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Cockroaches as carriers of bacteria in multi-family dwellings

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SUMMARY

The potential risk of bacterial dissemination due to the presence of cockroaches (*Blattella germanica*, Blattellidae) in low-income flats was investigated. Cockroaches can carry a great variety of bacterial species; we identified 30 different species from 52 different flats. *Klebsiella oxycytoca*, *K. pneumoniae* and *Enterobacter cloacae* were the most frequently found. Pathogenic and potentially pathogenic bacteria represented 54% of all the bacterial identifications. Bacteria were carried either on the cuticle or in the gut. Contamination through external contact is sufficient to insure bacterial diffusion. There was a very low level of overlap estimated by Pianka's index (*a*) between the bacterial flora of neighbouring blocks of flats, and (*b*) between bacterial flora of different flats in the same block.

INTRODUCTION

Cockroaches are some of the most important pests in urban environments [1]. They are frequently found in large multi-family dwellings where it is difficult to get rid of them completely [2]. Their presence can cause many problems as it reduces people's perception of their well-being and the satisfaction they derive from their own personal environment [3]. In flats, cockroaches are found mainly in kitchens, bathrooms, toilets and cupboards used for storing food. Cockroaches are able to move from one part of a building to another [4–7]. In large blocks sanitary conditions as well as cockroach population size are highly variable between flats [8], although the variations of these two factors are not always related [1]. In addition, cockroaches are omnivorous, and their feeding habits are such that they are in contact with many kinds of stored food used by people, as well as with different kinds of biological waste or detritus, garbage and sewage, dead insects, faeces, etc. [9]. They are known to carry passively many microorganisms such as bacteria, viruses, helminths and fungi [10–15]. The presence of cockroaches in urban areas is a potential hazard to human health.

The aim of this investigation was to analyse the potential risk related to the presence of cockroaches in multi-family blocks of flats and their capacity for disseminating bacteria. We compared the species richness and relative abundance of each bacterial species carried by cockroaches between flats and between blocks.

Table 1. *Frequency of occurrence of cockroach samples in a block of flats*

Number of samples from one block	1	2	3	5	6	7	9
Number of blocks	7	1	3	1	1	2	1

MATERIAL AND METHODS

Sampling

Blattella germanica (Dictyoptera: Blattellidae) were collected in low-income flats. It was the only cockroach species found in the blocks visited during this study. These blocks were built in the 1970s, and were in Rennes, France. Most of the blocks were large, 15-storey high buildings, with approximately 100 flats in a block. Conditions in these flats where traps (mainly near electrical appliances) were set were not particularly humid. Cockroaches were trapped following the method described previously by Rivault [8]. Each sample used for bacterial analysis was made up of five adult cockroaches all trapped on the same night from the same flat.

The cockroaches came from 52 different flats (i.e. 52 bacterial samples) situated in 16 different buildings. The number of samples collected and analysed for each block of flats is given in Table 1. In 5 of the blocks we were able to collect from 5–9 samples. These samples were used for comparisons between buildings.

Bacteriological analyses

Once collected, the insects were killed with diethyl ether. Only aerobic and facultative anaerobic bacteria were investigated, we did not look for the typical anaerobic cockroach bacterial intestinal flora. As bacteria could be carried by the insects either in their gut or externally on their cuticle, the insects were first washed in sterile water with 0·01 ml of Triton X-100 (Sigma Chemical Company, France) to collect cuticular bacteria, the guts were then dissected and mascerated in 1 ml sterile water. Serial dilutions of each sample in sterile water were inoculated on various bacteriological nutrient media (AES Laboratory, France) and incubated for 48 h at 37 °C.

The identification of Gram-negative bacteria was made after incubation by use of standard methods (API system, bioMerieux, France) after incubation on Drigalski medium.

Staphylococcus aureus were incubated on Chapman medium and identified by respiratory tests and by slide agglutination using Staphyslide tests (bioMerieux, France). Other gram-positive bacteria were not investigated as none are potentially pathogenic.

RESULTS

Thirty different species of bacteria were identified from the 52 samples analysed, one sample representing each flat (Table 2); 40% of the species were found only once, i.e. in only one sample, and therefore in only one flat. Three bacterial species appeared frequently, these were: *Klebsiella oxycytoca*, *K. pneumoniae* and *Enterobacter cloacae*.

Nine of the bacterial species identified in this series of cockroach samples have previously been reported to be potentially pathogenic for man and other

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Table 2. *Location of cockroach samples. Occurrence of bacterial species identified in the different blocks of flats*

	Blocks of flats*						
	A	B	C	D	E	O	Total
Bacteria No. of flats...	7	5	6	7	9	18	52
Acinetobacter calcoaceticus	0	0	2	1	0	4	7
Acinetobacter sp.	1	0	1	0	0	1	3
Aeromonas hydrophila	0	0	0	0	1	0	1
Buttiauxella agrestis	2	0	0	0	0	0	2
Citrobacter diversus†	1	0	0	0	0	0	1
C. freundii†	1	2	0	0	1	1	5
Enterobacter agglomerans†	0	0	0	2	0	0	2
E. cloacae†	4	3	1	1	3	7	19
E. aerogenes†	0	0	0	1	3	1	5
E. intermedium	1	0	0	0	1	1	3
E. sakazaki	0	0	0	0	0	1	1
Escherichia adecarboxylata	1	0	0	0	0	0	1
E. vulneris	0	1	0	0	0	0	1
Ewingella americana	1	0	0	0	0	0	1
Klebsiella oxcytoca†	1	2	1	1	2	2	9
K. pneuomoniae†	3	1	1	4	1	3	13
Kluyvera sp.	0	1	0	1	1	0	3
Morganella morganii	1	0	0	0	0	1	2
Providencia alcalifaciens	0	0	0	1	0	0	1
Pseudomonas cepacia	0	0	0	0	1	0	1
P. fluorescens†	0	0	0	0	0	1	1
P. maltophilia	0	0	1	0	0	1	2
P. paucimobilis	0	0	0	0	0	1	1
Pseudomonas sp.	0	0	1	0	1	0	2
Serratia liquefaciens	1	1	0	1	1	2	6
S. marcescens†	0	0	0	1	1	0	2
S. odorifera	3	0	0	0	0	3	6
S. plymuthica	0	0	0	2	0	0	2
S. rubibaea	0	0	0	0	0	1	1
Vibrio fluvialis	1	0	0	0	0	0	1
No. of species identified in each group of flats	14	7	7	11	12	16	30
Total occurrence of bacteria	22	11	8	16	18	31	105

* A, B, C, D, E, names of blocks of flats; O, data for the flats not in the five test blocks.
† potentially pathogenic bacteria carried by cockroaches [11 17].

vertebrates. [10–17]. The three predominant bacterial species are potential pathogens. The other 'pathogenic' bacterial species identified included the opportunist or potential pathogens *Enterobacter agglomerans*, *E. cloacae*, *E. aerogenes*, *Klebsiella* sp., *Pseudomonas fluorescens*, *Citrobacter* sp. and *Serratia marcescens*. When all these pathogenic bacteria were taken into consideration, they represented 54% of all the identifications.

None of the samples investigated revealed the presence of *Staphylococcus aureus*.

Cuticular versus gut transport of bacterial flora

Sixteen of the 30 different bacterial species identified from the cockroach samples were found both on the cuticle and in the gut. Five species (Table 2) were found in the cuticle samples only. Nine other species were found only in the gut.

Table 3. *Mode of transport of bacteria by cockroaches. Presence of bacteria on the cuticle, in the gut or both*

Bacteria	Cuticle*	Gut*	Both*	Total
Acinetobacter calcoaceticus	0	6	1	7
Acinetobacter sp.	1	1	1	3
Aeromonas hydrophila	0	1	0	1
Buttiauxella agrestis	0	2	0	2
Citrobacter diversus†	0	0	1	1
C. freundii†	0	3	2	5
Enterobacter agglomerans†	1	1	0	2
E. cloacae†	4	12	3	19
E. aerogenes†	1	2	2	5
E. intermedium	0	3	0	3
E. sakazaki	0	1	0	1
Escherichia adecarboxylata	0	1	0	1
E. vulneris	1	0	0	1
Ewingella americana	1	0	0	1
Klebsiella oxcytoca†	0	6	3	9
K. pneumoniae†	5	7	1	13
Kluyvera sp.	1	2	0	3
Morganella morganii	2	0	0	2
Providencia alcalifaciens	0	1	0	1
Pseudomonas cepacia	1	0	0	1
P. fluorescens†	0	1	0	1
P. maltophilia	1	1	0	2
P. paucimobilis	0	1	0	1
Pseudomonas sp.	2	0	0	2
Serratia liquefaciens	5	0	1	6
S. marcescens†	1	1	0	2
S. odorifera	4	2	0	6
S. plymuthica	1	1	0	2
S. rubibaea	0	0	1	1
Vibrio fluvialis	0	1	0	1
No. of species	16	22	10	30
No. of occurrences	32	57	16	105

* Five species were found on cuticle only, nine species in guts only and 16 species found both on cuticle and in guts out of a total of 30 species identified in these samples.

† Potentially pathogenic bacteria carried by cockroaches.

Only one of these nine 'gut' bacteria is classified as really pathogenic for man. The other eight pathogenic bacteria was opportunist or potential pathogens and were found in both cuticle and gut identifications, although not necessarily in the same sample (Table 3).

Comparisons between blocks of flats

Comparisons were made between the five blocks of flats, named here A, B, C, D and E, where we had collected at least five cockroach samples (Table 2). The aim of these comparisons was to determine whether each block possessed a characteristic, specific bacterial flora carried by cockroaches or whether the carried flora were similar in all the blocks.

Pianka's [16] niche overlap index, R, which evaluates the degree of overlap between two factors on one dimension of the ecological niche, was used to

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Table 4. *Pianka's overlap indices comparing bacterial flora between five blocks of flats*

Block	B	C	D	E
A	0·63	0·39	0·46	0·53
B		0·36	0·43	0·68
C			0·40	0·34
D				0·44

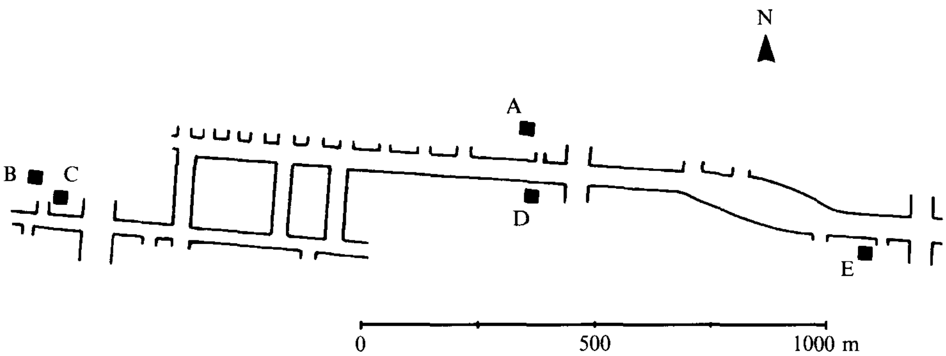

Fig. 1 Diagram to scale, showing the situation of the blocks of flats, A, B, C, D and E (black squares) where cockroaches were trapped for this study.

compare bacterial diversity between blocks and frequency of occurrence of each species.

$$R_x \frac{\Sigma\,(x_{ij} \times x_{ik})}{\sqrt{\Sigma\,(x_{ij})^2 \times \Sigma\,(x_{ik})^2}}$$

where x_{ij} and x_{ik} are relative frequencies of presence of bacterial species i in block j or k. This index varies from 0 to +1, 0 indicating no overlap and +1 complete overlap.

These indices (Table 4) indicate that the level of overlap is comparatively low. The highest values for these indices concerned overlap between block A and block B (0·63) on the one hand and between block A and block E (0·68) on the other hand. These three blocks were geographically relatively far away from one another (Fig. 1). We presumed that there were few exchanges between residents of these blocks.

Comparison between flats in a block

Comparisons were then made on a finer scale to see if there were correlations between bacterial populations in different flats inside each block.

Pianka's [16] overlap index was used to compare overlap of bacterial flora between two flats and to reveal the level of similarity between flats. However, because of the high level of specific diversity and the low number of bacterial species identified in each sample (mean: $2{\cdot}08 \pm 1{\cdot}31$ species per sample, $n = 52$, range 1–7), Pianka's index was often equal to 0. That means that there were no species shared by the two samples being compared. A low value for the index (less than 0·6) meant that these samples had one bacterial species in common. When the index was higher ($> 0{\cdot}6$), the samples had at least two bacterial species in common (Table 5).

Table 5. *Frequency of overlap of bacterial flora between two flats for the five different blocks*

Block	0	> 0	T	*P*
A	10	11	21	0·50
B	5	5	10	0·06
C	14	1	15	< 0·01
D	14	7	21	0·09
E	28	8	36	< 0·01
Total	71	32	103	< 0·001

0, Pianka's index equal to zero; > 0, Pianka's index positive, indicating overlap; T, number of comparisons between two flats; *P*, probability calculated using binomial tests; A, B, C, D, E, name of block of flats; Total, total number of comparisons, $z = -3{\cdot}75$.

Table 6. *Comparison of overlap indices between neighbouring and non-neighbouring pairs of flats*

	Neighbours		Non-neighbours	
Block	0	> 0	0	> 0
A	1	2	9	9
B	1	1	4	4
C	0	1	14	0
D	1	2	13	5
E	1	1	27	7
Total	4	7	67	25

0, Pianka's index equal to zero; > 0, Pianka's index positive, indicating overlap; A, B, C, D, E, name of block of flats.

The number of pairs of flats in each block that had a specific bacterial overlap equal to 0 was significantly higher than the number of pairs that had at least one bacterial species in common (binomial test, Table 5 in blocks C and E). No significant differences were found for the three other blocks (A, B and D). These data show therefore that flats in a given block generally show low or zero overlap. The bacteria carried by cockroaches trapped in one flat are characteristic of that flat and the probability that those bacterial species will be found in another flat in the same block is low.

Amongst the flats studied in the same block there were 11 pairs of closely neighbouring flats, that is they were either door-to-door on the same floor or they aligned vertically on two consecutive floors. Pianka's index was equal to 0 for four of these pairs and it was positive for seven other pairs (Table 6). The differences in proportion of positive/zero overlap indices were statistically significant ($\chi^2 = 6{\cdot}1$, D.F. $= 1$, $P = 0{\cdot}05$). This means that the probability that neighbouring flats share some bacteria species in common is higher than in non-neighbouring flats.

DISCUSSION

Our data show that cockroaches can carry a great variety of species of bacteria in these low-income flats. Amongst the species identified were several pathogenic and potentially pathogenic bacterial species, including mostly enterobacteria.

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These species can cause urinary tract infections, sepsis, gastroenteritis, urinary, biliary and peritoneal infection, pneumonia or wound infections [10–17]. All these species are usually found in a hospital [14, 15, 18, 19]. Their presence in flats, at a relatively high rate, points to an epidemiological problem. Even if many of these pathogenic species are only opportunist or potential pathogens [20] and the presence of immuno-depressive people is rarer in homes than in hospitals, there is risk factor which the presence of cockroaches can only increase.

Our data shows that contamination through external contact is sufficient to ensure bacterial diffusion. Bacteria can be carried on the cuticle and be disseminated by contact alone. Ingestion, intestinal transit of bacteria and their subsequent diffusion by faeces are therefore not an absolute necessity before cockroaches can disseminate bacteria and become involved in spreading bacterial diseases. However, it would seen that potentially pathogenic bacteria are generally carried by the cuticle as well as in the gut.

In a study of the distribution of bacteria carried by cockroaches in a hospital our data suggested the possibility of step by step proximity contamination between contiguous floors [14, 19]. According to this hypothesis cockroaches could be responsible for spreading bacterial contamination. In our present data proximity contamination seems possible, at least between neighbouring flats. This contamination depends on the size of the cockroach population, on the number of cockroaches moving from one flat to another.

Cockroach populations are highly variable in size and spatial distribution and are characterized by a complex interplay of many ecological and social factors. In these buildings various levels of sanitation were observed and behaviour of tenants towards cockroaches also varied [3, 4, 21]. The fact that the bacterial infection rate on cockroaches is higher than the acceptable rate on kitchen equipment under good hygiene standards [14, 22], indicates that they probably play a role in contamination. Rivault [7] using mark and recapture experiments evaluated the level of adult *Blattella germanica* capable of moving from one area to another at approximately 15%. These movements occur by degrees and are possible between contiguous floors. Owens & Bennett [6] observed up to 30% of inter-apartment movements following insecticidal treatment. According to Robinson and co-workers [4] only a few flats which keep producing animals to reinvade the surrounding, treated flats form the reservoir for an entire building. Therefore, exchanges between neighbouring flats are possible even if they are not very frequent.

All these results support our hypothesis: bacteria carried by cockroaches appear to indicate the areas where they have been and cockroaches can disseminate bacteria.

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