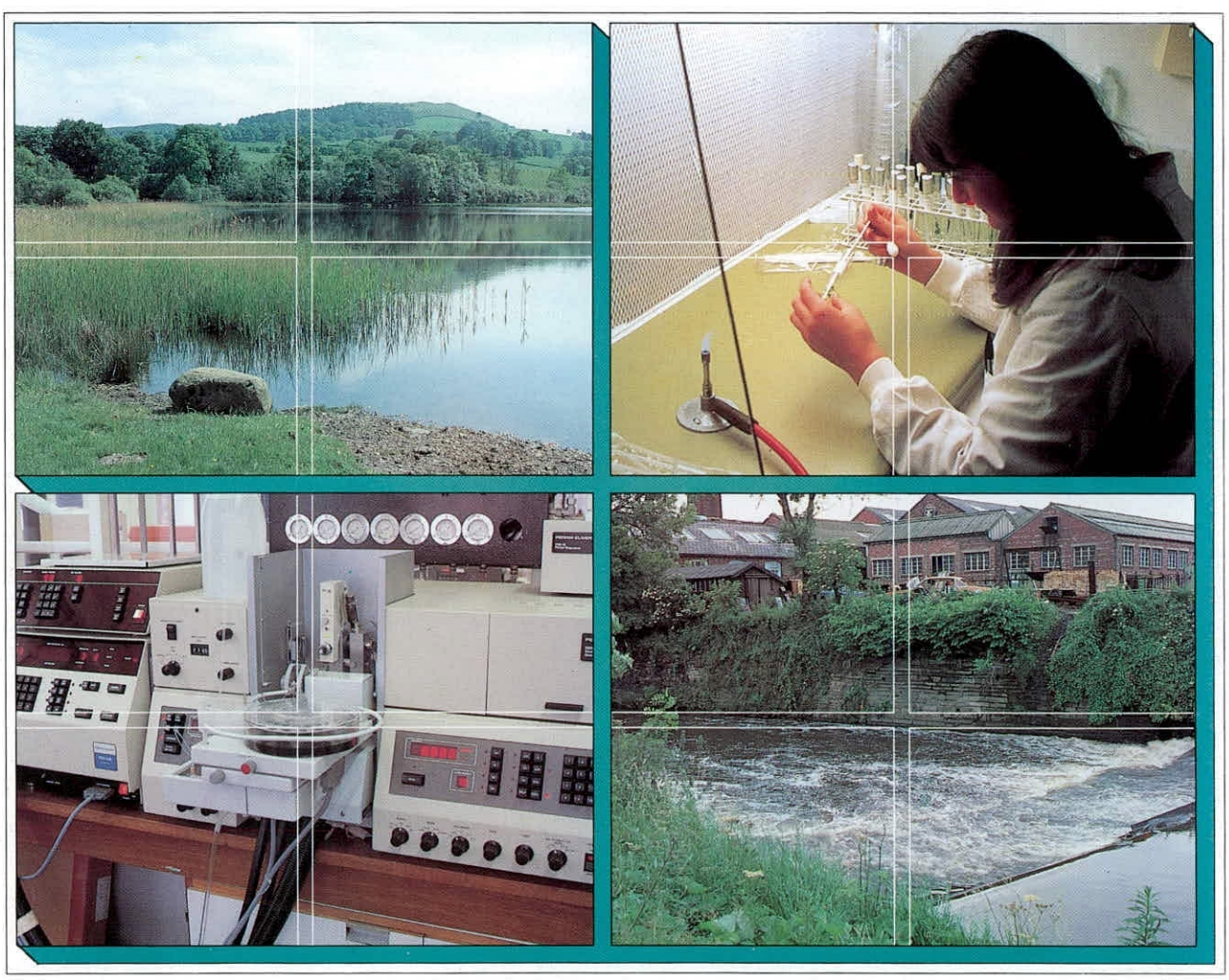
J.A.B.Bass
I.D. McCulloch

Report to UK Water Industry Research Limited (April 1998)

CEH Project No: T11060v7
IFE Report No.: 1



Natural Environment Research Council

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MAINTAINING AWARENESS OF ANIMALS* IN DISTRIBUTION SYSTEMS

Final Report

J.A.B.Bass
I.D. McCulloch

Report to UK Water Industry Research Limited (April 1998)

(Project Manager: Dr David Holt - Thames Water Utilities Ltd)

* For the purposes of this study animals refers to "macroinvertebrates"

CEH Project No: T11060v7
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Project Reference and Title: DW-02/G

Health significance of microorganisms growing in water distribution systems

Report Title: Maintaining awareness of animals* in distribution systems

(*macroinvertebrates)

Client: Water Industry Environment and Quality Committee

Managing Company: Thames Water Utilities Limited

Collaborator(s): None

Contractor(s): Institute of Freshwater Ecology

Authors: J.A.B.Bass and I.D. McCulloch

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CONTENTS

UK WATER INDUSTRY RESEARCH LIMITED

EXECUTIVE SUMMARY

Objectives

The current study was commissioned by UK Water Industries Research Ltd (UKWIR) to determine the extent of animal presence in UK distribution systems. The study included a literature review and analysis of questionnaire responses.

Conclusions

- In response to the questionnaire most UK Water Companies acknowledged the occasional presence of animals in distribution systems and 24 companies had initiated control measures, of varying types and frequency, over the period 1993-1997.
- Only five UK Water Companies indicated they had internal (unpublished) reports on animals in distribution systems.
- No companies indicated human health problems had arisen in connection with animals in their distribution systems and their investigations generally focused on complaints of animal occurrence rather than routine monitoring.
- Five UK Water Companies noted that specific improvements in treatment processes and distribution systems had reduced the occurrence of animals in distribution systems in recent years, whilst 4 companies suggested new treatment works processes have required new methods for tackling animal contaminants.
- A limited range of aquatic animals is capable of survival in water distribution systems in the UK. Resistance to residual disinfectant, availability of adequate and suitable food sources, appropriate reproductive strategies – are all important factors in terms of self-sustaining populations.
- The search for published literature (post-1993) indicated there were few recent studies on animals in distribution systems that have been published and these were largely confined to non-UK studies

Benefits

The study highlighted the lack of recently published information on animals in distribution systems, particularly from the UK, whilst the questionnaire indicated the types and levels of infestation experienced in the UK. No new concerns regarding the human health risks associated with these animals were revealed.

1. Background

The presence of live or dead animals (macroinvertebrates) in drinking water can give rise to complaints and customer concerns over risk to human health. The current view in the UK water supply industry is that there is no evidence indicating that the presence of animals in drinking water constitutes a risk to health.

The Drinking Water Inspectorate commissioned WRc (1996) to undertake a review of available literature determining the validity of the current assumption that animals in distribution systems do not present a risk to health. That particular study was also required to assess the value of laboratory research in relation to the conditions found in water treatment and distribution systems and to recommend whether further laboratory or field studies were necessary to establish if animal infestations may constitute a risk to health in the UK.

The current study was commissioned by UK Water Industries Research Ltd (UKWIR) to determine the extent of animal* presence in UK distribution systems. Detailed objectives are set out below.

(* - refers to macroinvertebrates)

2. Conclusions

- In response to the questionnaire most UK Water Companies acknowledged the occasional presence of animals in distribution systems and 24 companies had initiated control measures, of varying types and frequency, over the period 1993-1997.
- Only five UK Water Companies indicated they had internal (unpublished) reports on animals in distribution systems.
- No companies indicated human health problems had arisen in connection with animals in their distribution systems and their investigations generally focused on

complaints of animal occurrence rather than routine monitoring.

- Five UK Water Companies noted that specific improvements in treatment processes and distribution systems had reduced the occurrence of animals in distribution systems in recent years, whilst 4 companies suggested new treatment works processes have required new methods for tackling animal contaminants.
- A limited range of aquatic animals is capable of survival in water distribution systems in the UK. Resistance to residual disinfectant, availability of adequate and suitable food sources, appropriate reproductive strategies – are all important factors in terms of self-sustaining populations.
- The search for published literature (post-1993) indicated there were few recent studies on animals in distribution systems yielded very few recent references and these were largely confined to non-UK studies.

3. Objectives

- Review reports of animals in drinking water distribution systems.
- Maintain a watching brief on current and future research, during the contract, to identify whether there are any animals present in distribution systems which pose a risk of causing ill-health to customers supplied by the UK water industry.

4. Tasks

4.1 Collect and collate Water Company information on the presence of animals in drinking water distribution systems. Reports and information to be gathered from UK Water Companies on the understanding that confidentiality will be strictly maintained.

4.2 Prepare a review on the animals recorded from distribution systems and the relative success of different methods for their elimination/control.

4.3 Comment on:

- - the most numerous types of animals reported and their feeding mechanisms.
- - the types of animals that can grow in distribution mains and those that can be classed as intruders.
- - the nutrient sources available to animals in drinking water. (If possible provide estimates of growth rates)
- - the factors encouraging animal presence.
- - survival and growth of animals in the presence of a disinfectant residual.

4.4 Identify any animals known to grow in distribution systems that have been directly or indirectly implicated with adverse effects to health.

4.5 Be pro-active in advising UKWIR on any issues arising from the research that may affect water quality in distribution.

5. Results and Discussion

5.1 *Questionnaire to UK Water Companies*

The questionnaire (Appendix I) was distributed to selected UK water companies by the Water Services Association in early January, 1997. A single questionnaire was returned (direct to TWUL) on 27th January 1997 and no further responses were forthcoming, the questionnaire was dispatched again, in August 1997, to 28 water companies throughout the UK.

Twelve questionnaires were returned by 30th September 1997, and a further sixteen were available by 21st November 1997. A summary of the information provided is presented in (Appendix II).

From the outset the questionnaire was gauged to be the only source of unpublished internal Water Company data providing up-to-date information on animals in distribution systems in the UK. Without this information the review would be restricted to published data, much of which has effectively already been assessed by the recent WRc review (Stansfield & Carrington, report to the DWI, 1996).

5.2 *Literature Search*

It was anticipated that the recent WRc review (Stansfield & Carrington, 1996), "The Health Significance of Animals in Water Distribution Systems", provided a comprehensive account of the animals recorded from water supplies within the UK. For this reason the present study targeted the following potential sources of new information (all searched from January 1994 until November 1997):

Aquatic Sciences and Fisheries Abstracts, Water Resources Abstracts, AQUALINE,

MEDLINE, Biological Abstracts, Science Citation Index.
SIGLE - the System for Information on Grey Literature in Europe.
Current Contents on Disk - Agriculture, Biology and Environmental Sciences edition.
Current Contents on Disk - Life Sciences edition.

The keywords varied according to the database used, as they all have their own thesauri, but were variations on the following (where * is a truncation symbol):
water main*, water distribution, water suppl*, tap water, drinking water, animal*, invertebrat*, macroinvertebrate*, midge*, worm*, chironomid*, diptera*, oligochaet*, asellus.

Seven recent papers referring to macroinvertebrates in distribution systems were recovered (listed below) and some additional references* were provided by UKWIR committee members.

Alexander MK., Merritt RW. & Berg MB. (1997) New strategies for the control of the parthenogenetic chironomid (*Paratanytarsus grimmii*) (Diptera, Chironomidae) infesting water systems. *Journal of the American Mosquito Control Association.* 13(2):189-192

Anon (199) Problem Organisms in Water: Identification and Treatment. In: AWWA Manual M7, American Water Works Association. p33-53 & 91-101

*Beaudet, J-F., Prevost, M., Arcouette, N., Niquette, P. & Coallier, J. (in press) Controlling annelids in biological activated carbon filters.

Berg, M.B. (1995) Infestation of enclosed water supplies by chironomids: two case studies. In: Chironomids: from genes to ecosystems (ed. Cranston, P.) 241-246. Australia, CSRO.

Bott, T.L. (1995) Microbes in food webs. ASM News, 61, 580-585.

Brunke, M. (1994) Auswirkungen eines Flusstunnels auf das Macrozoobenthos. Erweiterte Zusammenfassungen der Jahrestagung 1993 28 September - 1 Oktober in Coburg *Deutsche Gesellshaft fur Limnologie*, 448-449.

Holmes, P. & Nicolls, L.M. (1995) Aeromonads in drinking-water supplies: their occurrence and significance. *Journal of Chartered Institution of Water and Environmental Management*, 9, 464-469

*Lieverloo, H., Buuren, R., Veenendaal, G. & Kooij, D. (in press) How to control invertebrates in distribution systems: by starvation or by flushing?

Schreiber, H., Schoenen, D. & Traunspurger, W. (1997) Invertebrate colonization of granular activated carbon filters. *Water Research*. 31(4):743-748

Westphal, B. (1996) Planktonic algae and metazoa in drinking water supply installations. GFW-Wasser/Abwasser, 137, 271-275.

The responses to the questionnaire circulated to selected UK Water Companies failed to reveal trends in the generation of unpublished water industry reports on animals in distribution and this may be attributable to the sensitive nature of such information. Only 5 of the 28 replies indicated internal reports had been generated on this topic in 1993-97. One company forwarded an internal report.

Internationally the general control of faunal biomass in GAC filters is being addressed in Germany (Schreiber, Schoenen & Traunspurger, 1997), where a programme of back-flushing has been neccessary when supplies originate from eutrophic rivers, such as the Rhine. In Canada the control of Naididae (Oligochaete worms) within carbon filters has recently been investigated (Beaudet *et al.*, in press). The authors describe a combination of filter backwashing following a 4-6 hour shutdown of individual filters as a successful and sporadic technique to reduce population densities and lessen the risk of unacceptable numbers of naid worms reaching the distribution system.

5.3 *Animals reported from distribution systems and their susceptibility to control measures.*

The following macroinvertebrate groups were most frequently reported in mains distribution systems in the UK:

Insects - Chironomidae (non-biting midges)
Crustacea - *Asellus* sp. (freshwater hoglouse)
- *Gammarus* sp. (freshwater shrimp)
Oligochaeta (worms)
Nematoda (round worms)

Chironomidae (non-biting midges)

Within the Chironomidae, colloquially known as "bloodworms" or "midge larvae", the majority of species have aquatic larvae and pupae, while the short-lived adults form mating swarms adjacent to water. Only one species, *Paratanytarsus grimmii* (Schneider), maintains a continuous presence within treated water supply systems, though a range of chironomid species can occupy sand filters (Armitage, Wotton, Blackburn & Hamburger, 1990) and enter the mains supply occasionally, particularly following filter backwashing. Unidentified chironomids occurred in 26 of 36 UK distribution systems surveyed by Smalls & Greaves (1968).

Paratanytarsus grimmii has a worldwide distribution (Langton, Cranston & Armitage, 1988), all individuals are female, reproduce parthenogenetically (without mating) and have the facility to hatch from eggs directly from the pupal stage under water. Such attributes greatly assist the establishment of populations in distribution systems. The small (0.5-4.0 mm) green larvae frequently occupy tubes which they construct from silk and detrital material. The tubes are

loosely attached to surfaces, such as provided by pipework and filter media. During the four larval stages (instars) feeding activity is largely confined to grazing the biofilm adjacent to the tube, though Berg (1995) records the ingestion of dead bacteria which he considered may have been recovered by filter-feeding. Larval development rates are temperature-dependant, with food supply an additional constraint. Under the most favourable conditions, the generation time is around three weeks with each individual capable of producing over 100 eggs (Langton *et al.*,1988).

Populations are comparatively resistant to total elimination from distribution systems. In addition to the parthenogenetic life cycle, *Paratanytarsus grimmii* has the facility to produce variable proportions of flighted adults (females) which colonise new locations.

Control Measures

Elevated chlorine dosing, mains flushing and pesticide treatment have been used as effective control measures in the UK, depending on the prevailing conditions, but complete elimination of larvae from the distribution system is rarely achieved . They are reported to be progressively susceptible to temperatures above 27 °C and the larvae cannot survive freezing (Langton *et al.*,1988).

Paratanytarsus grimmii is established in supply systems in about 30% of the states in the USA, where state and federal laws preclude application of pesticides to drinking water, but it is suggested that few customer complaints are recorded because the small larvae are generally overlooked (Berg, 1995). Most recently, mean densities of *P. grimmii* in a midwestern USA water distribution system ranged from approximately 140 to 560 individuals/sampling date, and all 4 instars and pupae were present throughout the sampling period. Two products were tested as potential chemical controls: Cat-Floc LS(R), a coagulant produced by the Calgon Corporation, and 35% hydrogen peroxide, a water purifier. The results of laboratory bioassays showed that Cat-Floc LS over a 15-day period was most effective against *P. grimmii* (Alexander, Merritt, & Berg, 1997).

Within the UK the continued 'seeding' of distribution systems with *P. grimmii*, from the water treatment phase, has prompted the development of measures to intercept or exclude egg-

laying females. Fine water mist sprays over tanks and filters are reported to be an effective deterent. The control of larval infestations within biofilms associated with GAC filters is being investigated by at least one UK Water Company. The development of short-term anoxic conditions appears to be a comparatively non-disruptive and successful approach, back-flushing regimes for GAC filters have been developed in Germany (Schreiber, Schoenen & Traunspurger, 1997) and are under further investigation

Asellus sp (freshwater hoglouse or slater)

Two closely similar species, *Asellus aquaticus* (L.) and *Asellus meridianus* Racovitza, are widely distributed detritus feeders in freshwater environments throughout the UK, their biology is outlined by Gledhill, Sutcliffe & Williams (1993). The former species is the most common and the majority of records from mains distribution systems will probably refer to this species. *Asellus* superficially resembles a flattened woodlouse and grows to a maximum length of around 12-14mm (males) and 9mm (females). Juveniles are carried by the female in a brood "pouch" and become free-living when around 2mm in length. Feeding activities include scraping biofilm from surfaces, ingestion of sediment deposits, opportunistic predation of the associated microfauna. In streams and rivers, a series of broods are released through the summer by the female, which may live for up to one year. Brood size increases as the females grow, with >100 eggs laid by the largest individuals. Slower growth and lower fecundity may be anticipated within distribution systems, nevertheless the capacity to acclimatise to chlorine at background concentrations of 0.5-0.8mg l^{-1} (Kooijmans, 1966) facilitates the development and maintenance of breeding populations. Though a poor swimmer, *Asellus* resists displacement by gripping surfaces.

Thirty years ago a survey of animals in distribution systems throughout the UK revealed half the 36 locations sampled yielded *Asellus* sp (Smalls & Greaves, 1968). More recently 35 of 36 distribution systems surveyed in the Netherlands yielded *Asellus* spp, though in contrast to the UK residual chlorine is not widely employed in their distribution systems (Lieverloo & Kooij, 1996).

Control Measures

The capacity of *Asellus* to acclimatise to chlorine at background concentrations of 0.5-0.8mg l^{-1} is well known (Kooijmans, 1966). It has been suggested that the numbers of *Asellus* might be reduced by lowering the concentration of organic carbon sources which promote nutritious pipework biofilms on which the animals feed (Lieverloo & Kooij;1996). In a similar vein, work in Finland (Mietinen *et al.*, 1997, quoted in "Stop feeding the bugs" - New Scientist, 30Aug.1997) claimed the practice of phosphate addition in softwater areas (to reduce the solubility of toxic metals) may promote biofilm food sources. However, the importance of controlling lead in drinking water may be the overiding factor in soft water areas of the UK ("Stop feeding the bugs" - New Scientist, 30Aug.1997).

Mains flushing in combination with air scouring, or following application of elevated residual chlorine, has been employed in the UK to reduce the numbers of *Asellus* in distribution systems. Such actions, which are triggered by customer complaints, generally target localised infestations and the problems are reported to recur intermittently. The rehabilitation of mains in recent years is reported to have reduced occurrence rates.

***"Gammarus"* (freshwater shrimp)**

Freshwater shrimps are flattened laterally, rather than dorso-ventrally (as in *Asellus*) and the largest species reach a similar maximum size. Three taxa from different genera have been recorded from UK distribution systems, namely, *Gammarus pulex* (L.), *Crangonyx* spp, and *Nipharus* spp.

The widespread and common species, *Gammarus pulex*, is the most frequent freshwater shrimp recorded from distribution systems, though occurrence rates are generally much lower (at 3 of 36 locations) than reported for *Asellus* (Smalls & Greaves, 1968). *Gammarus pulex* has a similar life cycle, growth rate and reproductive pattern to *Asellus*, but displays a greater tendency for opportunistic predation on other invertebrates (Welton, 1979; Gledhill, *et al.*, 1993). *Gammarus* is an active swimmer but is more easily displaced from smooth surfaces by flowing water than *Asellus*. In streams, *Gammarus* seeks shelter in plants, gravel and leaf-litter deposits. It is anticipated there is a general absence of suitable coarse debris for *Gammarus* in

distribution systems

Crangonyx pseudogracilis Bousfield is a native of N. America and has colonised a range of water bodies throughout much of England and Wales over the last 60 years, it also occurs in Scotland and Ireland (Gledhill, *et al.*, 1993). Males can attain a maximum length of about 7mm. *Crangonyx subterraneus* Bate and *Niphargus* spp, which are generally less than 4mm in length, occur predominately in groundwater and may be transferred from boreholes to the distribution system.

Control Measures

Freshwater shrimps (*Gammarus/Crangonyx* spp) are reported to be more susceptible than *Asellus* to the residual chlorine concentrations typically found in distribution systems. The same control measures adopted for *Asellus*, namely mains flushing in combination with air scouring, or following application of elevated residual chlorine, are generally adopted in the UK.

Oligochaetes (segmented worms)

A wide range of segmented worms occur in soil and aquatic habitats. The largest species are terrestrial and the majority are incapable of breeding or long-term survival in water, though some colonise filters and by this means gain access to distribution systems. Aquatic species, include common sediment dwellers within the following Families: Lubriculidae, Tubificidae, Naididae, Aelosomatidae and Echytraeidae (Brinkhurst, 1971). Species of Naididae, Aelosomatidae and Echytraeidae are the most frequently reported in distribution systems, all are relatively small, inconspicuous (maximum length 1-5mm) and capable of grazing sediment or biofilms. The Naididae are weak swimmers, species in the other families are entirely sedentary. About two thirds of 36 water mains sampled by Smalls & Greaves (1968) yielded small oligochaeta.

Control Measures

No control measures, specifically for oligochaetes, were described by UK water companies. In Canada the control of Naididae (oligochaete worms) within carbon filters has recently been

investigated (Beaudet *et al* , in press). The authors described a combination of filter backwashing following a 4-6 hour shutdown of individual filters as a successful and sporadic technique to reduce population densities.

Nematodes (round worms)

The Nematoda are unsegmented worms and have a smooth, transparent, shiny cuticle. Free-living and parasitic species occur in a wide range of environments and within other organisms. Many species are too small to see by eye and their recorded presence in more than two thirds of samples from distribution systems gave rise to no specific customer complaints (Smalls & Greaves, 1968). It is anticipated that most nematodes in distribution systems are detrital feeders, closely associated with biofilms and sediment deposits (Mouchet & Pourriot, 1992).

Control Measures

No control measures, specifically for nematode worms, were described by UK water companies.

5.3 *Characteristics of animals reported from distribution systems*

Self-maintaining populations of animals in distribution systems include a wide range of basic morphological types, with species from many families. The most common groups (Section 5,2) are resistant to washout and water treatment processes, have the facility to invade distribution systems, exploit available food sources and breed within the system. They are naturally occurring freshwater species which are physiologically predisposed to exploit the habitats available in water distribution systems. Their success may depend in part on the limited losses to predation and reduced competition for resourses they experience in an otherwise hostile environment.

5.4 *Connections between ill-health and animals reported from distribution systems*

Considerable interest has arisen in the possible survival and conveyance of human pathogens associated with animals in distribution systems. Two modes of association have been

considered: (1) external attachment and (2) gut contents of macroinvertebrates.

External attachment of microflora

The body surfaces of a range of macroinvertebrates (examined using SEM techniques), from a distribution system in the USA, revealed bacteria present singly and as colonies (Levy, Hart & Cheetham, 1986). Parallel studies, using culture techniques indicated no coliforms were present. In the same study, the largest macroinvertebrates examined had the most attached bacteria present. It is noteworthy that externally attached bacteria are exposed to the same chlorine concentrations as free-living bacteria in the water. At relatively high ambient water temperatures (23-26 °C) and in the absence of chlorine, it has been demonstrated that when *Vibrio cholerea* is attached to living crustacean cuticle it multiplies more rapidly that when incubated in water without crustaceans (Anwarul, et al.; 1985). It is anticipated that water temperature in UK distribution systems are generally not conducive to such growth, particularly in the presence of a chlorine residual.

Macroinvertebrate gut 'flora'

Bacteria occurring in the macroinvertebrate alimentary tract have been extensively reviewed by Harris (1993), she noted that both transient (food) and resident (possibly symbiotic) bacterial communities may be present, depending on the invertebrate species concerned. Also, certain bacteria may increase in numbers during gut-passage. Experimental studies in the USA (Levy, *et al.*, 1984) revealed that coliforms ingested by *Hyalella azteca* (a freshwater 'shrimp') can be temporarily protected from disinfection and remain viable. They concluded that microbial communities may be translocated within distribution systems by macroinvertebrates. It is considered that the source of macroinvertebrates (and their gut contents) within distribution systems are critical regarding the occurrence and persistence of coliforms. Macroinvertebrates that are long-term residents within the distribution system will ingest resident micro-organisms, which rarely include coliforms. Whilst invading invertebrates carry micro-organisms which are transient contaminants. *Hyalella* rapidly voided coliforms after removal from constant exposure (Levy, *et al.*, 1984).

The health risks associated with other groups of heterotrophic bacteria in distribution system biofilms are less clear. Unlike coliforms, these organisms survive and grow at a wide range of temperatures. It has been suggested that Aeromonads may be opportunistic pathogens of man, causing a variety of illness symptoms (Holmes & Nicolls; 1995). Their presence in mains biofilms may be long established and they are ingested by particle-feeding macroinvertebrates. Holmes & Nicolls (1995) described Aeromonads peaking in numbers in late summer when biofilm development was most rapid in parts of distribution systems most remote from chlorination (concentration <0.2mg/l), this coincides with the peak in problems with animals in distribution systems reported by some UK Water Companies (Questionnaire; Appendix II).

It is noteworthy that ingestion rates (and by implication potential voiding rates) of bacteria by a broad range of invertebrate groups were reviewed by Bott (1995) and individual macroinvertebrates are capable of ingesting 1,000-100,000 bacteria per hour.

5.5 *Aspects of control measures or occurrence of animals that may affect water quality in distribution systems*

Physical control measures (flushing, air scouring, swabbing) may be counter-productive for water companies in the short term. Flushing the mains can cause mobilisation of animals and their faecal pellets (fine sediment) and erosion of the biofilm may also occur. The increased numbers of animals and debris appearing in domestic supplies, in turn leading to consumer complaints (eg, Berg, 1995). In The Netherlands a high proportion of groundwater is utilised and this is generally supplied to the distribution systems without addition of residual chlorine Lieverloo, *et al.* (in press). Customer complaints prompted studies to assess the effectiveness of flushing contaminated sections of pipework. An alternative approach was also considered; the reduction of food available to animals in distribution systems as a means to restrict animal populations. Preliminary results indicate that distribution systems at risk of contamination by animals can be assessed by measuring biofilm development rates on pipework. Biofilm development was shown to be most rapid when *Aeromonas* bacteria were numerous

indicating that reducing the concentration of dissolved organic nutrients in the groundwater supply would be an indirect effective control measure for animals in distribution systems, in combination with selective mains flushing (Lieverloo, *et al.*; in press). Aspects of the study continue.

Earlier work in the UK (eg Sands, 1969; Evins & Greaves, 1979) also stressed the importance of controlling the food supply available to animals in distribution systems. The practice of phosphate addition in softwater areas, to reduce the solubility of toxic metals, may promote biofilms which provide food sources for macroinvertebrates. However, the importance of controlling lead in drinking water may be the overriding factor in such circumstances in the UK ("Stop feeding the bugs" - New Scientist, 30Aug.1997

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Appendix I

Animals* in distribution systems

(*macroinvertebrates)

UKWIR Questionnaire

Q1 Has your company experienced any problems with animals in recent years?

Yes **No**

Q2 Has the frequency of animal problems changed in the past 5 years?

Yes **No**

Increased -
Decreased -
Same -
Unknown -

Q3 Has your company carried out surveys for animals in distribution systems?

Yes **No**

Q4 Has your company investigated the presence of animals in the later stages of the water treatment process (eg GAC filters)?

Yes **No**

Q5 Do you have internal company reports on the incidence of animals in your distribution systems and/or treatment processes?

Yes **No**

Q6 Are you in a position to permit examination of these reports:

a) in response to this enquiry?
b) only following specific authorisation?

Q7 Does the appearance of animals in your distribution system lead to specific (and effective) actions? Such as -

A) physical (mains flushing)?
Effective?

B) additional chlorine dosing?
Effective?

(as chloramine)
Effective?

(as chlorine dioxide)
Effective?

chlorine concentration used?

C) other chemical treatment?

- chemicals used -

D) combinations of treatments?

E) other actions taken by your company? (please specify)

Q8 How frequently is action required to eliminate animals from troublesome parts of the distribution system? (please tick <u>one</u> of the following)

Not Applicable
A) more than once a year
B) every year
C) every second or third year
D) very rarely

Q9 When do you investigate for animals in distribution systems? (please tick <u>any</u> of the following - more than one if appropriate)

Not Applicable ☐
A) following complaints
B) B) specific investigations
C) general routine monitoring
D) other circumstances (please specify)....
appearance at treatment works

Q10 When are animal problems most frequently encountered? (please tick one of the following)

Not Applicable
A) December to February
B) March to May
C) June to September
D) September to November
E) No seasonal trend

Q11 Please provide a short summary of your views on animal occurrences in distribution systems, particularly mentioning any important points you consider are not covered by this questionnaire.

Appendix II

Animals* in distribution systems

(*macroinvertebrates)

UKWIR Questionnaire Responses

Questionnare Response Summary

A broad geographic spread of 25 Water Companies, returned the questionnaire circulated to 28 different companies, throughout England, Wales, Scotland and Northern Ireland in 1997. One company supplied separate data for four regional areas and for the purposes of this review they are treated as separate companies, giving a total of 28 responses to consider.

Ten UK Water Companies reported the need to eliminate animals occurring in parts of their distribution systems every year, or more than once per year (1993-1997). These companies with the most severe problems were based in all regions of the UK

Over the same period, three companies reported known occurrence of animals in distribution systems every second or third year. Eleven companies reported very rare occurrence and four companies stated there had been no known occurrence of animals in their distribution systems over this timescale. Seasonal occurrence of animals in distribution systems was pronounced with most problems encountered in June-September (13 companies) and March-May (6 companies). 'No seasonal trend' in animals in distribution systems was reported by 8 companies.

The perception of whether these animals present companies with a problem generated a "yes" from 20 of the 28 companies. The eleven companies reporting occurrence rates at every 2nd or 3rd year included seven companies regarding this level of frequency as a problem (Question 8).

Thirteen companies did not specify which group(s) of animals occurred in their distribution system, whilst *Asellus* was mentioned by six companies ,chironomids by three, *Gammarus* by one and 'small snails' by one company.

Animals* in distribution systems
(*macroinvertebrates)

UKWIR Questionnaire Responses

Q.1. Has your company experienced any problems with animals in recent years?

Yes=20 **No=8**

Q.2. Has the frequency of animal problems changed in the past 5 years?

Yes=11 **No=17**

Increased - **6** (incl.**3** - 'variable'),
Decreased - **5**
Same - **9**
Unknown - **2** (+ **6** Not Applicable)

Q.3. Has your company carried out surveys for animals in distribution systems?

Yes=13 **No=15**

Q.4. Has your company investigated the presence of animals in the later stages of the water treatment process (eg GAC filters)?

Yes=11 **No=17**

Q.5. Do you have internal company reports on the incidence of animals in your distribution systems and/or treatment processes?

Yes=5 **No=23**

'Short laboratory reports' - **2**

'Data' - **3**

Q.6. Are you in a position to permit examination of these reports:

a) in response to this enquiry?

Yes=2

b) only following specific authorisation?

Yes=3

Q.7. Does the appearance of animals in your distribution system lead to specific (and effective) actions? Such as -

A) physical (mains flushing)?

Yes=24 (+ 4 Not Applicable)

Effective?

Yes=10 (+ 12 partial)
No=1 (+ 4 Not Applicable)
Unspecified=1

B) additional chlorine dosing?

Total=8 Effective? **Yes=3** (+ **3** uncertain, sometimes or partial)
No=1
Unspecified=1

- (as chloramine)

Total=2 Effective? **Yes=2**

- (as chlorine dioxide)

Total=1 Effective? **No=1**

chlorine concentration used? **0.5-1.5**....mg/l (**20**mg/l - a single company)

C) other chemical treatment? Effective?

- chemicals used -

Permethrin/pyrethrin - **(1)**(pre-1990)	conc.= >0.0001mg/l	**uncertain=1**
Permethrin - **(1)**(pre-1991)	conc.= 0.01-0.025mg/l	**Yes=1**
Permethrin - **(1)**	conc.= 0.008mg/l (in comb.)	**uncertain=1**
Permethrin - **(1)**	conc.= 0.01-0.02mg/l (in comb.)	**uncertain=1**
Permethrin - **(1)**	conc.= 'WRC protocol' mg/l	**uncertain=1**

D) combinations of treatments? Effective?

(**14** Not Applicable)

Mains Flushing +Permethrin -	**Total=4**	**Yes=2**
		uncertain=2
Mains Flushing +Chlorine -	**Total=1**	**Yes=1**
both Chlorine +Permethrin	**Total=1**	**Yes=1**
Mains Flushing + Chlorine dioxide	**Total=1**	**No=1**

E) other actions taken by your company? (please specify)

none - **Total=16**

(multiple answers provided)

(distribution system)	
swabbing	**Total=3**
air scouring	**Total=8**
in-line filters (to tackle a specific problem)	**Total=2**
future flushing planned	**Total=1**
main rehabilitation undertaken	**Total=2**
chloramine 'relatively high dose' over short period	**Total=1**
applying 'combined Cl residual' (0.5mg/l) -	
localised problem -	**Total=1**
(treatment process based)	
water mist spray (deter adult chironomids)	**Total=2**
microstrainer	**Total=1**
GAC briefly sent anaerobic	**Total=1**
increased filter washing	**Total=1**

Q.8. How frequently is action required to eliminate animals from troublesome parts of the distribution system? (please tick <u>one</u> of the following)

Not Applicable **Total=4**

A) more than once a year	**Total=5**
B) every year	**Total=5**
C) every second or third year	**Total=2**
D) very rarely	**Total=11**
B to D 'depends on the location'	**Total=1**

Q.9. When do you investigate for animals in distribution systems? (please tick any of the following - more than one if appropriate)

(multiple answers provided)

Not Applicable	**Total=3**
A) following complaints	**Total=24**
B) specific investigations	**Total=8**
C) general routine monitoring	**Total=5**
D) other circumstances (please specify)....	
appearance at treatment works	**Total=1**

Q.10. When are animal problems most frequently encountered? (please tick one of the following)

(Some companies indicated two periods).

Not Applicable	**Total=4**
A) December to February	**Total=0**
B) March to May	**Total=6**
C) June to September	**Total=13**
D) September to November	**Total=1**
E) No seasonal trend	**Total=8**

Q.11. Please provide a short summary of your views on animal occurrences in distribution systems, particularly mentioning any important points you consider are not covered by this questionnaire.

Faunal groups mentioned:

Not Applicable	**Total=4**
None -	**Total=3**
Animals unspecified -	**Total=13**

(Some companies indicated more than one group)

Chironomids/midges -	**Total=3**
(+ infestation in the treatment works only)	**Total=2**

Asellus -	**Total=6**
'Gammarus' -	**Total=1**
'Snails' -	**Total=1**

"Specific improvements in treatment proccesses and distribution systems: reduced the occurrence of animals in distribution systems in recent years".

Total=5

general improvements=3;
mains scouring/flushing by 'zone' =1,
higher residual chlorine=1

"New treatment works processes have required new methods for tackling animal contaminents".

Total=4

"Certain infestation problems demand specific approaches".

Total=3

A higher risk of infestation problems is associated with:

- surface water sources (in contrast to groundwater). Companies relate this to higher water temperatures and total organic carbon, which can occur in surface sources.

Total=1

- pre-war cast iron mains.

Total=1

- 'dead ends' in distribution.

Total=1

- regions of lowest residual chlorine.

Total=1