J. Hyg., Camb. (1979), **83**, 547
Printed in Great Britain

Possible origin of the bluetongue epidemic in Cyprus, August 1977

By R. F. SELLERS, E. P. J. GIBBS and K. A. J. HERNIMAN
Animal Virus Research Institute, Pirbright, Woking, Surrey

and D. E. PEDGLEY and M. R. TUCKER
Centre for Overseas Pest Research, London W8 5SJ

(*Received* 23 *April* 1979)

SUMMARY

Possible origins of an epidemic of bluetongue in Cyprus in August 1977 have been analysed. First outbreaks occurred simultaneously in the south-east of the Famagusta district and on the north coast of the Kyrenia district respectively. Although the epidemic was due to type 4, which had been responsible for the previous outbreak in 1969, no evidence of persistence of virus could be found. Imports of domestic animals in the past year were not implicated since the imported cattle were introduced only to the southern part and not to the northern part of the island. Easterly, north-easterly and northerly winds during the period 11–14 August could have brought infected midges at a height of 0·5–1·5 km from Syria and Turkey, and such a movement would fit well the dates of the first outbreaks (20–25 August). Temperatures at a height of 1·5 km were 20–25 °C and at 0·5 km 30–35 °C, and with wind speeds 10–20 km h^{-1} the distance from Turkey and Syria would have been covered in 5–20 h. It follows that, in addition to surface winds, winds at all levels warm enough for flight should be taken into account when the possibility of disease spread by windborne midges is being assessed.

INTRODUCTION

At the end of August 1977, bluetongue disease of sheep due to type 4 broke out in Cyprus (Polydorou, 1978). The epidemic started simultaneously in the south-east of the island (in the Famagusta district) and on the north coast (in the Kyrenia district) and eventually involved sheep in most of the island apart from the Karpas peninsula.

Since the last outbreak of bluetongue in Cyprus, in 1969, a team from the Animal Virus Research Institute, Pirbright, has been studying the ecology of vectors, hosts and virus (Sellers, 1975). The team's findings, together with records from 1977, have been used to examine three possible origins of the outbreak: persistence of virus since 1969, importation in carrier animals in 1976, and windborne spread of infected midges during August 1977.

0022–1724/79/0035–1979 $01.00

METHODS

Records

Details of previous outbreaks were obtained from the Annual Reports of the Veterinary Department, Nicosia, some of which have been summarized by Gambles (1949) and Sellers (1975). The same reports provided details of imports of domestic livestock to Cyprus.

Dates of the initial outbreaks of the 1977 epidemic were obtained from the Veterinary Services and individual farmers were questioned during visits.

Weather records for August were made available by the Cyprus Meterological Service at Larnaca Airport, the Main Meteorological Office at Akrotiri Airport and from other countries in the Middle East (via the international meteorological communications network and received at the Centre for Overseas Pest Research through the British Meteorological Office). Some ship reports were obtained from the Royal Netherlands Meteorological Institute.

Host and vector

Bluetongue virus type 4 has been shown to produce clinical disease in sheep 5, 6, 7, 8, 9 and 12 days after inoculation; clinical signs in the majority of sheep began on the 6th, 7th or 8th day (Goldsmit, Barzilai & Tadmor, 1975). Growth of bluetongue virus type 4 in the midge after taking an infected meal and other aspects of the life-cycle in the midge and of the hosts and disease, are the same as those already described for bluetongue type 10 (Sellers, Pedgley & Tucker, 1978).

With an incubation period in most sheep of 5–9 days and a minimum incubation period in midges of 7 days, the shortest period between a midge biting an affected animal and the disease being seen later in a sheep bitten by that midge could be from 12 to 16 days with a mean of 14 days, i.e. the time for one vector-host cycle.

HISTORY OF THE EPIDEMIC

Bluetongue first broke out in the last 2 weeks of August in the villages of Ayios Amvrosios, Lapithos and Karavas on the northern coast of the Kyrenia district, and in the villages of Vrysoules, Phrenaros, Sotira, Paralimni, Avgorou and Ayia Napa in the Famagusta district in the south-east (Fig. 1).

In the northern part of the island, bluetongue was found in sheep at villages on the coast from Akanthou in the east to Kormakiti in the west. By the end of September, the disease was present in villages south of the Kyrenia range, in other villages near Morphou, and at Ayios Yeoryios in the Famagusta district. Further cases were reported in October near Kythrea and in other villages in the Famagusta district.

In the south, flocks in nine villages in the Famagusta district were affected, and disease occurred in the second week in September in the Larnaca district. Bluetongue was also present in villages south of Morphou in the Nicosia district from the third week of September and, at the end of September, flocks in the Paphos district were affected.

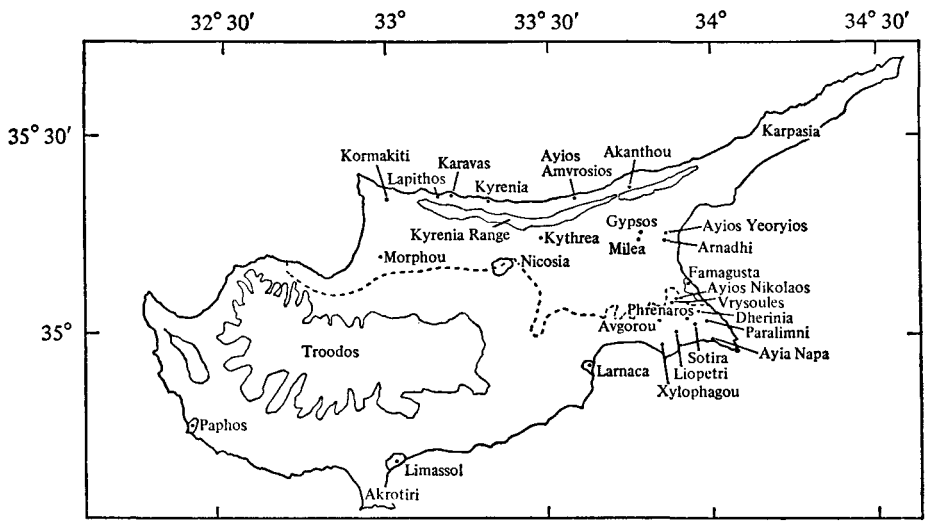

Fig. 1. Location map of Cyprus showing sites of outbreaks of bluetongue. Contour line at 800 m shown.

Table 1. *Numbers of flocks and sheep affected and dying during the epidemic of bluetongue in Cyprus, August–November* 1977

Area	No. of flocks affected	No. of sheep in these flocks	No. of sheep affected	No. of sheep dying
Northern	162	13223	1683 (12·73%)	201 (1·52%)
Southern	303	27837	3653 (13·12%)	549 (1·97%)
Total	465	41060	5336 (13%)	750 (1·83%)

Further cases of disease in both northern and southern areas were reported in October and November. Thus much of the island was involved apart from the Karpas region and the Nicosia district south and south-west of Nicosia.

The total number of flocks and sheep affected and dying in northern and southern areas of the island is given in Table 1. About 1·5–2% of all sheep in Cyprus were affected. Further details of the outbreaks in the south have been described by Polydorou (1978).

ANALYSIS

Dates of the first outbreaks in the south are given in Table 2. Those for the north are not known so precisely, but the evidence available indicates that the initial outbreaks in both north and south areas of Cyprus were within 1 week of each other. There is no official movement of animals between the two areas. Thus, since a minimum period of 12 days is required for one sheep-midge-sheep cycle to elapse, sheep in the villages first infected could not have been a source of virus for sheep in villages in the other area. Sheep in both areas would therefore have been infected about the same time.

On some farms a second wave of disease in sheep occurred 14–16 days after the

https://doi.org/10.1017/S0022172400026401 Published online by Cambridge University Press

Table 2. *Initial outbreaks of bluetongue in the southern area of Cyprus*, 1977

Village	Date of outbreak	Possible dates of infection of sheep	Latest possible dates of infection of midges
Phrenaros	20 August	11–15 August	4–8 August
Vrysoules	20 August	11–15 August	4–8 August
Avgorou	22 August	13–17 August	6–10 August
Paralimni	25 August	16–20 August	9–13 August

first. This agrees with the period of 12–16 days taken as one vector-host cycle. The first case in the Larnaca district occurred on 8 September, and this would support an initial date of disease of 23–27 August (12–16 day period).

No type other than type 4 bluetongue virus was isolated during the epidemic.

The following hypotheses to account for the origin of the epidemic were considered.

(i) Bluetongue virus had persisted in Cyprus since 1969 without causing recognizable clinical signs. (The outbreaks in 1969 were also caused by type 4 virus.)

(ii) Bluetongue virus had come from carrier cattle, sheep or goats imported legally or illegally into Cyprus.

(iii) Bluetongue virus had been introduced to Cyprus by infected *Culicoides* midges carried on the wind (from the most likely sources – eastern Turkey, northern Syria or northern Iraq).

(i) *Persistence of bluetongue virus in Cyprus since* 1969

Several unsuccessful attempts were made from 1972 to 1977 to isolate bluetongue virus from midges and the blood of cattle, sheep and goats by intravenous inoculation of 10- or 11-day-old chick embryos. From 1970 to 1974, sera were taken from cattle, sheep and goats over most of the island and especially from sheep and goats on four farms in Sotira, Liopetri and Xylophagou in the south-east of the Famagusta district. In serum neutralization tests in microtitre plates (Parker *et al.* 1975), low-titre antibodies to bluetongue were demonstrated (Gibbs, Lawman & Herniman, quoted by Sellers, 1975), but the titres are probably not significant. Further samples taken in March 1975 and March 1977 failed to demonstrate the presence of significant titres of antibody, except to type 7 in one goat (titre 1/110).

The failure to isolate virus or demonstrate antibody does not mean that the virus could not have persisted. In countries such as Cyprus, in which conditions during part of the year are unsuitable for midges, virus might persist in surviving adult midges or in ruminants. In North America, South Africa and Israel, bluetongue virus probably persists in cattle; virus has been isolated from cattle blood for 100 days and in some cases up to 3 years after infection, and dams infected in early pregnancy transmit the virus transplacentally to their offspring over a period of at least 180 days (Luedke, Jones & Walton, 1977). Cattle, however, form only about 3–4% of the ruminant population in Cyprus, and in

the areas where the disease broke out, sheep and goats predominate. In sheep and goats, virus had not been found to persist in the blood and tissue beyond 21–50 days (Goldsmit *et al.* 1975; Luedke & Anakwenze, 1972; Lawman, 1978 – unpublished data), whereas persistence of virus for 145 days can be demonstrated by transplacental passage in pregnant sheep (Gibbs *et al.* 1979). In 1969, however, the year of the previous bluetongue outbreaks, only 21 sheep were clinically affected, and it seems unlikely that this would be sufficient weight of infection to persist for as long as 8 years, unless the virus persisted in tissues or in hosts as yet undiscovered. In addition, the virus is unlikely to have persisted in wild ruminants as they are few and are found mainly in the Troodos mountains (Sellers, 1975).

(ii) *Introduction of bluetongue virus by imported carrier animals*

Pregnant Friesian cows and heifers were imported from Israel to the south area in 1976, and blood and serum samples were taken from some of these animals in March 1977. No virus was found in the blood, but antibodies to type 4 were present in the serum of some animals, titres as high as 1/640 being found.

The cattle were imported through the port of Larnaca, remained for a quarantine period near the port and were then distributed to farms in villages in various parts of the south. None of the cattle went to the north area of the island nor to those villages in the south where the disease started. In some of the villages in the southern area which received cattle, bluetongue did not occur in sheep until, at the earliest, 2 weeks after the initial outbreaks; in the other villages which received cattle, no disease was found during the epidemic.

If these cattle were responsible for introduction of the virus, it is difficult to explain how the disease broke out (i) in the south, only in the south-eastern part of the Famagusta district, and (ii) in the north, only in the Kyrenia district, where no cattle were introduced. The only possibility is that there was latent spread of bluetongue virus in 1976 and 1977, followed by expression of the disease in the two areas at the same time.

No other imports of susceptible animals were recorded, and there is no suggestion of illicit import of infected animals.

(iii) *Carriage of infected midges on the wind*

The sites of the first outbreaks in the Kyrenia and Famagusta districts suggest movement of infected midges on winds from between north and east, i.e. from Turkey and Syria. The period during which this movement could have occurred would have been from 5 days before the earliest outbreaks (minimum incubation period for type 4 in the sheep) to 16 days (9 days incubation period in the sheep and 7 days in the midge). Midges would therefore have arrived between 4 and 15 August.

Wind soundings at Ayios Nikolaos, close to the first outbreaks in the Famagusta district, using pilot balloons three times a day, showed that there were northerly winds on 5–6 and 14 August and easterlies from 11 to 13 August, but not in the lowest 0·5 km of the atmosphere. On other days during the first half of August,

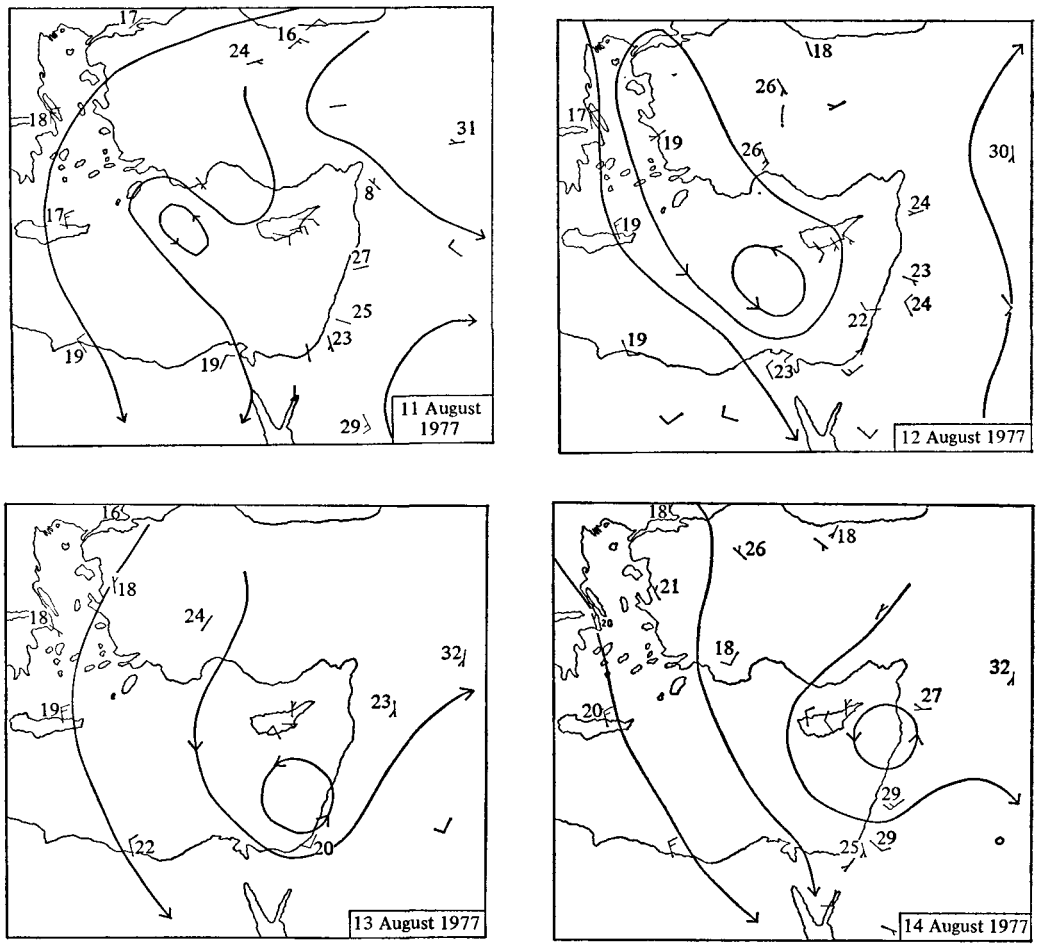

Fig. 2. Sequence of 850 mbar charts (about 1·5 km above sea level) for 12.00 GMT, 11–14 August 1977, showing temperatures (°C), winds and schematic streamlines. Winds shown thus: ⟋ 2·5 ms^{-1}, ⟨ 5 ms^{-1}.

winds were from north-west or south-east. Movement during the period 11–14 August would fit very well the reported dates of the first outbreaks (20–25 August).

Throughout 11–14 August the surface wind pattern over the eastern Mediterranean Sea changed very little. Over Cyprus and nearby seas the winds were light and variable, but with diurnal coastal breezes. Elsewhere the Aegean northerly winds turned north-westerly towards Egypt, and westerly towards Israel and Lebanon. Hence there seems to have been no chance for midges to come to Cyprus on surface winds. At 1·5 km above sea level, and downwards to about 0·5 km, winds were blowing in a weak cyclonic circulation whose centre moved slowly eastwards from the southwest to the east of Cyprus, with winds over Cyprus consequently backing from east or south-east on the 11th and 12th through north-east on the 13th to north by the 14th (Fig. 2). It is these winds that could have brought midges to Cyprus. With wind speeds reported mostly

https://doi.org/10.1017/S0022172400026401 Published online by Cambridge University Press

10–20 km h^{-1}, distances of about 100–200 km (from Turkey and Syria) would have taken 5–20 h, comparable with flight durations inferred from other studies (Sellers, Pedgley & Tucker, 1977). Throughout the period, air temperatures over the sea at a height of 1·5 km were about 20–25 °C and at 0·5 km probably about 30–35 °C, all high enough not to inhibit flight. Air temperatures near the sea surface were about 25 °C and there is likely to have been a strong temperature inversion over the sea at a height of about 0·5 km, separating the cool and variable winds beneath from warm east and north winds above.

DISCUSSION

In past years most outbreaks have been recorded in the Famagusta and Kyrenia districts. In 1943, 1946 and 1965, years in which disease of exceptional virulence and extent was noted, bluetongue started either in the south-east of the Famagusta district alone (1943) or simultaneously in that district and in the north-west of the Kyrenia district (1946 and 1965). In the last 2 weeks of September 1965, outbreaks were found in Phrenaros, Sotira, Paralimni, Avgorou, Ayia Napa, Dherinia, Liopetri, Milea, Gypsos, Arnadhi and Xylophagou in the south-eastern corner, and in Ayios Amvrosios, Karavas and Lapithos in the Kyrenia district. The first five villages in the south-east and the three villages in the Kyrenia district are the same as those first affected in August 1977. Thus, there would appear to be a common factor which affects the location of the initial outbreaks at the start of an epidemic.

No correlation was found in the years up to 1965 between the imports of cattle, sheep and goats from countries having bluetongue and subsequent outbreaks in Cyprus (Sellers, 1975). In 1946, 1964 and 1965 there were no imports of animals; importation of goats from Syria (1952, 1953), cattle and goats from Turkey (1952) and sheep from Israel (1956, 1971, 1972) did not lead to widespread outbreaks of bluetongue in the same or subsequent years. Thus, on past history, the origin of the bluetongue in 1977 from imported animals is unlikely.

From 1965 to 1969 bluetongue was reported each year; from June 1966 to June 1968 the longest interval between outbreaks was 4 months – between January and May in both 1967 and 1968. It is possible that bluetongue virus could have persisted in midges or in sheep and goats during this period. For bluetongue virus to survive 8 years, however, and to reappear in specific locations in Kyrenia and Famagusta districts, must mean an especial method of latency.

Thus, of the three hypotheses considered, the most likely origin of bluetongue virus in 1977 was the introduction of infected midges on the wind. The outbreaks in 1965 began on or after 15 September in almost the same villages in the Famagusta and Kyrenia districts as in 1977 (see earlier). An examination of weather data for August and September 1965 has shown that outbreaks starting on or after 15 September were preceded by winds from between north and north-east from 1 to 4 September, and present up to at least 2 km above sea level on the 1st and 2nd. These winds could have brought the infected midges from Turkey. (Previous similar winds were confined to early August.) Temperatures were

15–20 °C at 1·5 km above sea level and probably 25–30 °C at 0·5 km, and the flight duration would have been 7–20 h at wind speeds of 10–15 km h^{-1}. It should also be noted that at the time of the African horse sickness epidemic in the Middle East during 1960, north and north-east surface winds during late August most likely brought midges infected with African horse sickness virus to Cyprus (Sellers *et al.* 1977).

Thus, during the months of August and September, and possibly during other months, midges infected with viruses may be carried from the mainland to Cyprus. When the chances of a midge invasion are being assessed, in addition to surface winds, there is a need to take into account winds at all levels warm enough for midge flight. In the analysis of possible windborne spread of bluetongue to Portugal in June 1956 (Sellers *et al.* 1978), it was noted that a cyclonic wind circulation similar to that at the surface occurred to a height of more than 3 km and that temperatures greater than about 20 °C were recorded up to 1·5 km. On this occasion in August 1977 the passage of a cyclonic circulation was masked by a shallow layer of variable winds near sea level and surface winds gave no guide to the likely date of arrival and source of midges.

Wind directions suggest sources in Syria and eastern Turkey for the 1977 Cyprus outbreak. No disease was reported from these areas in August 1977, but an outbreak of bluetongue in October 1977 was diagnosed in Aydin province, western Turkey (37° N, 28° E). There was bluetongue in Syria in 1943 and in Turkey from 1944 to 1947 (Gambles, 1949). In November 1975 and June 1976, clinical cases of bluetongue disease were reported from Iraq: Ramadi (33° 25′ N, 43° 20′ E) and Musaiyib (32° 40′ N, 44° 20′ E) districts, respectively (Hafez, Pollis & Mustafa, 1978). In addition, Hafez (1978) found precipitating antibodies to bluetongue in 3–97 % of sheep sera collected between September 1976 and May 1977 in the 18 provinces of Iraq. In many areas of Syria and eastern Turkey, however, the disease may remain unrecognized unless the strain of virus is particularly virulent, as was the case with the Cyprus strain of 1943. In addition, the virus may circulate in the local breeds of animals without causing the disease, as is found in endemic areas in Africa (Sellers *et al.* 1978).

We should like to thank Dr K. Polydorou (Director), Dr G. Pitzolis, Dr Th. Hadjisavvas, Dr A. Ioannides, Dr L. Michael and other members of the Department of Veterinary Services, Cyprus, for their assistance in supplying information and collecting samples. We also thank Dr V. Güven, Dr V. Volkan and Dr Y. Altan, Turkish Cypriot veterinarians, for supplying information and samples. Mr K. L. Philaniotis and his colleagues of the Cyprus Meteorological Service kindly provided meteorological information as did Mr F. P. Sims of the Main Meteorological Office, Akrotiri. The work in Cyprus was financed by the Ministry of Overseas Development under their technical assistance programme.

REFERENCES

GAMBLES, R. M. (1949). Bluetongue of sheep in Cyprus. *Journal of Comparative Pathology and Therapeutics* **59**, 176–90.

GIBBS, E. P. J., LAWMAN, M. J. P. & HERNIMAN, K. A. J. (1979). Preliminary observations on transplacental infection of bluetongue virus in sheep – a possible overwintering mechanism. *Research in Veterinary Science* **27**, 118–20.

GOLDSMIT, L., BARZILAI, E. & TADMOR, A. (1975). The comparative sensitivity of sheep and chicken embryos to bluetongue virus and observations on viraemia in experimentally infected sheep. *Australian Veterinary Journal* **51**, 190–6.

HAFEZ, S. M. (1978). Serological evidence of bluetongue in Iraq. *Bulletin de l'office international des épizooties* **89**, 13–22.

HAFEZ, S. M., POLLIS, E. G. & MUSTAFA, S. A. (1978). Serological evidence of the occurrence of bluetongue in Iraq. *Tropical Animal Health and Production* **10**, 95–8.

LUEDKE, A. J. & ANAKWENZE, E. I. (1972). Bluetongue virus in goats. *American Journal of Veterinary Research* **33**, 1739–45.

LUEDKE, A. J., JONES, R. H. & WALTON, T. E. (1977). Overwintering mechanism for bluetongue virus: biological recovery of latent virus by bites of *Culicoides variipennis*. *American Journal of Tropical Medicine and Hygiene* **26**, 313–25.

PARKER, J., HERNIMAN, K. A. J., GIBBS, E. P. J. & SELLERS, R. F. (1975). An experimental inactivated vaccine against bluetongue. *Veterinary Record* **96**, 284–7.

POLYDOROU, K. (1978). The 1977 outbreak of bluetongue in Cyprus. *Tropical Animal Health and Production* **10**, 229–33.

SELLERS, R. F. (1975). Bluetongue in Cyprus. *Australian Veterinary Journal* **51**, 198–203.

SELLERS, R. F., PEDGLEY, D. E. & TUCKER, M. R. (1977). Possible spread of African horse sickness on the wind. *Journal of Hygiene* **79**, 279–98.

SELLERS, R. F., PEDGLEY, D. E. & TUCKER, M. R. (1978). Possible windborne spread of bluetongue to Portugal, June–July 1956. *Journal of Hygiene* **81**, 189–96.