Epidemiological aspects and implications of the disappearance of leprosy from Norway; some factors contributing to the decline

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The aim of epidemiology is to study variations in factors potentially responsible for disease in man, viz. determinants of disease, together with variations in the occurrence of disease itself, in order to clarify aetiology of disease. In short, epidemiology may be defined as the study of aetiology.

Primary prevention of leprosy has to be based on knowledge of the aetiology, i.e. epidemiologic knowledge. However, due to several reasons, the epidemiology of leprosy is still only known to some extent. Of particular interest is that accurate data on all cases and on the population at risk, necessary for epidemiological studies, are hard to obtain in areas where leprosy is most frequent today. Furthermore, due to the considerable incubation period, long periods of observation are required. This is the case when time trends are to be studied, and particularly when control measures are to be assessed. There is, therefore, a special need to evaluate and utilize for epidemiological purposes, relevant data already gathered in medical files and registers.

The National Leprosy Registry of Norway

The disappearance of leprosy in Norway, implying a considerable fall in incidence rates over a period of 70 years, from 1850 and onwards, represents an abundant amount of epidemiological experience, documented in a central patient registry for leprosy covering all Norway. The material of the Leprosy Registry substantiates an organization of high quality (1): case ascertainment was obtained by adequate methods of epidemiological surveillance, and detailed clinical descriptions, forming a basis for diagnostic criteria, document that the disease, described and notified as leprosy in Norway, in fact was leprosy as the disease is known today. Even the classification into types appeared to be closely related to current classification. Thus, the Leprosy Registry represents a valuable source of information as to the clarification of the aetiology of the disease.

The aetiological web

M. leprae represents a necessary but not sufficient factor in leprosy. Only a minor proportion of exposed persons are taken ill (2,3). Furthermore, immunological techniques have demonstrated that a large number of persons exposed may even become infected, but without developing any signs or symptoms (4). Accordingly, additional factors are decisive as to whether an exposed person is to develop leprosy or not (figure 1).

Fig. 1. Possible etiological factors in leprosy.

Stated simply, additional factors may be of genetic or environmental origin, both influencing "susceptibility" or "resistance" of the host. These terms have until now, mainly been used for theoretical discussions. From an epidemiological point of view, knowledge of the substance of these terms and their practical implications, is still scarce. Nevertheless, the terms may prove fruitful in the epidemiological discussion of additional factors. In addition to non-bacteriological factors, individual susceptibility may hypothetically be influenced by extra human sources of *M. leprae* or *M. leprae*-like organisms. Furthermore, there are indications that susceptibility, as measured by immunological techniques, may be altered even by quantitative variations in human sources of *M. leprae* (5): a large dose of infection appears to increase susceptibility. The source of infection may also relate to qualitative aspects, like different strains of *M. leprae* with variations

in pathogenicity; e.g. primary dapsone-resistant strains appear to have been demonstrated (6).

Strictly speaking, extent of exposure represents no aetiological factor. However, to separate the bacteriological agents' effects on susceptibility, be it due to quantitative or qualitative variations, from effects of variations in exposure, is often difficult without the use of immunological techniques. Furthermore, factors which often are considered as related to susceptibility, may also be related to risk of exposure; e.g. different sociological patterns of males and females. For these reasons, and since the effects of dose and duration of exposure in itself represent an important question, also extent of exposure should be taken into account in epidemiological analyses of leprosy.

Distribution of leprosy in Norway GEOGRAPHICAL DIFFERENCES

Fig. 2. Average incidence rates of leprosy in Norway 1851-1920 by county.

As found in most countries today, considerable differences occurred in morbidity rates from area to area (figure 2).

In East Norway, with approximately one half of the population, leprosy was almost unknown, while in the rest of the country, leprosy represented a serious health problem. Also within these regions, the high frequency areas, average annual incidence rates during 70 years varied considerably and the highest rate, 28.1 per 100.000 per year, was found in the county of Sogn and Fjordane. Even within this county, great differences occurred; the highest rate, 92.6 per 100.000 per year, was found in Naustdal (1).

Furthermore, leprosy was more prevalent in coastal than in inland districts and was far more prevalent in rural districts than in towns (figure 3), reflecting another epidemiological pattern commonly found.

Fig. 3. Incidence rates of leprosy in Norway 1851-1920 high frequency areas, in towns, rural coastal and rural inland districts. Crude rates by year of onset.

A relation between the geographical differences observed and risk of exposure, in terms of traffic, should not be totally neglected. Passenger traffic, in those days by boat, was far more extensive in districts with high rates, i.e. in districts near the sea. This may have been particularly important to the population occupied in the fisheries of West and North Norway, implying close contact over periods of months and under poor hygienic conditions. Yet, pattern of traffic cannot explain the difference in rates between rural districts and towns, nor that leprosy was unknown in

East Norway even in districts close to the sea.

RELATIONSHIP WITH TUBERCULOSIS

As in other countries (7,8), morbidity rates in Norwegian counties of leprosy and tuberculosis appeared to be inversely related. If this negative association were involved in the aetiology of leprosy, the explanation might be that *M.tuberculosis*, as a fast-growing mycobacterium, influences susceptibility, inducing protective immunity against leprosy, as BCG appears to do under special conditions (5,9). The apparent negative association between leprosy and tuberculosis suggests that mycobacteria do not only represent a source of infection, but may also influence susceptibility.

OTHER MYCOBACTERIA IN THE ENVIRONMENT

Other findings in Norway appear to support the same hypothesis. It is generally known that sphagnum bog vegetation represents a source of mycobacteria in nature (10). During two expeditions to the formerly leprosy high frequency areas in West Norway, non-cultivable acid fast bacilli were found in such vegetation (11). These bacilli could not be differentiated from *M.leprae* by conventional methods (12). The material of the Leprosy Registry was utilized to test the hypothesis that this source of mycobacteria may be relevant to the occurrence of leprosy.

One of the conditions necessary to growth of sphagnum bog vegetation as well as mycobacteria in the vegetation, is a relatively high air humidity. Only some parts of Norway offer suitable possibilities (figure 4), i.e. coastal districts of West and North Norway. Average incidence rate in health districts where relative humidity in July was above 75% was 12.4 against 0.7 in the other districts, and the ratio of risks was 17.7.

Also at the local level, possible associations between environmental mycobacteria and the occurrence of disease were studied. For the health district of Naustdal, the Leprosy Registry contained information on case load at every farm. Even at farm level, the occurrence of the disease varied considerably. At 29 out of a total of 84 farms no case was registered, i.e. leprosy negative farms, while 192 cases were registered at the remaining 55 farms, i.e. leprosy positive farms. In comparisons of farms, a total farm rate was used, defined as total number of cases divided by number of inhabitants living at the farm in 1865 and multiplied by 1000.

On the basis of a series of variables, relevant to growth of mycobacteria in the vegetation and registered during the Naustdal expedition, a sphagnum index was established. High values indicated good local conditions for growth and vice versa. When the farms were grouped according to median sphagnum index, a

Fig. 4. Average relative air humidity in July, 1874-1913, in Norway.

significant positive association was found between sphagnum index and leprosy status of the farm (figure 5). Median total farm rates were 72 in farms with a high sphagnum index and 0 in farms with a low index; 0 implies that more than the half of these farms were leprosy negative. These results suggest that also at the local farm level, leprosy was more frequent in areas where conditions in the environment for growth of sphagnum vegetation and growth of mycobacteria in the vegetation were favourable.

The results are consistent with the fact that leprosy in general occurs much more frequently in rural districts, where mycobacteria may be found in the natural environment, than in towns. The finding of leprosy, as a naturally occurring disease in wild armadillos, may be envisaged in the same perspective.

Fig. 5. Farms in Naustdal, Norway, by leprosy status according to whether sphagnum index of the farm was below or above the median.

Fig. 6. Farms in Naustdal, Norway, by leprosy status of the farm according to whether number of persons per house was below or above the median.

OTHER ENVIRONMENTAL VARIABLES

At farm level, other independent variables were at hand for comparisons with the occurrence of leprosy. The general population censuses hold information on all persons present at the farm as well as assets and production of the farm.

- overcrowding

Leprosy did not occur more frequently at farms where number of persons per house was high (figure 6). Median total farm rate at these farms was 55 against 53 at farms where number of persons per house was low. It seems reasonable to assume that if close physical skin to skin contact, e.g. sharing a bed, were necessary for transmission of the disease, overcrowding might represent an additional factor. On the other hand, if direct contact is not necessary, the disease may propagate to susceptible members in a family, irrespective of overcrowding. Accordingly, the findings support the hypothesis that nasal discharge with droplets represents a potent source of infection.

- malnutrition

In a community based on barter economy, associations may be assumed to exist between production of a farm, in Naustdal potatoes, oats and milk, on one hand, and nutrition of its inhabitants on the other.

Grouped according to median production per person no association was demonstrated between production of potatoes and leprosy status of the farm ($p=0.18$). At farms where production of potatoes was low, median total farm rate was 58, while at the other farms, median total farm rate was 50.

Neither any significant association was found between production of oats per person and leprosy status of the farm ($p=0.08$). Median total farm rates at farms with high and low production were 58 and 53 respectively.

However, a significant association was found between production of milk per person and leprosy status of the farm ($p=0.02$). Median total farm rates were 80 and 28 respectively.

In these comparisons, no consideration was given to the fact that a farm in Norway consists of one or more basic units for housing and production, i.e. the farm sections. Thus, a farm might cover a considerable range with some wealthy and some poor farm sections. Hence, a farm index was used, defined as the proportion at each farm of farm sections where production per person was lower than the 25-percentile. Thus a high index implied low production per person. The 25 percentile was based on data from all farm sections. Grouped according to median farm index for total production, an even more significant association was demonstrated (figure 7). At farms with a low production, median total farm rate was 74, while more than the half of other farms were leprosy negative, implying a median total farm rate of 0.

These findings strongly support a hypothesis advocated by several authors (13, 14) that malnutrition, and particularly a specific protein deficiency, may increase the individual susceptibility.

- poverty

Obviously, it may be argued that the findings do not preclude an effect of production not associated with nutrition per se, e.g. more unspecific aspects of production like assets or general poverty. In a community based on barter economy, poverty is related to low production. However, further information on poverty was available. The official tax value system was based on potential assets of the farm, i.e. potential optimal production in barn and fields. Grouped according to the median, no significant association was demonstrated between tax value per farm section and leprosy status of the farm ($p=0.08$). This finding gave support to the hypothesis that nutrition per se represents an important additional factor.

Fig. 7. Farms in Naustdal, Norway, by leprosy status of the farm according to whether farm index for total production was below or above the median.

Fig. 8. Incidence rates of leprosy in Norway, high frequency areas, 1851-1920. Average age and sex specific rates.

DISTRIBUTION ACCORDING TO SEX, AGE AND TYPE

In the discussion of the distribution according to sex, age and type a concept relating to differences between infection in the household and infection in the community at large should be introduced. The concept implies that the disease, both from an epidemiological and a preventive point of view, acts differently when it occurs in the household and in the community at large. The difference does not relate only to risk of exposure, but to the hypothesis that dose and duration of exposure represent an additional factor, influencing the susceptibility of the individual at risk and important to host responses as well as differentiation into types (figure 1).

From a theoretical point of view, infection in the household is associated with a low mean age at onset since infection frequently occurs during childhood. Sex ratio is close to 100, since risk of exposure is equal in males and females. And type index is high, since dose and duration of exposure within a household are high. Infection in the household is supposed to be relatively predominant when morbidity rates are high.

Infection in the community is associated with a high age at onset due to a postponement of the time of infection. Sex ratio will be high, if males, as in Norway in the last century, have more extensive contacts outside the home than females. Type index

is low since dose and duration of exposure are low. Infection in the community at large is supposed to be relatively predominant when morbidity rates are low.

The distribution of leprosy according to sex, age and type varied in accordance with this theoretical concept.

The trend in age-specific incidence rates with a peak in young adults (figure 8) may in part be due to varying lengths of incubation periods, in part to different risks of exposure in different age groups. The low rates in the age group 0-14 years represent cases infected in the household with short incubation periods. The higher rates between 15 and 50 years represent in part cases infected in the household with long incubation periods, in part cases infected in the community. The lower rates in the age group over 50 years probably reflect in most cases a reduced risk of exposure, but also the relatively low frequency of patients with extremely long incubation periods.

The trend in sex ratio by age, with a peak in the age group 30-49 years, may be related to an increased risk of exposure in adult males due to work outside the household.

The trend in type index by age and sex (figure 9), with a relatively low type index in the age group 0-9 years, with a higher index in the group 10-14 years, and with no difference between males and females, is apparently related to children infected during the first years after birth, indicating a longer incubation period in lepromatous cases. A longer incubation period in such cases has been suggested by several authors (15, 16). A high type index in males 20-39 years and in females 20-24 years, and a lower type index in females than in males 25-59 years, may be related to the fact that vocational contacts, primarily of males, outside the household, were more close and prolonged than nonvocational contacts, in particular because of the fisheries during which many men, and especially from the high frequency areas, lived together in small shanties for longer periods. These contacts might involve a dose of exposure even as high as in a common household. The lower index in the age group 50+ in both males and females probably refers to the relatively few patients who were infected at a late age with a low dose and short duration in the community at large through nonvocational contacts.

The distribution of leprosy according to sex, age, and type varied by level of incidence (table 1). At high incidence rates, like in Naustdal, infection in the household was frequent, implying a low mean age at onset; most patients were infected during early childhood. The same trend was found in the distribution according to age at onset (1). The trend might have been even more marked if infection in the household was not associated with a high relative frequency of lepromatous cases with long incubation periods. Accordingly, also an extremely high type index was found where incidence rates were high. In the same areas, sex ratio was close to 100, implying equal risk of exposure in males and females.

Table 1. Mean age at onset, sex ratio and type index of leprosy in Norway, 1850-1920, by residential district.

Residential district	Mean age at onset	Sex ratio	Type index
Naustdal	31.0	108.7	73.6
Sogn & Fjordane except Naustdal	31.5	126.4	63.8
High frequency areas except Sogn & Fjordane	34.5	160.3	64.9
Low frequency areas	39.3	145.1	45.5

COHORT ANALYSES

An important question in leprosy, and particularly from a preventive point of view, is whether infection takes place almost only in childhood or whether also the adult may be infected. If infection only occurs in childhood, patients taken ill at a high age would obviously represent cases with long incubation periods. As already stated, there are indications that also adults may be infected. However, cohort analyses gave another clue to the question.

Tabulated by year of onset, mean age at onset increased throughout the observation period from 1850 to 1920 (figure 10).

Fig. 9. Type index of leprosy in Norway, 1851-1920, by sex and age at onset.

Fig. 10. Mean age at onset of leprosy in Norway, high frequency areas, 1851-1920, by sex and year of onset.

The same trend was found in the age distribution by year of onset (1). There are two possible mechanisms to explain the trend. One would be that patients with extremely long stages of incubation, through the years, inevitably became relatively more frequent. They would be few compared to all patients infected at the same time, i.e. early in the period. But due to the drastically decreasing incidence rates, they would gradually be more frequent compared to all patients taken ill at the same time, i.e. late in the period.

The other possible mechanism would be that towards the end of the period, infection in the community at large would be relatively more frequent, postponing time of infection to a higher age group.

If the first mechanism were the most important, one would expect that age distribution in subsequent cohorts of birth would be the same throughout the observation period. However, the cohort analyses showed that mean age at onset decreased in subsequent cohorts (figure 11). The same trend was found in the age distribution by year of birth (1). This finding implies that age at infection in leprosy may vary to a considerable extent dependent on the epidemiological situation in the community, and the fate, as to contract leprosy or not, is not decided in childhood only. The low age at onset in the youngest cohorts is due to the fact that in these cohorts, childhood represented the only age with any risk of exposure.

The finding illustrates a general epidemiological principle relevant in all diseases, in which time of exposure is not confined only to childhood: when an aetiological factor appears in a community for a period and then disappears, mean age at onset in consecutive cohorts of birth will initially be high and then decrease, eventually through a period of steady state, for finally to approach childhood. In Norway, the tail of this development was registered for leprosy and it appeared to be identical with the trend for tuberculosis, based on mortality rates (17).

Fig. 11. Mean age at onset of leprosy in Norway, high frequency areas, 1851-1920, by sex and year of birth.

OCCURRENCE IN FAMILIES

In Norway, as elsewhere, leprosy has been known to affect certain families more than others. This fact has led several authors to the assumption that genetic factors play a part in the aetiology of the disease (18, 19, 20). To test such a hypothesis, kinship between 8027 patients with known type of leprosy was studied.

The registry patient record contains information on the patient's relatives affected by leprosy, and a mutual system of constituting a series of families consisting of affected relatives. In these families, type index and degree of concordance with respect to type were studied.

Complete concordance with respect to type implied that all diseased members of a family were affected by the same type of leprosy. The families were divided into groups according to number of patients. For example, in a category of families consisting of only diseased siblings, there were 87 families with three patients. A total of 22 families belonged to the subgroup consisting of only lepromatous patients, while 22 families belonged to the subgroup consisting of two lepromatous patients and one tuberculoid. Based on observed marginal type-frequencies, in each group, of the three different types, and on the assumption of independence with respect to the type of disease between members of any one family, expected frequencies in each group of all possible subgroups were calculated. Observed and expected frequencies were compared by a χ^2 statistic for each group, which were added to characterize, for instance, all families consisting of siblings.

Of the 8027 patients as many as 2317 were mutually related in some way (table 2). Type index increased with an increasing number of patients per family, indicating a more serious clinical course in families with numerous patients.

Table 2. Families of leprosy patients in Norway, 1851-1920, with type index by number of patients per family.

Patients per family	Families	Patients	Type index
1	5710	5710	60.4
2	618	1236	66.3
3	203	609	71.0
4	79	316	67.8
5+	28	156	75.8
Total	6638	8027	62.7

Table 3. Sibship groups of leprosy patients in Norway, 1851-1920, with type index by number of patients per group.

Patients per sibship group	Sibship groups	Patients	Type index
2	399	798	67.6
3	89	267	70.6
4+	28	121	77.6
Total	516	1186	69.4

Furthermore, and of greater importance, the distribution of cases by type within the families differed significantly from what was expected. In subgroups implying concordance, higher frequencies were observed and vice versa. In other words, more patients within a family tended to be concordant with respect to type than expected.

These findings may suggest an association between case load in a family on one hand, and clinical course on the other, both probably being influenced by a common factor. An equal load of this factor on each member within a family, probably produces the high degree of concordance with respect to type. Evidently, the findings are consistent with aetiological hypotheses related to factors of genetic origin as well as environmental. In general, relatives share a more homogeneous genetic background than non-relatives do, but at the same time relatives often live together and thus also share a common environmental background.

In an attempt to clarify the question, families consisting of two or more affected siblings were studied (table 3). Also in the sibship groups, type index increased with an increasing number of siblings, and more patients were concordant with respect to type than expected. Evidently, these results do not contribute to the clarification of the question.

However, a division of the sibship groups into subcategories according to age at onset, gave a clue to the problem (table 4).

In the sibship groups, in which all patients were taken ill before the age of 30 years, the trends previously described, persisted. On the other hand, in the sibship groups in which one or more of the patients were taken ill at, or after the age of 30 years, no such trends were found. There was no increase in type index with an increasing number of patients in the families, and even more important, the distribution of cases according to type did not differ significantly from what was expected, implying a degree of concordance found when cases are randomly distributed in the family.

Table 4. Sibship groups of leprosy patients in Norway, 1851-1920, with type index by number of patients per group and age at onset.

Patients per sibship group	Age at onset					
	< 30 years			>= 30 years		
	Sibship group	Pa- tients	Type index	Sibship groups	Pa- tients	Type index
2	227	454	64.9	172	344	71.2
3	51	153	78.2	38	114	60.2
4 ⁺	17	77	80.3	11	44	72.2
Total	295	684	69.9	221	502	68.7

This finding may be interpreted as the effect of a dilution, in older siblings, of a common domestic environmental background in childhood, implying a more recent influence from a new and unshared environment.

Factors contributing to the disappearance of leprosy from Norway

Apparently, the occurrence of leprosy in Norway reached a peak in the middle of the last century. Subsequently a continuous and increasing decline was registered (figure 3). This conspicuous decline has aroused justified attention in Norway and abroad (8, 21, 22, 23) - justified since this experience proves that leprosy, under certain conditions, may disappear from a population during few generations, but also challenging because of evident implications for primary prevention. Obviously, some of the possible additional factors already discussed, might have been relevant also to the rapid decline in morbidity rates.

NUTRITION

The nutritional situation of the population in Norway, and particularly the high frequency regions, was poor at the time, even assessed by contemporary standards (24, 25). No doubt, these conditions greatly improved during the latter half of the 19th century, presumably rendering the population less susceptible to leprosy.

ISOLATION

Different epidemiological patterns are already suggested for infection in the household and infection in the community at large. Accordingly, it seems reasonable to infer that the removal from a household of all infectious patients would greatly diminish the risk of the remaining persons, though infected, of developing clinical disease. On the other hand, the removal of a patient from the community at large would, to a negligible extent, reduce the risk of the total population, i.e. persons belonging to other households, of contracting clinical disease. As long as infectious patients remain in the community, susceptible individuals may be infected and contract the disease, even if the dose is low and duration of exposure is short.

In an attempt to clarify this question and its relevance to the effects of isolation, isolation and subsequent relative fall in incidence rates were studied in Norwegian counties. It appeared that both degree of isolation and relative fall in incidence increased by time (1). In a simple regression analysis based on all seven counties, between degree of isolation in five decades 1856-1905 and subsequent relative fall in incidence rates, a highly significant association was found (table 5).

Table 5. Simple linear regression in seven counties 1856-1920 of relative fall in incidence rate in a period on previous degree of isolation.

Isolation observed			
Time	Prevalence (per 10,000)	Level of significance	Correlation coefficient
1856-1910	All levels	<0.01	0.80
1856-1875	All levels	<0.01	0.77
1881-1910	All levels	>0.05	0.16
1856-1875	>15.0	<0.01	0.81
1881-1910	≤15.0	>0.05	0.32

In an attempt to eliminate the effect of time on this association, the material was split into groups covering different periods of isolation. It appeared that the association persisted during the first period. However, later no association was demonstrated. Further analyses made it clear that the association was highly dependent on level of prevalence: below a certain prevalence level, viz. 15 per 10,000, no association was found. This finding supports the hypothesis that isolation may prove effective when morbidity rates are high, infection taking place mainly in the home.

Even if there is no longer need for physical isolation of patients as a measure in leprosy control today, more than theoretical interest attaches to the epidemiological mechanisms and effects of isolation. Medical therapy may, from an epidemiological point of view, be regarded as chemical isolation, and probably its effects should be envisaged in the same perspective as physical isolation. However, comparisons with other countries, perhaps different in demographic and topographic aspects, should be made with caution. Networks of contacts, for instance, are supposed to be more comprehensive and involving more persons in India than at remote, isolated farms in Norway, and this may obviously influence the effect of isolation.

EMIGRATION TO THE USA

Time trend in age adjusted, sex specific incidence rates gave a clue to a third factor which no doubt has greatly contributed to the decline in incidence rates (1). Seemingly, a continuous fall was recorded in both sexes. However, sex ratio by time showed a peculiar dip in the decade 1891-1900 (figure 12), and this was most likely due to a lower incidence in males than anticipated and not the opposite, a higher rate in females. The dip was so marked that it was hardly attributable to temporary variations in exposure or susceptibility in males. Apparently, this dip should be related to emigration to the USA. A study of the statistics of emigration revealed

that a maximum in emigration rates occurred in the previous decade (1881-1890) in the county with the highest leprosy rates. Furthermore, there was a considerable excess of relatively young males among the emigrants. In other words, the emigrants represented high risk groups which, by the emigration, was removed from the local community. This hypothesis is supported by more elaborate calculations based on the Leprosy Registry and the official statistics of emigration (1).

Fig. 12. Sex ratio of leprosy in Norway, high frequency areas, 1851-1920, by year of onset. Ratio based on sex specific age adjusted incidence rates.

GENETIC FACTORS

Genetic factors were probably not responsible for the high degree of concordance with respect to type in affected relatives, demonstrated in Norway. And genetic factors did definitely not play an important part in the decline of the disease, almost eradicated as it was during a little more than one generation. Certainly, the hypothesis of an influence of genetic factors is not disproved by the present findings; however, such a hypothesis is not supported either.

Conclusions

First of all the Norwegian experience demonstrates the need for and benefits from an adequate system for acquisition of information on leprosy patients. Such a system is important from a practical preventive as well as from a general epidemiological point of view. Thus, the Norwegian experience supports the initiative taken by WHO in establishing information systems in countries where leprosy is prevalent today.

Furthermore, taking into consideration the often highly insufficient nutrition found in endemic areas today, the Norwegian experience suggests a systematic approach towards improved nutritional conditions in such areas, evaluating its effects in the perspective of leprosy control.

Finally, the possible epidemiological implications of the finding of *M. leprae*-like organisms in the environment should be further pursued.

Both in the evaluation of nutritional programmes and in the analyses of the epidemiological significance of environmental mycobacteria, there is a great need for immunological tools. The implementation of such tools in epidemiological settings seems necessary to clarify most of the problems challenging leprology today.

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