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The public and domestic domains in the transmission of disease

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Summary This paper discusses the distinction between the transmission of infectious diseases within the domestic domain (the area normally occupied by and under the control of a household) and that in the public domain, which includes public places of work, schooling, commerce and recreation as well as the streets and fields. Whereas transmission in the public domain can allow a single case to cause a large epidemic, transmission in the domestic domain is less dramatic and often ignored, although it may account for a substantial number of cases. Statistical methods are available to estimate the relative importance of the two. To control transmission in the public domain, intervention by public authorities is likely to be required. Two examples show how environmental interventions for disease control tend to address transmission in one or the other domain; interventions are needed in both domains in order to interrupt transmission.

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Definition of the two domains

More than 20 years ago, Bradley and colleagues proposed the classification of water-related infections according to their mode of transmission, rather than the type of organism which caused them or their effect on the patient (White *et al.* 1972). This classification into water-borne, water-washed, water-based and water-related insect vector groups was a new paradigm which has stood the test of time with only a few modifications, and greatly helped to clarify our thinking about how environmental interventions such as water supply improvements affect disease. It has three advantages. First, it was so simple and (in retrospect) obvious that it was hard to argue with it or forget it. Second, it built on existing knowledge, and drew together the conclusions of a number of studies and authors in widely differing environments. Third, it helped to clarify the issues for the practitioner.

The one significant improvement, made to the Bradley classification by Richard Feachem (1977), was to consider it as a classification of transmission routes rather than of diseases, because (as Bradley had recognized) some diseases could be transmitted by more than one route. This helped to redouble the interest in the transmission process, which is the particular concern of those of us who seek to control disease by environmental modification rather than by immunization or the treatment of patients.

We propose another division of transmission routes which cuts across the preceding categories and is complementary to that classification. It is not limited to the water related diseases and can apply to all infections. Our division is between transmission occurring within the *domestic domain*—the area normally occupied by and under the control of a household—and that in the *public domain*, which includes public places of work, education, commerce and recreation as well as the streets and fields.

The domestic domain is not necessarily limited to the interior of the family house; in many cultures in the tropics, houses are little used during the day except for storage; domestic work, bathing, relaxation, eating and other activities all take place in the yard outside. Nor are the limits of the domestic domain necessarily defined by ownership. A household may own fields, but if they are away from the home strangers are free to visit them. They are thus in the public domain.

In this paper, I shall consider the epidemiological significance of the two domains as arenas for disease transmission, and the implications of this distinction for environmental control strategies.

Disease transmission in the two domains

In the early 1930s, when the researchers of the Rockefeller Foundation reported their studies of intestinal helminth infection in Panama and the American South, they stated clearly that 'the factors influencing the spread of *Ascaris lumbricoides* and *Trichuris trichiura* and to a somewhat lesser extent hookworm are very largely centred in the family' (Otto *et al.* 1931), and that a heavy worm burden in one person was usually associated with heavy infections in the others in the same household. This suggested that these parasites were largely transmitted between family members, presumably within the domestic domain. Indeed, the Rockefeller team found evidence in the form of stools on the ground, and the association of infection with the lack of a latrine, that both stages of the transmission cycle (the excretion of worm eggs, and the infection of the next host) frequently occurred within the physical confines of the peri-domestic area.

They rightly pointed to improvements in the domestic environment, such as the installation of latrines, and to behaviour changes, such as improved management of children's defaecation, as being central to the control of transmission.

Their discussion of the role of children raises the interesting question of whether the age groups involved in domestic transmission and public domain transmission are the same. In his epidemiological review of *Ascaris* infection in West Africa, Prost (1987) took the view that, where the prevalence was less than 50%, the source of infection in the household was the youngest children, and Killewo *et al.* (1991) found that most young children with ascariasis were in households where other members were infected.

Transmission in the domestic domain can also play an important role in endemic and epidemic disease without more than one person in the household necessarily being infected, although one needs exceptionally intimate knowledge of the lives of those involved in order to be able to demonstrate this conclusively. One person who had such knowledge was W.N. Pickles, a country doctor in Yorkshire in the 1930s, who charted epidemics of dysentery, hepatitis and other infectious diseases in the villages for which he was responsible (Pickles 1972). He showed that numerous cases of faecal–oral disease transmission had occurred during visits to relatives and friends in their homes.

On the other hand, he also showed how a single case could give rise to dozens or even hundreds of others if the patient was allowed to go to school or attend a village fête, giving rise to transmission in the public domain. He went so far as to suggest the closure of schools during epidemics, because 'knowledge is not the only thing which is disseminated in these institutions'.

In general, it is recognized that transmission in the public domain is potentially more dangerous as it may give rise to large epidemics. Thus, for example, in the first 50 years of drinking water microbiology, the emphasis was almost entirely on the risk of contamination of water at the source or in the distribution system (the public domain), rather than in the home. Feachem *et al.* (1978) could find only two previous studies of contamination of domestic water storage vessels, although more have been published since then.

In the field of water-borne transmission of disease, domestic contamination of water has been blamed for reducing the beneficial impact of water supplies (Wagner & Lanoix 1959). Moe *et al.* (1991) suggested that domestic domain transmission of diarrhoeal disease limited that impact to cases where

Table 1 Clustering of intestinal parasite infections by household; results of a survey in Dar es Salaam, Tanzania

	No. of households with			
	0 cases	1 case	2 cases	3 or more
Hookworm				
Expected	102.4	32.6	5.2	0.67
Observed	104	30	6	1
Ascaris				
Expected	118.2	20.8	1.9	0.1
Observed	124	12	2	3

Expected values calculated from binomial distribution. Clustering of *Ascaris* significant ($P<0.05$) by Fisher's exact test.
Source: Killewo *et al.* (1991).

the unprotected water source had more than 1000 *E. coli* per 100 ml.

On the other hand, transmission within the household is often seen as practically inevitable. In the intimacy of the family home, it has been argued, people are almost certain to pass their pathogens around. However, as Khan (1982) has shown, at least for shigellosis, most of the domestic transmission can be prevented by a simple behavioural change. Indeed, the ingenious design of Khan's experiment, which focused exclusively on secondary attack rates in the households of known shigellosis cases, meant that he studied *only* the domestic domain transmission. From Khan's reduction of 84% in secondary cases, Feachem (1984) estimated, on the basis of various assumptions, that such a handwashing intervention might reduce the incidence of shigellosis as a whole by 35%. He had in effect assumed that domestic domain transmission accounted for 42% of all cases before the intervention.

Estimating their relative importance

A simple method to assess the relative importance of the two domains in disease transmission is to examine the clustering of cases by household. This is illustrated in Table 1, where cases of *Ascaris* infection show a significant tendency to cluster in specific households, while hookworm infection does not. It follows that, in the community studied, significant *Ascaris* transmission took place in the domestic domain. On the other hand, most of the hookworm transmission was between households rather than within them, so that the domestic environment was not the main area where transmission occurred.

An assumption is involved here. Some degree of aggregation by household could be produced if certain groups of households are at greater risk than others, even if no transmission of infection takes place within the household. Allowance can be made for this, if the risk factors are known, by stratifying the analysis as was done by Conway *et al.* (1995). Interestingly, these authors found a higher degree of household aggregation of *Strongyloides* infection in households that had their own latrine, rather than a shared one or none. A procedure to allow for risk factors but maintain the full sample size was developed for Chagas disease by Smith and Pike (1976).

Other methods, such as the Monte-Carlo method used by Bailey *et al.* (1989) for trachoma, or comparing the households of index cases with the households of similar controls, an approach used by Speizer *et al.* (1976) on cases of respiratory disease in England, have also been used to analyse household clustering. Special problems are encountered with infections such as endemic cholera where asymptomatic infections predominate (Craig 1988).

Another approach is to use multivariate models to compare the influence of risk factors associated with the household and with the neighbourhood as a whole. For example, a number of researchers have shown that differences in environmental conditions between urban neighbourhoods may be associated with larger differentials in child health than are household-level facilities (Koopman *et al.* 1981; Bapat & Crook 1984; Pickering *et al.* 1987; Bateman & Smith 1991; Stephens *et al.* 1994).

For those of us interested in the infections associated with water supply and sanitation, the diarrhoeal diseases are the group of greatest public health importance, so there is particular interest in a recent study by Katz *et al.* (1993). The authors assessed the aggregation of cases of children's diarrhoea by village and by household using data from very large cross-sectional studies in four developing countries. Mothers were asked if the child had experienced diarrhoea within the past week. The degree to which cases were clustered by household was represented

Table 2 Domestic transmission of diarrhoeal disease in young children; increased risk when another child in the household is ill

	Country of study			
	Malawi	Zambia	Indonesia	Nepal
No. of children	5441	4316	28 586	27 541
Age range (years)	0–5	0–5	0–5	0–4
Mean children per household	1.9	1.8	1.7	1.6
Prevalence of diarrhoea (%)	16.1	27.1	7.8	10.5
Odds ratio	4.15	3.88	10.02	2.66
(95% CI)	(3.23–5.33)	(3.18–4.75)	(8.38–11.97)	(2.28–3.11)

Source: Katz *et al.* (1993).

by a pairwise odds ratio, which 'reflects the increased odds in favour of diarrhoea for a child from a household where another child chosen at random from that household has diarrhoea, relative to the odds ... if that randomly chosen child does not have diarrhoea'.

The results (Table 2) show a wide variation between the four study sites in the degree to which a child's risk of diarrhoea was increased by the presence of another ill child in the household—in other words, the relative intensity of domestic transmission compared with transmission between households, with a far higher value in the Indonesian than in the other surveys. The possible explanation offered by the authors—that the Indonesian survey data were collected over a whole year, while the other surveys were conducted in a few months—raises the interesting question of whether the intensity of diarrhoeal transmission, which often varies widely between seasons of the year (e.g. Feachem *et al.* 1978), shows a different seasonal pattern in the domestic and the public domains.

The significance of the domains

The significance of dividing disease transmission between the two domains is that different interventions are appropriate to control the two types of transmission. For the diseases preventable by vaccine, or which can be successfully controlled by mass chemotherapy, this is not important; but where environmental interventions are concerned, it is fundamental. As the foregoing discussion illustrates, the infections targeted by environmental improvements, such as diarrhoeal diseases, are frequently transmitted in both domains, so that interventions in both domains are needed to control them successfully.

Thus an intervention aimed only at the domestic domain, such as the provision of household latrines to control hookworm, is unlikely to have any impact on transmission in the public domain such as that caused by open defaecation in the fields. On the other hand, an intervention to prevent public domain transmission of diarrhoeal diseases such as the disinfection of public water supplies will not prevent domestic transmission, for example in contaminated weaning foods. This can be illustrated by two examples of intervention programmes.

Guinea worm in Ghana

The first is Ghana's Guinea worm eradication programme, which since 1989 has relied largely on health education, promoting the purchase and use of cloth filters by which villagers can remove infected *Cyclops* from their drinking water. Tayeh *et al.* (1996) found that they were not completely effective in protecting households from Guinea worm infection, not because of any deficiency in the cloth but because they were not always used. Table 3 shows the degree of clustering of cases in households which bought no filter, which bought less than one for every ten members, and which bought at least one for every ten members.

The smaller mean number of cases in households buying a reasonable number of filters is noteworthy,

Table 3 Clustering of Guinea worm disease in rural Ghanaian households according to filters purchased the previous year

Cases per household	No. of households buying: no filters at all		<1 filter/10 people		⩾1 filter/10 people	
	Observed	Expected	Observed	Expected	Observed	Expected
0	299	269	98	81	285	278
1	110	148	57	78	103	116
2	48	54	38	38	31	26
3	29	18	13	14	4	5
4	6	6	7	4	1	1
5	3	2	2	1	1	<1
6	2	1	1	<1	0	0
7	0	<1	1	<1	0	0
8	1	<1	0	0	0	0
Totals	499		217		425	
Mean cases/household	0.65		1.03		0.44	
Significance	$z=4.59$, $P<0.0001$		$z=3.66$, $P<0.0005$		$z=1.60$, $P>0.05$	

Source: Tayeh *et al.* (1996)

as the households buying filters tended to be the ones having most cases in the previous year. This smaller number of cases shows no significant clustering by household, indicating that in those households, infection with Guinea worm is not occurring in the home; that is, from the water carried home. The problem is that the filters were rarely used outside the home, and those fetching water, working in fields, and travelling outside the village were more exposed than others to infection acquired from casual use of unprotected water sources (Tayeh *et al.* 1993). The cloth filters prevented transmission in the domestic domain, but did not prevent public domain transmission. Some Guinea worm eradication programmes are now experimenting with a portable 'straw' filter which has a piece of filter cloth fixed over one end, and which one can hang around the neck while travelling or working in the fields (Cairncross *et al.* 1996).

Ascariasis in Brazil

The second example is of a study of intestinal worms in children aged 5–14 in *favelas* (shanty towns) of the city of Salvador in North-east Brazil (Moraes, unpublished data). Moraes compared three favelas with no drains or sewers with three where *there were drains serving also as sewers. There were* 631 children in each group.

As can be seen from the results (Table 4), drainage was associated with a reduction, but of course not elimination, of *Ascaris.* Among the reduced number of cases in the favelas with drains, there was a very significant tendency to cluster by household, although this was not seen in the undrained favelas. Moreover, the domestic risk factors for a household to harbour cases of infection became more numerous and more significant as one moved from the communities without drainage to those which had it.

Both of these factors point to a greater relative importance of the household in the transmission of *Ascaris* in the favelas where the drains had prevented most of the waste-water contamination of the streets which is found in many shanty towns, and which often affects the areas where children play. One can deduce that the drainage made infection with *Ascaris* a less haphazard affair, less likely to occur in the streets, play areas or other public places; thus the characteristics of the household, and transmission between household members, became relatively more important as the transmission in the domestic domain was unaffected.

Moraes also treated all his subjects, and observed their reinfection 9 months after the treatment. Table

Table 4 Effect of drainage on *Ascaris* infection in favelas of Salvador, Brazil

	Without drains	With drains
Prevalence of infection (%)	66.4	47.1
Significance of household clustering	–	***
Significant household risk factors		
No. of children aged 5–14	*	****
House wall material	*	–
House floor material	*	–
Crowding (persons/room)	*	–
Small floor area	*	**
Luxury items possessed	–	*
Unprotected water storage vessel	–	***
Animals in the household	–	**
Absence of rubbish container	–	**
Poor sullage disposal	–	*
Sites nearby with visible overflowing sewage	–	*
Frequency of interruption of water supply	–	*
Total no. of significant factors	5	9
Relative risk of reinfection (9 months)	1.30	2.35
(95% Confidence interval)	(1.12–1.52)	(1.93–2.86)
Correlation of infection/reinfection egg counts	0.05	0.23
(Pearson's r; n, no. of children infected twice)	(n=250)	(n=166)
Significance of correlation	–	***

–, Not significant.
*$P<0.05$; **$P<0.01$; ***$P<0.001$; ****$P<0.0001$.

4 also shows how the predisposition of certain individuals to reinfection became stronger when drains were present—that is, when the public domain transmission was controlled. The risk of reinfection among children who were previously infected was greater than among those who were not, and the relative risk increased from the undrained to the drained favelas. Moreover, among the children who were infected on both occasions, there was a correlation between their pretreatment and reinfection worm burdens, as indicated by the egg counts in their stools. This correlation was significant only in the favela with drainage, in spite of the smaller number of children involved. Thus the installation of drainage in a favela is associated with an increase in predisposition not only to reinfection with *Ascaris*, but also to reinfection with a high worm burden.

Predisposition to reinfection with intestinal helminths has often been discussed in the literature (Anderson & May 1991) which frequently treats it as if it were an intrinsic property of the parasite. Here we can see that it is not invariable, but a function of the mode of transmission, and particularly associated with transmission in the domestic domain and therefore more visible in the favela with drainage. These tendencies were also found with the other intestinal parasites considered in this study; the hookworms, and *Trichuris*.

Political implications

There are political implications to this. Transmission of disease in the public domain is a public concern, requiring public investment or public regulation to prevent it. The investment would typically be in infrastructure, such as drains, excreta disposal facilities and solid-waste collection systems. The regulation would probably include water quality standards, and by-laws against discharge or dumping of wastes. If the street is regularly flooded with sewage, national or local government cannot abdicate its responsibility on the basis that it is up to individuals to protect themselves, or to avoid dumping rubbish in the drains.

Domestic domain transmission, on the other hand, is largely a question of people's behaviour, and is susceptible to control by interventions which seek to change that behaviour. Health education is the intervention which springs most readily to mind, but infrastructure and regulation may also have a role to play. For example, there is ample evidence that an improved level of water supply provision can cause increased domestic water consumption, and that much of the increased consumption is used for hygiene purposes (White *et al.* 1972; Cairncross & Cliff 1987). Indeed, Curtis *et al.* (1995) found to their surprise that a tap in the yard was also a good predictor of hygienic excreta disposal.

To those of us who are concerned with public health, however, the goal must be the elimination of all avoidable transmission of infectious disease. We must attend to transmission in both domains, introducing interventions appropriate to each, if we are to reach that goal.

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