Primary health care approach to trachoma control in Aboriginal communities in Central Australia

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Abstract

This study concerned a primary health care approach to trachoma control in two Central Australian Aboriginal communities. The World Health Organization (WHO) has advocated that the best method to control trachoma is the SAFE strategy (Surgery, Antibiotics, Facial hygiene, and Environmental improvements), and this approach was adopted.

The communities, Pipalyatjara and Mimili, with populations slightly less than 300 each, are located in the Anangu Pitjantjatjara (AP) lands of Central Australia, in the northwest corner of the South Australia territory. At Pipalyatjara, a full SAFE-type intervention was undertaken, with the ‘E’ component designed and implemented by the NHC (Nganampa Health Council Inc.). At Mimili, only a SAF-type of intervention was implemented.

Baseline data was gathered for 18 months from March 1999 through September 2000 (five visits to Pipalyatjara and four at Mimili), and included determining trachoma prevalence levels using the WHO system, facial cleanliness, and nasal discharge parameters. A trachoma health program was implemented at the end of this period and a one-time dose of azithromycin was given in September of 2000. The chief focus of the study was children under 15 years of age.

Improvements in road sealing, landscaping, and the creation of mounds were started to improve dust control. Concurrently, efforts were made in the houses of the residents to improve the nine healthy living practices, which were scored in two surveys, in March 1999 and August 2001. Trachoma prevalence, and levels of facial cleanliness and nasal discharge were determined at 3, 6, and 12 months following antibiotic administration.

In children less than 15 years of age, the pre-intervention prevalence level of TF (Trachoma Follicular) was 42% at Pipalyatjara, and 44% at Mimili. For the 1-9 year age group, the TF prevalence was 47% and 54% respectively. For TI (Trachoma Intense), the pre-intervention prevalence was 8% for Pipalyatjara, and 9% for Mimili. The TF prevalence, adjusted for clustering, and using only individuals present at baseline and follow-up (3, 6, and 12 months post-intervention), was 41.5%, 21.2%, 20.0%, and 20.0% at Pipalyatjara respectively. For Mimili, the corresponding prevalence figures were 43.5%, 18.2%, 18.2%, and 30%.

In the 1-9 year age group, a lower TF prevalence existed between the pre-intervention and 12-month post-intervention points at Pipalyatjara compared to
Mimili. The TF prevalence after the intervention was also lower for males compared to females, when the cohorts were grouped by gender, rather than community. It is posited that reinfection was much higher at Mimili within this age group, however, in both communities, there appeared to be a core of females whose trachoma status did not change. This is speculated as mainly being caused by prolonged inflammation, though persistent infection *C. Trachomatis* cannot be ruled out.

Facial cleanliness and nasal discharge continued to improve throughout the intervention at both communities, but at the 3-month post-intervention point no longer became a good predictor of trachoma.

It is not known whether the improvements in the environment at Pipalyatjara were responsible for the reduction in trachoma prevalence 12 months after the intervention, relative to Mimili.
Declaration

This is to certify that

(i) the thesis comprises only my original work towards the PhD except where indicated in the Preface,
(ii) due acknowledgement has been made in the text to all other material used,
(iii) the thesis is less than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.
(iv) parts of chapters 3, 4, and 5 of this thesis have been published:

Van Charles Lansingh M.D.
Preface

The entire environmental component of the thesis was designed, implemented, and monitored by the NHC (Nganampa Health Council Inc.) with input from CBMI Australia (Christian Blind Mission International), Rio Tinto, Appropriate Technology, and Prof. Ian Dadour from the University of Western Australia, and the author takes no credit for this.

The study was a collaborative operational research project between the CBMI Australia, CERA, the Centre for Eye Research Australia at the University of Melbourne, and the NHC.
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As with most major undertakings, several people were involved, and I would be remiss if I did not first acknowledge my wife, Martha, and our three children, Killian, Van and Paul whose support and love have afforded me the strength and encouragement to work in the field. My supervisors, Associate Professor Jill E. Keeffe, Ph.D., Professor Hugh R. Taylor, M.D., and LeAnn Weih, Ph.D. gave me invaluable insight into the formulation of a thesis. I would also like to thank Bickol Mukesh, Ph.D. for all his input, statistical help, and coaching, and Marissa Carter, Ph.D. for her valuable insight into facets of epidemiology.
Dedication

This thesis is dedicated to the Christian Blind Mission International Australia, the Nganampa Health Council Inc. (NHC), its workers and supervisors, as well as the Anangu Pitjantjatjara people themselves, for making this study possible.
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CHAPTER 1
INTRODUCTION

The purpose of this chapter is to introduce the problem of the study and to provide pertinent background information. Subsequent chapters review the literature on trachoma, describe the study setting, explain the materials and methods used in the study, present results, and discuss the findings.

1.1 Trachoma

Trachoma has been characterized as a disease of children, since its active form is most found in pre-school and school-age children. While it can be considered a form of chronic conjunctivitis, repeated infections lead to scarring of the eyelid tissues, trichiasis, corneal damage, and ultimately, secondary blindness. The disease continues to be hyperendemic in many parts of the world, primarily poorer countries, including parts of Africa, Asia, the Middle East, and Australia.

The organism responsible for the disease, *Chlamydia trachomatis*, is highly infectious and can reside in extraocular pools besides the eye, though it is unclear whether these sources play an important role in reinfection. Some studies suggest that reinfection following antibiotic administration is most likely due to external sources, but other investigations have not found this to be the case. Separating treatment failure from genuine reinfection, whether from internal or external sources, is complicated by the fact that prior to treatment, high ocular loads of *C. trachomatis* can exist in individuals with or without trachoma signs. Moreover in infants (< 2 years old), two months after azithromycin administration, high ocular loads can still persist.\(^1\) Much evidence indicates that it is the tissue seclusion of *C. trachomatis* in humans that enables it to evade cell defence mechanisms and become such a successful human pathogen.

Diagnosis and classification of trachoma is performed clinically. Although laboratory testing using a variety of methods can be performed, besides the logistical problems and cost, there continues to be a frustrating lack of correlation between such tests and clinical findings. Although many researchers have suggested that clinical signs of trachoma can still be present in the absence of the *Chlamydia* as a result of prolonged inflammation, the reverse findings (prolonged presence of bacterium but no clinical signs) cannot be so easily explained.
At the hyperendemic level, control of trachoma is only possible through well-organized large-scale interventions, in part because the required health infrastructure in most areas affected is missing, or too rudimentary to cope.

1.2 The SAFE Strategy

In February 1999 the World Health Organization (WHO) launched Vision 2020, a global initiative for the elimination of avoidable blindness by the year 2020. A major component of the overall Vision 2020 framework is the Global Alliance for the Elimination of Trachoma—(GET 2020)—which also aims to reach its objective by 2020.\(^{(2)}\)

Central to GET 2020 is the adoption of an integrated primary health approach, known as the SAFE strategy, for the management and control of trachoma. This acronym includes Surgery to prevent blindness in those who have trichiasis and or entropion, Antibiotics to combat active chlamydial infection and to reduce transmission, Facial hygiene, and Environmental changes.\(^{(3)}\) Where trachoma is endemic, antibiotic treatment is necessary to provide short-term relief and to reduce the reservoir of \textit{C. trachomatis} in the community.\(^{(4)}\) Some researchers maintain that antibiotics alone cannot always eliminate trachoma for a variety of reasons,\(^{(5-9)}\) or should not be used exclusively because of problems,\(^{(10)}\) and a recent Cochrane review\(^{(11)}\) was relatively pessimistic in tone, ‘merely suggesting that either oral or topical treatment seems to reduce the relative risk of clinical disease and infection 3-12 months after treatment.’\(^{(12)}\) Other researchers insist that antibiotics alone (such as azithromycin), provided that they are applied with the correct strategy, can be successful.\(^{(13,14)}\) In all likelihood, there are geographical areas where an appropriate antibiotic strategy alone employed against a moderate prevalence of trachoma will work, but equally, there are many areas where it is only with concurrent environmental and hygiene changes that the long-term treatment and sustained elimination of trachoma will be achieved.\(^{(9,15)}\)

Data on the prevalence of trachoma in Australian Aboriginal communities are limited.\(^{(16-19)}\) (Although in a usual setting they would be considered villages, due to the strong interaction, close family ties and small size, they call themselves communities; therefore, throughout the thesis we use this term as stated in most Aboriginal-related publications and those of Nganampa and the Northern Territory
Trachoma and Eye Health studies conducted by Taylor in the early 70s.) The current study examined not only the extent of the problem, but also assessed and compared the effects of implementation of components of the WHO SAFE strategy in selected Australian Aboriginal communities. The project was conducted in collaboration with the Nganampa Health Council Inc. (NHC), and was a community-based trachoma control program implemented in two communities, Pipalyatjara (SAFE) and Mimili (SAF only), in the area known as the Anangu Pitjantjatjara Lands in Central Australia. At the time this study was planned, it was the only known study then being undertaken that attempted to evaluate the concomitant administration of all four aspects of the WHO SAFE strategy.

1.3 The Components of SAFE

It is generally agreed that the ‘S’ portion of SAFE is one of the least expensive components, though periodic surgery will have to continue until the endemicity level of trachoma in a given geographical area is reduced to a certain level. (Specific cost data for the intervention is provided in section 5.9.) What that level is or should be is still a matter for debate. Some researchers argue that eradication of the disease worldwide is an unrealistic target, and that even elimination of the disease in a specific geographic area will require infection monitoring, which is time-consuming, logistically difficult, and expensive.\(^{20}\) One standard definition that has been proposed for blinding trachoma is ‘When active inflammatory trachoma is maintained at less than 5% in children aged 1-9 years in a defined geographical area’.\(^{21}\) Some investigators think that once a lower, threshold level of endemicity is reached—the so-called Allee Effect\(^{22}\)—reinfection levels will automatically be reduced, though Gaynor\(^{20}\) points out there is no a priori reason to expect this will be the case for trachoma.

How much proportionate effort should be placed into the ‘A’ component? Antibiotics, such as azithromycin are expensive, unless much of the cost is absorbed through donation programs, although the results of single component interventions involving only antibiotics can be remarkable. For example, annual administration of azithromycin for a period of three years in Nepal to children aged 1-10 years was fairly successful—only 4% of the children still had a clinically active infection at six months after the third antibiotic treatment.\(^{20}\) Nevertheless, in some countries, without
the ‘F’ and ‘E’ strategies in place, depending on the number of times the antibiotic is administered, reinfection can occur and levels of trachoma prevalence eventually increase.\(^{(15)}\)

Face washing by itself—the ‘F’ component—is not particularly expensive to institute; it is more an exercise of education and instilling new habits in communities. However, it appears to have little effect on trachoma levels by itself.\(^{(8)}\)

What constitutes an effective ‘E’ component depends on the given environment. Bailey and Lietman\(^{(8)}\) sum it up succinctly: ‘No single environmental intervention can be recommended for trachoma control since the environmental risk factors are not the same in all settings. Few studies have been free of methodological difficulties, and observational studies typically find that a number of attributes indicative of poverty are correlated.’ This is a reminder that the presence of many diseases, including trachoma, are the result of poor living conditions and low income. Indeed, in the pre-antibiotic era, prevalence of trachoma was eliminated or vastly reduced in what are now considered developed countries through rises in the living standard and general hygiene. One recent example in a developing country was documented by Dolin et al., in a community in The Gambia: From 1959 to 1996, the active trachoma prevalence in children aged 0-9 years fell dramatically from 65.7% to 2.4% through improvements in hygiene, sanitation, water supply, education, and access to health care.\(^{(23)}\) Kuper et al. list increasing water availability, improving access to latrines, reducing the density of flies in the environment, and avoiding crowding, especially in sleeping areas, and health education as generally desirable ‘E’ components.\(^{(12)}\)

Another facet of the problem is that it is almost impossible to separate ‘E’ factors out and study their effectiveness independently—many are known to be correlated. The nine critical healthy-living practices developed for Australian indigenous populations, which are discussed in Chapter 3 in more detail, are certainly a pragmatic approach to the problem. However, it was not known at the time of the study design which of these might most impact the SAFE intervention in terms of reducing trachoma prevalence. For example, only removing waste safely, reducing crowding, and reducing negative contact between people and animals, vermin or insects are related to the E factors highlighted by Kuper et al.\(^{(12)}\) Moreover, it is reasonable to suspect that other unidentified environmental factors could also play a role. Emerson et al. identify improved access to water, enhanced hygiene, and better sanitation as E factors that reduce trachoma transmission, but in their meta-analysis of F and E...
factors caution, ‘…there is currently no single specific tool for trachoma control that can be recommended for inclusion in the F and E part of SAFE’. These potential perils are highlighted in the SAFE-style intervention (minus the ‘S’) initiated in Central Australia in 1998 in an Aboriginal community in Central Australia by Ewald and co-workers, and published in 2003. Although high expectations were held for this intervention, it appeared to have failed. Discussion in the paper and further comments in the literature point to several possible reasons, but in the final analysis, the nature of the failure currently remains unknown.

Clearly, therefore, in some countries, a balanced approach is required that adopts all the components of SAFE: surgery, antibiotic administration, face washing, and environmental improvements. In one of the two proposed communities for the study (see section 1.4), there were no resources available for any environmental improvements at Mimili, which would therefore become a SAF intervention. However, it could serve as the control for the full SAFE intervention proposed for Pipalyatjara, so that the contribution of the ‘E’ component might be elucidated.

It must be stressed that the author had no control over the environmental improvements planned for the Pipalyatjara community per se. But there was an opportunity to collect environmental data, and plans were made to investigate climatic variables (wind, rainfall), dust concentrations, vehicle movements, and fly populations. Such data, it was hoped, might provide some clues to delineate some of the environmental factors.

1.4 The Communities Selected for the Study

Pipalyatjara had been the site of many studies including an environmental health review in 1987. Uwankara Palyanyku Kanyinjaku, A Strategy for Well-being described and quantified a physical environment, which prevented the practice of healthy living choices by the Aboriginal people on the Anangu Pitjantjatjara freehold lands of South Australia. The review developed a list of nine healthy-living practices required to improve the health status of Aboriginal people that ranged from the provision of water to dust control. It also emphasised the importance of providing functioning and appropriate housing. Many of the review’s recommendations were being implemented or were planned for implementation in Pipalyatjara, and this provided the opportunity to monitor and assess their impact in that community.
The author anticipated that these interventions would work positively to reduce the prevalence of trachoma and also permit a comparison with outcomes in Mimili where those environmental interventions could not take place due to lack of financial resources. Moreover, the two communities were more than six-hours’ drive apart, which enabled the impact of the environmental interventions to be isolated in regard to the prevalence of trachoma, though the overall environment of both communities is similar.

Pipalyatjara, therefore, provided an opportunity to assess the impact of the WHO SAFE strategy in its entirety. The results from Mimili, where only SAF strategies were implemented, offered a useful basis for a comparative assessment of the impact of those environmental interventions.

### 1.5 Study Objectives

The research question posed was as follows: Is there a significantly different effect between the implementation of SAFE versus SAF strategies regarding the prevalence of active trachoma in remote Australian Aboriginal communities? From this question, a number of objectives were developed for the study:

1. Obtain current data on the prevalence of trachoma in the Mimili and Pipalyatjara communities
2. Design appropriate health educational tools and activities related to trachoma that could be successfully used by Aboriginal Health workers in order to promote general hygiene with an emphasis on facial cleanliness
3. Determine the potential risk factors for active trachoma infection in both communities
4. Ensure the implementation of the S, A, and F components of the strategy in both communities
5. Ensure successful implementation of the E component of the strategy in Pipalyatjara
6. Assess the clinical significance of environmental interventions in the reduction of trachoma prevalence.
CHAPTER 2
LITERATURE REVIEW

2.1 Overview

The purpose of this chapter is to examine the current state of knowledge regarding trachoma, its historical status, epidemiology and associated risk factors, and recent developments in the approaches and strategies for the management and control of the disease. By reviewing and understanding the historical endemicity and geographical distribution of the disease, we might be better equipped to strategically manage the current problematic areas, and promote control and prevention strategies.

2.2 History

Trachoma is a disease that has been well known since ancient times,\(^{26}\) and descriptions of the disease were mentioned as early as 5,000 years ago.\(^{27}\) The disease was known in the Middle East, Mongolia, and China from where it might have spread to the Americas—trachoma was known in China as early as 27th century BC. Descriptions also appeared in the \textit{Papyrus} discovered by Ebers in 1889,\(^{28}\) and epilation forceps, as well as medications, were discovered in tombs in ancient Egypt.\(^{29}\) Treatment for trachoma and the chronic sequelae for the infection also featured in the writings of ancient Greek physicians including those of Hippocrates.\(^{29}\)

With the beginning of the 19th century, trachoma became endemic in Europe after the return of affected soldiers from the military campaigns in Egypt where trachoma was rife, undertaken by Britain, France, and Turkey.\(^{26}\) During the latter part of that century the pathology of trachoma began to be recognized, although the causative organism was not identified until 1907.\(^{26}\) Public health and treatment strategies were described in the early part of the 20th century.\(^{29}\)

In Australia there has been debate as to whether trachoma was a problem in Aboriginal communities prior to European contact and subsequent settlement. Until the 1960s the prevailing view, put forward by Dr. Ida Mann,\(^{30}\) was that trachoma was an introduced disease, however, some evidence suggests this is probably not so. Both Abbie\(^{31}\) and White\(^{32}\) relied on the usage and interchangeability of the words ‘old’ and ‘blind’ in arid areas of Australia—where blindness is accepted as part of the aging process—in suggesting that in these areas it was not an introduced disease. However, the blindness could have had causes other than trachoma.
Further support that trachoma in Australia pre-dated European contact comes from early writings of explorers and settlers. Thus, Dampier in 1688, described Aboriginal people in a way which, if not providing clear evidence of trachoma, shows that the presence of eye-seeking flies on faces seemed to have been a problem.\(^{(33)}\) Several early accounts also mention Aborigines suffering from some form of eye disease.\(^{(34)}\) The existence of a dusty and dry environment—two important factors associated with the presence of trachoma—suggest that trachoma could have been present in Australia prior to European settlement.

Whilst not providing compelling evidence, these accounts do support arguments for the ‘pre-contact’ presence of trachoma. Additional support can be drawn from the Aboriginal people’s knowledge of treatments for inflammatory eye disease, which is consistent with a familiarity of a disease of this kind.\(^{(35)}\) The presence of fly totems strengthens the argument that there was an understanding of the connections between flies and eye disease, at least in Central Australia.\(^{(36)}\) Some rather unusual data comes from a study by Webb,\(^{(37)}\) who undertook a palaeopathological survey of Australian Aboriginal skeletal remains. He found lesions in one or both orbital plates of the frontal bone of many of the crania examined. The lesions constituted a round or oval hole with a diameter of up to 12 mm and depth of 4 mm with a neat appearance, and a porous and often slightly discoloured texture to the surrounding bone. Some were shallower, with a marked porosity.

Webb also undertook a comprehensive differential analysis of the few pathological conditions that could cause lesions such as these to determine their possible cause based upon the frequencies found.\(^{(37)}\) While many causes of infection or disease were considered, he concluded that the likely cause was trachoma. The geographical pattern of distribution closely follows reported frequency patterns in recent studies of Aboriginal communities, and trachoma was the only eye disease probably prevalent and severe enough to cause the scarring in frequencies close to those found in the survey.\(^{(16)}\) Although Webb’s work provides evidence of the presence of trachoma in Aboriginal communities prior to European settlement, the causal link between trachoma and the paleopathological findings remains unsubstantiated, as there is no known mechanism by which trachoma could cause the cranial lesions. It also might be interesting to consider the influence of demographic changes since Webb conducted his study. Could changes, such as increased clustering
of Aboriginal communities in urban locations, have made the trachoma situation worse?

2.3 The Disease

Trachoma is a chronic conjunctivitis caused by repeated episodes of infections with the obligatory intracellular organism *Chlamydia trachomatis*.\(^{38,39}\) It is a disease first evident in childhood with the active disease most common in pre-school children.\(^{40}\) Several studies provide evidence that the causal reservoir of chlamydial infection is in the ocular discharges, and possibly nasal discharges of pre-school and school aged children.\(^{41-44}\) It is also an acute inflammatory illness, typified by recurrent infections and scarring of the tissues of the eyelid, which eventually causes trichiasis.\(^{38}\) Trichiasis then leads to corneal damage and scarring, causing secondary blindness and or low vision.

Trachoma continues to be hyperendemic in many parts of the world including Africa, the Middle East, Asia, and Australia.\(^{45}\) In its active form, trachoma affects up to 150 million people worldwide, of which 5.6 million people are blind or visually impaired because of trachoma sequelae.\(^{46,47}\) It is also the leading cause of preventable blindness in the world and was the second largest cause of blindness after cataract when this study was being conceived.\(^{46}\) More recent data from 2002 published by Resnikoff et al. place it as the seventh leading cause of blindness,\(^{48}\) though the absolute numbers of those afflicted have not significantly changed—rather the situation reflects increases in other causes of blindness, such as glaucoma and diabetic retinopathy.

Australia is one of 46 countries still to have hyperendemic blinding trachoma,\(^{49}\) and a recent report places trachoma as the leading cause of blindness in many Aboriginal communities in Australia.\(^{50}\)

2.4 Chlamydia Trachomatis

*Chlamydia trachomatis*, the organism responsible for trachoma, is a gram-negative obligate, intracellular bacterium with a unique life cycle. The bacterium is classified in the genus *Chlamydiae*, which also includes the *psittaci* and *pneumoniae* species, and is responsible for a wide spectrum of disease. Although the three species differ in their inclusion type, all grow intracellularly and share a unique
developmental cycle. After entering the phagosome of the epithelial cells, the bacterium remains there throughout its entire life cycle, thereby avoiding normal cell defence mechanisms. It is this tissue seclusion that makes it such a successful human pathogen.

Like other Chlamydiae species, *C. trachomatis* alternates between two different cell types: the infectious elementary body (EB), and the noninfective, metabolically active reticulate body (RB). EBs are adapted to extracellular survival, while the larger, labile RBs only exist intracellularly. Moreover, the EB is the extracellular infective form well-adapted to transmission. The RB is non-infectious but multiplies rapidly, transforming approximately 20 hours after infection into the infectious elementary bodies. Fifteen different serovars have been described within the *C. trachomatis* species, and seroepidemiologic studies have indicated that the serovars most commonly associated with trachoma are A, B, Ba, and C. The other serotypes are associated with genital disease, lymphogranuloma venereum, and genital-related inclusion conjunctivitis. Genotyping populations in the field is becoming more commonplace, and in Australia, one study in the Northern Territory showed that the predominant serovar was C (87.1 %), followed by Ba (12.9%). The latter serovar was found almost exclusively more inland. The authors of this study also found evidence that there is an evolutionary distinct *C. trachomatis* population causing eye infections in Australia.

Although serovar classification is based on immunological epitope analysis of the major outer membrane protein (MOMP) using polyclonal and monoclonal antibodies, the basis for serovar association with tissue tropism—why certain genotypes prefer the eye or urogenital system—remained unknown until recently. It is now thought that serovars D-K possess the tryptophan synthase gene cluster, which enables these strains to utilize indole as a substrate produced by vaginal microbial flora.

Trachoma and inclusion conjunctivitis are the two forms of ocular disease caused by this organism—*C. trachomatis* causes an inclusion conjunctivitis in adults and neonates. In both the adult and the infant forms, the responsible immunotypes are D-K. In addition to the eye, *C. trachomatis* is also found in the genital tract, adult inclusion conjunctivitis being transmitted primarily by direct contact of infected genitourinary secretions to the eye. In the case of infants, contact with the bacteria occurs during passage through an infected birth canal. *C. trachomatis* can also cause
pneumonia in infants. Although both trachoma and inclusion conjunctivitis are caused by *C. trachomatis*, they represent different syndromes, with inclusion conjunctivitis being a milder disease having less likelihood of corneal scarring leading to visual loss.\(^{(59)}\)

Sexually transmitted genital chlamydial infection caused by serovars D-K is very common in the general population, but especially amongst sexually active people in non-monogamous relationships.\(^{(54,59)}\) Although previously regarded as an important route of transmission for trachoma,\(^{(60)}\) this has now been discounted.\(^{(61,62)}\)

Some studies have suggested that *C. trachomatis* infections in trachoma endemic areas are not limited to the eyes alone, but can also involve the naso-pharynx and gastrointestinal tract.\(^{(63,64)}\) However, it is unclear whether naso-pharyngeal infection constitutes a separate reservoir of infection for trachoma transmission.\(^{(15)}\) One study found that children with positive nasal specimens for the *C. trachomatis* were also likely to have trachoma. Nevertheless, following four weeks of treatment with topical antibiotic, the rate of reinfection was similar in children with a positive, as well as those with a negative nasal swab at baseline.\(^{(65)}\) This suggests that reinfection is due to an external source and not a result of latent or persistent infection, although this is not proven in all cases.

### 2.5 Infection

Trachoma is an immunopathologic disease with the more severe progressive infections resulting in pannus, and scarring occurring only after repeated re-infection. Field observation studies of the natural history of trachoma, monkey studies, and trachoma vaccine studies conducted by Taylor\(^{(39)}\) and also by Grayston et al.\(^{(38)}\) confirmed that re-infection was important in the pathogenesis of trachoma. Further data from another longitudinal study in Taiwan offer additional confirmation.\(^{(66)}\) However, this latter study also highlights that further characterisation of the immunologic differences between subsets of children with various duration of infections is required to permit the development of targeted immuno-intervention strategies for children.

Data from Kongwa, Tanzania, showed that persistent chlamydial infection is a common pattern for children living in a trachoma endemic village.\(^{(67)}\) The association of persistent infection with high chlamydial loads indicates that chlamydial replication
possibly proceeds unchecked by the host. Duration of infection differed between siblings, demonstrating that persistent chlamydial infection is not necessarily shared by family members. More extensive studies from the same geographic area employing qualitative and quantitative PCR (polymerase chain reaction) techniques demonstrated that more than one quarter of children aged 0-10 years and 10% of adults still harboured significant infection two months after azithromycin administration.\(^{(1)}\)

The correlation between clinical assessment and infection determined by diagnostic techniques is a generally poor.\(^{(52)}\) In part, this is because after an infection is cleared, subsequent inflammation can persist for several weeks or months, which clinically still presents as trachoma. The degree of inflammatory response following an infection is often more severe when the subject has had a history of several infections. While the chlamydial load generally correlates with the severity of the clinical symptoms of the disease, the distribution of the bacterial load with regard to age group of the population seems to vary with the level of endemicity in the community in a complex manner.\(^{(68)}\)

Recent data have shown that active trachoma is associated with several proinflammatory cytokines, as well as and cytokines indicative of a cell-mediated immune response.\(^{(69)}\) In particular, the role of MMP-9, which is a proteolytic enzyme that regulates the extra-cellular matrix (ECM), is implicated in trachomatous scarring, and might be the mechanism balancing inflammation against ECM breakdown in the absence of infection.\(^{(69)}\) Chlamydial heat shock protein (hsp60) also appears to be another factor that can prolong the inflammatory response, and there is a suggestion that other types of chlamydial, and indeed, other bacterial infections can prime the immune response to this antigen.\(^{(70)}\)

Another possible explanation for the persistence of clinical trachoma signs is that other ocular pathogens could cause conjunctival symptomology similar to trachoma in those individuals who have had a history of \textit{C. trachomatis} infection.\(^{(13)}\)

Although it is common to find active trachoma in the absence of infection, it is not uncommon to find infection in the absence of clinical symptoms. For example, West et al. noted that 23% of their subjects in Tanzania who had a high chlamydial load, also had no clinical signs of trachoma.\(^{(1)}\) While some proportion of these individuals are likely to be in the early stages of infection, and would not have clinical manifestations, this is unlikely to be the case for all. Moreover, the age distribution of such individuals seems to vary with both the level of trachoma endemicity, and the
geographic locale. Solomon et al. refer to an assay-detected infection after clinical resolution or without clinical signs as persistent infection. Some researchers think that ‘cryptic’ infections—low-level ocular infections that might or might not be assay or culture detectable, with non-metabolically active chlamydial bodies—exist, and could explain some the results seen. In vitro studies confirm that addition of azithromycin does not always result in clear cut elimination of chlamydia from host cells, and researchers characterise the bacteria as ‘temporarily arrested in a persistent state, characterized by culture-negative, but viable, metabolically active Chlamydia, as demonstrated by the presence of short-lived rRNA transcripts’. Morrison suggests that such quiescent infections in urogenital areas could be the result of chlamydial strains responding to gamma interferon pressure by utilizing their tryptophan synthase genes.

### 2.6 Extraocular Infection

In trachoma-endemic areas it has been shown that children with active ocular chlamydial infection also have extraocular chlamydial infection with Chlamydia being isolated or identified in the otitis media, respiratory and gastrointestinal tracts, as well as the genital tract. Reinfection from extraocular sources of infection, therefore, might play a role in transmission of the infection. However, two other studies have not confirmed this, indicating that the source of Chlamydia reinfection following trachoma might not be extraocular infection. The use of a systemic antibiotic did not lower the reinfection rates at follow-up. Nor was the incidence rate of new infections found to differ between children who had a positive nasal specimen at baseline and children who had a negative one. In addition, a study of Tanzanian children found that after microbial treatment, at six months post-treatment, the best predictor of infection was infection at two months, especially if the infection was severe.

More precise studies of the source of reinfection are needed to enable a clearer picture of the epidemiology of reinfection by trachoma, as studies appear to be not conclusive.
2.7 Epidemiology

A report of a Global Scientific Meeting on ‘Future Approaches to Trachoma Control’ held in 1996 noted that trachoma was found in the remote, rural areas of most African countries, especially sub-Saharan Africa, the Middle East, Southwest Asia, and the Indian sub-continent. While trachoma is also prevalent in Aboriginal communities in Australia and in certain parts of Central and South America, it has largely disappeared from developed countries, but remains a significant cause of blindness in developing countries. Trachoma is responsible for some 15% of the global burden of severe visual loss and the loss of productivity worldwide due to the disease was conservatively estimated at U.S. $2.9 billion, not counting the full social cost. A decrease in trachoma prevalence has been associated with a reduction in poverty, and socioeconomic development: improved roads and transport, sanitation, water supply, better access to health care, and education lead to general public health improvements. This in turn leads to a reduction in the presence of trachoma even without specific health interventions. Several studies have also shown a higher prevalence of trachoma in households with lower income and where the household head is poorly educated. More recent data also indicates that in developing countries, the influence of antibiotics prescribed for non-trachoma infections can have a significant collateral effect in reducing infection due to trachoma.

There is evidence that trachoma and subsequent trichiasis remain a major cause of blindness in Australian Aboriginal people. Anecdotal evidence and a major survey showed that trichiasis affects approximately a ten-percent proportion of the elderly Aboriginal population. The National Trachoma Eye Health Program of the Royal Australian College of Ophthalmologists, in a survey conducted between 1976 and 1979, found trichiasis in 11.8% of the Aboriginal population aged over 60. Some instances were also found in younger age groups, but the development of trichiasis is strongly age-related and found most often in mid-to-late age groups. A 1990 survey in the Anangu Pitjantjatjara Lands found 36 cases, and a later survey of 308 people in the Fitzroy Crossing region in 1993 found trichiasis in 1% of people, but scarring in a further 50%. The 1997 Taylor report concluded that there is no reason to suspect any change in the fundamental pattern of the effects of trachoma in Australia in the last 20 years. Moreover, it predicts that trichiasis will remain an ongoing health
problem as the long-term effects of current active trachoma will continue to emerge for many years to come.

Trachoma in Australia primarily affects the Aboriginal populations in remote and rural areas in Western Australia, South Australia, and the Northern Territory. The current prevalence of trachoma varies between Aboriginal communities in the affected areas, and has been reported as ranging from 12%-60% of children in communities from East Arnhem Land in the Northern Territory\textsuperscript{(78)} and the Pilbara in Western Australia.\textsuperscript{(50)} In the mid-nineties, it was thought that in East Arnhem the prevalence rate had dropped below 5%, but a recent survey in 2002 found an average of 26% with a range of 17%-38%.\textsuperscript{(83)} In addition, a prevalence rate of 36% was found in a 1999 survey undertaken in a Central Australian Aboriginal community.\textsuperscript{(19)} The variation in observed prevalence does not have a ready explanation, though it could be attributed to the improvement of living conditions. However, the surveys might not be directly comparable, as they are not consistent with their measures of trachoma. Some used only trachomatous inflammation follicular (TF) as the indicator of trachoma and others TF or trachomatous inflammation intense (TI).

A population-based study of trachoma prevalence in the Anangu Pitjantjatjara (AP) Lands was undertaken in 1990 by Stocks, Newland, and Hiller.\textsuperscript{(17)} During this study, approximately 58% of the estimated Aboriginal population in the AP Lands was examined, and the investigators found active inflammatory trachoma in 17.6% of the population surveyed, scarring in 25.2%, and trichiasis in 2.6%. In this study it was noted that those 14 years of age or younger represented the majority of the disease burden, or 83% of the total cases of follicular trachoma. In younger age groups, particularly those in the 2-9 years group, the presence of trachoma was hyperendemic ($\geq 20\%$).

A later study by the same authors, of prevalence in South Australia,\textsuperscript{(76)} lead them to conclude, when comparing the results of the 1990 survey with two earlier surveys,\textsuperscript{(16)} that the prevalence and severity of trachoma appeared to have lessened. However, the validity of such comparisons is limited, primarily because of the variation in the grading systems used to assess trachoma. Data for scarring and corneal opacity could not be compared because of the difficulty of matching grades between surveys. Notwithstanding apparent reductions in the prevalence of trachoma, it remained overall endemic (5%-20%), and hyperendemic ($\geq 20\%$) in children,
according to the WHO definition (Table 1), comparable to that found in developing countries.\(^{44,46}\)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Hyperendemic</th>
<th>Endemic</th>
<th>Non-endemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence Rate</td>
<td>≥ 20%</td>
<td>≥ 5-20%</td>
<td>≤ 5%</td>
</tr>
</tbody>
</table>

Table 1. WHO grading of prevalence rates\(^{84}\)

It was difficult to determine current levels of prevalence of trachoma in Australia with accuracy, due largely to the mobile nature of the population. In addition to intercommunity mobility, travel is also necessary for educational, cultural, and health reasons. For example, those who wish to go on to advanced study must at a minimum travel to Alice Springs. Figure 1 shows the geographical relation between the communities and Alice Springs.

The approximate distance by road to Alice Springs from Mimili is 581 km, and 780 km from Pipalyatjara. Also, secondary and tertiary medical treatments are not available in remote communities, thereby requiring travel to larger regional centres.

Prevalence was also difficult to estimate because of the limited number of current surveys that compare prevalence and their varying methodologies. Recent data on the prevalence of trachoma in the Australian Aboriginal population are often based on the
examination of older children only, whereas those of pre-school age are most susceptible to infection or active trachoma and the most important age group to examine.\(^{85-87}\) The prevalence of trachoma in this population could well be underestimated, as fewer children (compared to a less mobile population) could be available for study as a direct result of living within a mobile community.

There is evidence that mobility is not just into and out of the communities but between households and living quarters. A study by Pholeros, Rainow, and Torzillo, reported in 1993,\(^{88}\) clearly demonstrated the levels of mobility in the Pipalyatjara community. The survey also noted significant mobility between houses for both individuals and family groups over the survey period (1991-1992). While this does not have a great effect on prevalence estimates of trachoma, it could have implications for the effective implementation of the SAFE strategy if it is applied at a household rather than community level. (Antibiotics were administered and censuses taken at the household level in the SAFE intervention reported by Ewald.)\(^{24}\)

### 2.8 Risk Factors

A number of risk factors have been identified as associated with trachoma. The key risk factors include: the presence in a family or household unit of a child with active trachoma, age, gender, hygiene practices, and household and environmental factors. No single risk factor predominates, although some are more important than others, particularly facial hygiene.\(^{89-91}\) Not all factors need exist for trachoma to occur. For example, whilst trachoma is particularly common and severe in countries with hot, dry, and dusty conditions, it is also found in temperate and tropical climates, indicating that other factors are important in these areas. Trachoma is common in people living in areas characterised by lack of water and sanitation,\(^{92}\) excess of flies, lack of health or eye-care services, poverty, and isolation.\(^{81}\) However, it is also associated with poor personal and community hygiene.\(^{93,94}\) In Australia, all of these risk factors have been identified to be associated with trachoma, though the weighted individual impact of each factor is not known.

One difficulty in analysing studies that have considered the risk factors associated with trachoma, and in evaluating the significance of individual factors, concerns the interrelationship between the factors. For example, environmental factors which have a tendency to occur in the same families and within the same communities. Lack of
water, and poor sanitation, including the absence of latrines and inadequate waste disposal, for example, all tend to exist together and have a compounding effect. Few studies control for this effect, thus leading to a possible inaccurate estimation of the association.\(^4\) Even in areas with high prevalence or in which trachoma is hyperendemic (≥ 20%), the disease is found in clusters, both within the neighbourhood or village, and within particular households.\(^{43,85,86}\)

2.8.1 Age

Trachoma is described as a disease of the ‘crèche’, as children, especially those under the age of five, are most susceptible to active trachoma infection.\(^{43,85-87,95}\) The prevalence of active trachoma decreases with increasing age, and there is an observable decline after ten years of age in both males and females.\(^{43}\) Concomitant with the age-related decline in active trachoma is an increase in the presence of scarring and trichiasis, with the greatest prevalence being observed over 25 years of age.\(^{44}\) In areas of high and persistent endemicity, such as rural Egypt, the prevalence of scarring can be very high. Thus, Courtright et al. found 90% of the surveyed study population older than 25 years had substantial conjunctival scarring,\(^{44}\) and that over 75% of women, and 50% of men over the age of 45 years had trichiasis and entropion.

2.8.2 Gender

Both male and female children under 10 years have similar rates of the active disease, although significantly higher numbers of infected boys or girls have been found in several communities.\(^{43,44,96-98}\) Women, as caretakers of children, might be more likely to become infected and consequently subjected to higher risk of blinding complications in some communities.\(^{95,99}\) However, this has not been demonstrated in Australian Aboriginal communities in which the blinding sequelae of trachoma occur equally frequently in men and women.\(^{100}\) This observed difference could possibly be due to the differences in socioeconomic roles taken by males and females in varying cultures. In many modern Aboriginal communities, young adolescent men stay closer to the family unit than might have previously been the case, which would bring them readily into contact with the disease.
2.8.3 Environmental factors

A recent review of the evidence for associations between environmental sanitation and transmission of trachoma identified the presence of flies, availability and use of water, presence of latrines, garbage collection and disposal, and animal hygiene as the important factors associated with trachoma.\(^{(4)}\) The evidence is not sufficiently consistent or clear to permit isolation without further research of the dominant or prime determinants. Factors implicated in the transmission of trachoma and increased risks of trachoma are often interrelated when two or more are present. In particular communities, their absence or presence and relative importance will vary, supporting the desirability of a comprehensive approach to addressing them. It is considered that a focus on single determinants as priorities is likely to be less useful and less cost effective in the longer term. The individual effect of the relevant environmental factors is discussed in greater detail in section 2.18.

2.9 Clinical Features

Follicles are the paramount clinical indicator of trachomatous inflammation of the conjunctiva. They appear as yellow or white rounded spots in the tarsal conjunctiva, and histologically are lymphoid germinal centres. The conjunctiva often appears red and swollen, and there might also be some visible papillae. Severe inflammatory trachoma is characterised by thickening of the conjunctiva obscuring the deep-sited tarsal vessels.\(^{(45)}\)

Limbal follicles might appear, and new vessels develop, producing corneal pannus. Once the limbal follicles resolve, depressions remain in the periphery of the cornea, resulting in a pathognomonic sign of trachoma known as ‘Herbert’s Pits’. Multiple infections are eventually followed by evidence of scarring of the conjunctiva. In some cases, the scarring is severe enough to cause trichiasis, which, in turn, initiates damage to the cornea, resulting in corneal scarring seen as an opacity. Trichiasis and entropion eventually require corrective lid surgery in order to prevent secondary blindness.\(^{(83)}\)
2.10 WHO Simplified Grading System

WHO has developed a simple method to assess community prevalence and it should be used to determine the presence and severity of trachoma.\textsuperscript{(102)} The classification scheme is based on the five clinical signs of trachoma (see Table 2).

<table>
<thead>
<tr>
<th>The Five signs of clinical trachoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachomatous inflammation follicular (TF)</td>
</tr>
<tr>
<td>Trachomatous inflammation intense (TI)</td>
</tr>
<tr>
<td>Trachomatous scarring (TS)</td>
</tr>
<tr>
<td>Trachomatous trichiasis (TT)</td>
</tr>
<tr>
<td>Corneal opacity (CO)</td>
</tr>
</tbody>
</table>

Table 2. The five signs of clinical trachoma

The proportion of the population with TF and/or TI represents the prevalence of the active disease. Those with TI have severe inflammation and thus need prompt treatment. The prevalence of TT indicates the backlog of surgical cases, while CO is an indication of the potential impact of visual impairment in the community.

The WHO simplified grading system can be used to give a picture of active trachoma, intensity of the disease, and potentially disabling lesions. After training, primary-level health-care workers and paramedical staff are easily able to apply the scheme, which can be used in a variety of settings including field studies.\textsuperscript{(103)} Use of the grading scheme requires only minimal equipment,\textsuperscript{(47)} and although training is needed to apply the system correctly and to identify the various stages, it is neither demanding nor lengthy. The system has also been applied with good reliability and inter- and intra-grader consistency.\textsuperscript{(103)} It therefore permits a more accurate determination and comparison of prevalence in a community than earlier systems did.

While the WHO simplified grading system\textsuperscript{(47)} is now universally recommended for use in field surveys of trachoma, it does have its drawbacks. It underestimates the number of TF cases because the presence of five or more 0.5 mm follicles are required; it has also been criticised because it assesses individuals as having trachoma when they might have inflammatory conjunctival disease of other etiology.\textsuperscript{(52)}

A binocular loupe with x2 or x2.5 magnification used in the presence of an
adequate light source, such as a good torch, or direct sunlight, is required (Figure 2).

![Figure 2. Prof. Hugh Taylor examines a subject using a binocular loupe and torch. To the right of him is the author with a head-mounted loupe (Courtesy NHC).]

Each eye should be examined separately starting with the right eye. The eye is examined first for trichiasis—either in-turned eyelashes actually rubbing on the eye, or evidence of previously removed eyelashes. To check for the former, it is important to expose the lid margins. The cornea is examined for opacities, and lastly, the tarsal conjunctiva is examined for follicles, signs of intense inflammation, and scarring. Trichiasis is generally examined for in adults rather than in children, as it is generally the clinical outcome of long-term or repeated episodes of infection, and thus is not as prevalent in children.

Table 3 provides specific descriptions for each of the five clinical stages of trachoma, as well as visual images.
<table>
<thead>
<tr>
<th>SIGN</th>
<th>ACRONYM</th>
<th>IMAGE</th>
<th>DESCRIPTION</th>
<th>SIGNIFICANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trachomatous Inflammation – Follicular</td>
<td>TF</td>
<td><img src="image1.png" alt="Image" /></td>
<td>The presence of five or more follicles of at least 0.5mm in diameter in the upper tarsal conjunctiva. (Follicles are whitish round spots paler than the surrounding conjunctiva.)</td>
<td>Current active infection requiring antibiotic treatment</td>
</tr>
<tr>
<td>Trachomatous Inflammation – Intense</td>
<td>TI</td>
<td><img src="image2.png" alt="Image" /></td>
<td>Pronounced inflammatory thickening of the tarsal conjunctiva that obscures 50% or more of the normal deep tarsal vessels. With TI, the tarsal conjunctiva often appears red, roughened and thickened. Inflammatory thickening of the conjunctiva should not be confused with that caused by scarring.</td>
<td>Severe current infection with an increased risk of scarring and also requiring antibiotic treatment.</td>
</tr>
<tr>
<td>Trachomatous Scarring</td>
<td>TS</td>
<td><img src="image3.png" alt="Image" /></td>
<td>The presence of scarring in the tarsal conjunctiva. These should be easily visible as white lines or bands on the tarsal conjunctiva—glistening and fibrous in appearance. Scarring can also obscure the tarsal blood vessels and it must not be confused with diffuse inflammatory thickening.</td>
<td>The patient has or has had trachoma and will require regular review to identify and deal with possible progression to trichiasis.</td>
</tr>
<tr>
<td>Trachomatous Trichiasis</td>
<td>TT</td>
<td><img src="image4.png" alt="Image" /></td>
<td>At least one eyelash rubs on the eyeball. Evidence of recent removal of inturned eyelashes should also be graded as trichiasis.</td>
<td>The patient might develop corneal opacity and visual loss and require trichiasis surgery to correct the condition as soon as possible.</td>
</tr>
<tr>
<td>Corneal Opacity</td>
<td>CO</td>
<td><img src="image5.png" alt="Image" /></td>
<td>Easily visible corneal opacity over the pupil. This refers to central corneal scarring that is so dense that at least part of the pupil margin is blurred when viewed through the opacity.</td>
<td>This is a disabling lesion. The patient will require rehabilitation and support and should be referred to an ophthalmologist to consider possible surgical correction.</td>
</tr>
</tbody>
</table>

Table 3. WHO simplified trachoma classification grading system.(102)

1 Images courtesy of World Health Organization Grading Card.
2 The “Significance” column is not part of the WHO grading system. It has been added by the author to provide guidelines for use of the system by Aboriginal health workers to aid in the comprehension of symptoms, appropriate referral, and management strategies.
2.11 Sequelae of Active Trachoma

The more severe consequences of repeated infection appear mostly in young adulthood and in middle age. There is no good longitudinal study of risk factors for the development of scarring or trichiasis to show why only a small proportion of the children who have the active disease go on to develop the blinding complications. However, a number of studies have shown that women are more likely than men to develop the blinding complications of trachoma.\(^{43,44}\) It is postulated that this is because women have much closer contact with small children, the prime source for the transmission of infection.\(^{104}\) However, Turner et al.\(^{86}\) found that prolonged exposure to child care as a young girl and as a mother showed no significant difference between cases and controls. In that study, each case of trichiasis was matched with two women from the same village and of the same age with no trichiasis. This was a retrospective study and, therefore, could not directly measure exposure to children with active infection.

The failure to find a relationship might have resulted from this problem. The same study found that women with trichiasis were more likely to have had mothers with trichiasis, possibly indicative of similar home environment and hygiene practices. Courtright and West suggest that the higher incidence of trichiasis and its recurrence in women is probably due to several factors:\(^{95}\) ‘dry eye’ due to hormones; less aggressive use of surgical services (compared to men); use of primitive eye cosmetics; and more severe trichiasis prior to surgery; and because of reinfection as children, and adults.

In the Central Northern Territory within Australia, a recent survey showed that although the prevalence of trachomatous scarring among Aboriginals has decreased in individuals older than forty years over the last 13 years, the prevalence of trachomatous trichiasis, and corneal opacity has not changed.\(^{106}\) Moreover, the figures are still relatively high (53%, 10% and 2%, respectively), and disturbing for a developed country.

2.12 Diagnostic Testing

Many diagnostic tests of variable cost, accuracy, specificity, and ease of use exist to identify chlamydial infections. However, the set of feasible diagnostic tests available to laboratories and health-care providers is limited. Issues of cost,
difficulties with handling, the storage and transportation of specimens, the lack of standardization of protocols, and result evaluation guidelines predominate.\textsuperscript{(28,52,107,108)}

The laboratory diagnosis of chlamydial infection in the individual is made through detection of the organisms in ocular specimens where the infection is suspected on clinical grounds,\textsuperscript{(109)} or for research interests. Diagnosis can be made using various methods, including cytological examination of stained slides of conjunctival swabs, growing the organism in tissue culture cells, or by detection of antigen or nucleic acids.

A conjunctival biopsy and cytology with iodine or Giemsa staining can reveal the chlamydial inclusions, with Giemsa staining being slightly more sensitive. Although highly specific, it has a low overall sensitivity even in the presence of severe disease. In addition, the false negative rate in Giemsa staining can be as high as 90%, thus decreasing its reliability.\textsuperscript{(110)}

A study in Saudi Arabia, which used enzyme-linked immunoassay (ELISA) kits and indirect fluorescent antibody test kits, confirmed that the pattern produced using the ELISA kits compared well with cell culture and immunofluorescence. However, false-positive tests can result unless confirmatory tests are also performed.\textsuperscript{(107)}

The ‘gold standard’ diagnostic test has been the isolation of the bacterium in cell culture.\textsuperscript{(59)} The sensitivity of the culture technique has improved with the introduction of the irradiated or cycloheximide-treated McCoy cell line, and it has a high specificity rate of near 100%, although its sensitivity is less than 100%.\textsuperscript{(52)} Sensitivity is affected by improper storage, handling and delays in transport. In addition, it is technically demanding, time consuming, costly, and subject to variability of performance.\textsuperscript{(107)}

Alternative methods for detection of \textit{C. trachomatis} are direct staining of smears of secretions with fluorescein-labelled monoclonal antibodies (direct fluorescent antibody) and enzyme immunoassay.\textsuperscript{(107)} Direct fluorescent antibody (DFA) cytology is an effective technique for detecting chronic chlamydial conjunctivitis, offers an alternative to the tissue-culture isolation method, and is more sensitive and specific than enzyme immunoassay. Data suggest that DFA tests might be capable of detecting lower levels of chlamydial infection in the eye than chlamydial culture.\textsuperscript{(109)}

A newer qualitative test for \textit{Chlamydia trachomatis} is the polymerase chain reaction assay (PCR) and a variant called the ligase chain reaction (LCR).\textsuperscript{(111)} These are DNA amplification tests performed on material obtained on swabs from patients
with suspected trachoma. The majority of tests are directed at plasmid genes (such as pCT), \textit{omp1}, the gene coding for MOMP, and the gene coding for 16S r-RNA. It has been argued that commercial test kits based on detecting plasmid genes, such as Amplicor, developed by Roche Diagnostic Systems, are orders of magnitude more sensitive than kits based upon detection of chromosomal DNA, because there are more plasmid copies per RB.\(^{(112,113)}\)

More recently, quantitative PCR methods, also known as real-time or true kinetic tests, have been developed by determining \(E\)—the efficiency of DNA synthesis during the exponential phase of PCR—several times during the process in closed systems employing fluorescence monitoring.\(^{(52)}\) This permits experimenters to accurately determine chlamydial loads from ocular swabs in subjects, and study in a given population how those loads are distributed.

Although PCR is an extremely valuable tool when used in conjunction with clinical assessment of trachoma, it should not be used by itself to assess the level of trachoma in any community. For example, in a recent study conducted in Nepal, in an area that previously had blinding endemic trachoma and still has a 6% prevalence of clinically active conjunctival disease, no Chlamydia agent could be detected using LCR.\(^{(111)}\) In the light of these data, it is clear that the diagnosis of trachoma remains a clinical one and interventions should be monitored this way rather than on a laboratory basis, due to the comparatively high cost and logistical demands of lab tests. Clinical examination revealing follicles shows evidence of current or recent past infection not detected by labs, and thus should be considered the ‘gold standard’ for diagnosis.

### 2.13 Strategies for the Management and Control of Trachoma

The aim of programs to manage and control trachoma is not only to treat active trachoma where it is found, but also to reduce and ultimately eliminate the risk factors associated with trachoma. The successful control of trachoma is dependent on individual and community-based interventions and treatment, and there is a need for these to be part of appropriate public or primary health strategies.\(^{(114)}\)

The current impetus for widespread implementation of strategies for the management and control of trachoma comes from a series of consultations convened by the WHO Program for the Prevention of Blindness and Deafness (PBL) in Geneva
in 1996 and 1997. The purpose of the meetings was to develop a global plan to enable all organisations and individuals involved in combating blindness to work in a focused way to achieve the common goal of eliminating avoidable blindness. Resulting from the meetings was the launch of an initiative to eliminate the five most amenable causes of blindness at the present time, including trachoma, by the year 2020 (Vision 2020).\(^{(115)}\)

Central to this broader trachoma initiative is GET 2020 (Global Elimination of Trachoma, a program to eliminate blinding trachoma by the year 2020). GET 2020 has adopted a comprehensive set of strategies and control measures for trachoma-endemic areas, summarised as the SAFE strategy.\(^{(47)}\) The SAFE strategy consists of four components to give a combined medical, behavioural, and environmental approach:

- Surgery to correct trachomatous trichiasis
- Antibiotics to reduce the reservoir of chlamydial infection within the community
- Facial cleanliness
- Environmental changes to reduce the transmission of trachoma.

The SAFE approach is based on evidence, which suggests that if the prevalence of \(C.\ trachomatis\) in communities is reduced with antibiotics,\(^{(116)}\) whilst transmission is reduced with improved hygiene\(^{(12,15)}\) and environmental conditions,\(^{(12,15)}\) then infection levels might not return to pre-treatment levels even if ocular Chlamydia itself is not eradicated entirely. Further, the gradual disappearance of the disease, as a result of socio-economic progress and medical intervention in many parts of the world, supports the adoption of a broad-based public health approach.\(^{(117)}\) The large-scale applications of community-based interventions against trachoma could, therefore, lead to its global elimination, at least as a cause of blindness even if the causative agent is not eradicated.\(^{(47,118)}\)

### 2.14 Surgery

Lid surgery can correct the trichiasis that leads to corneal scarring\(^{(119)}\) and a number of different surgical procedures can be used to achieve this.\(^{(120)}\) These include tarsal rotation, and tarsal advance and rotation, which are each reasonably effective.
However, tarsal advance was ineffective for trichiasis complicated by defective lid closure, which requires more advanced surgical procedures. Results were positive when tarsal advance and rotation with incision of the tarsal insertion of the levator and tarsal inlay grafts was used for defective lid closure.\(^{120}\)

The approach recommended by WHO is for bilamellar tarsal rotation surgery unless there is defective lid closure.\(^{121}\) This is the only procedure that has been fully evaluated in randomised clinical trials,\(^{122}\) and its efficacy proven.\(^{121}\) A prospective, randomised controlled clinical trial performed in Oman showed that bilamellar lid rotation was more effective than other forms of surgery for upper lid trichiasis due to trachoma.\(^{122}\)

Bilamellar tarsal rotation surgery is quick, requires minimal equipment, and can be performed under local anaesthetic as a day procedure. Trained paramedical eye health workers have successfully undertaken this procedure in the community setting.\(^{123}\)

A randomised community trial\(^{124}\) conducted in Gambia examined the frequency of surgical uptake when surgery was provided at the village level, compared with providing surgery at distant health centres. The results strongly suggest that there is better surgical uptake when surgery is provided at the village level, because of a lower cost to the patient, time saved, and less fear related to the procedure.

However, warning notes sound from recent studies showing that the incidence of recurrence of trichiasis after surgery can be as high as 56%.\(^{125}\) It appears that the longer the interval following surgery, the greater the likelihood that there will be recurrence. Taylor comments that this can be due to inadequate surgery, but also to the fact that tarsal scarring trachoma is of a progressive nature, and that ‘…trichiasis is likely to recur because of ongoing scarring, even after otherwise successful surgery’.\(^{126}\) What is most apparent is that surgery must be complemented by the other components of the SAFE strategy to have a sustained effect.\(^{127}\) People who have had surgery should be followed up regularly, and patient/community education regarding trachoma should be promoted to prevent recurrence. Yet there is still an entire generation that will suffer the complications of trichiasis as a result of chronic infection, as environmental improvements and antibiotics can do little for cicatricial trachoma already present.\(^{127}\)
2.15 Antibiotics

2.15.1 Tetracycline ointment

Until recently, the treatment recommended by WHO was an application of tetracycline ointment (1%) twice per day for six weeks. Also acceptable were intermittent treatment schemes of ointment applications twice a day for five consecutive days per month for at least six consecutive months, or once a day for ten consecutive days for six months.\(^{(128)}\)

Difficulties associated with the use of topical tetracycline treatment that lead to poor patient compliance can be summarised as:

- Ointment is difficult to apply particularly to young children and infants.
- There is discomfort and blurring of vision associated with its use.
- The infection can be symptomless, and motivation is lacking to continue with a course of treatment.

2.15.2 Azithromycin

An alternative to the use of topical tetracycline ointment is azithromycin, which overcomes most of the difficulties associated with the use of ointment. Azithromycin is an erythromycin-like macrolide antibiotic requiring only a single oral dose to maintain adequate tissue levels for up to eight days.\(^{(129)}\) The use of azithromycin increases the likelihood of successfully implementing the ‘A’ component of the SAFE strategy. Where this drug is available, WHO recommends its use in both individual and community programs for the treatment of trachoma;\(^{(130)}\) where it is unavailable, doxycycline is an alternative.

2.15.3 Azithromycin compared to topical tetracycline

A single dose of azithromycin taken orally is as effective as a six-week course of topical tetracycline in clearing ocular chlamydial infection and in resolving signs of active trachoma.\(^{(74)}\) Studies undertaken in the Gambia\(^{(65)}\) and randomised clinical trials in Saudi Arabia,\(^{(131)}\) as well as Northern Egypt,\(^{(132)}\) have demonstrated this point.

In each of these studies, the administration of tetracycline ointment was carefully supervised, which allowed this regime to perform equivalently to azithromycin. Bailey et al.\(^{(74)}\) noted in their study that, because of the resources needed to achieve
the high level of compliance with conventional tetracycline treatment, success with the tetracycline could probably not be achieved outside a ‘research’ setting.

A community-based randomised trial conducted in Egypt, The Gambia, and Tanzania assessed the long-term effect at the community level of mass treatment with azithromycin compared to tetracycline. One year after treatment, both clinical disease and laboratory evidence of infection in the community were reduced in each treatment group. However, there was a significant and more sustained reduction in chlamydial infection with azithromycin treatment, compared with topical tetracycline.\(^6\)

A recent, masked randomised trial conducted in The Gambia\(^{133}\) in a setting of relatively low prevalence of trachoma, and involving 12% of children being screened, compared the effect of azithromycin and topical tetracycline under practical operational conditions. Tetracycline was given in the absence of supervision. The results showed that azithromycin was again a significantly more effective treatment than tetracycline for clinical cases of trachoma, particularly for intensive disease (\(p = 0.023\)). This result was obtained both at ten weeks (a prevalence reduction of 68% versus 51%; cure rate ratio: 1.31; 95% confidence interval [CI], 1.08-1.59; \(p = 0.007\)), and at six months (a prevalence reduction of 88% versus 73%; cure rate ratio: 1.19; 95% CI, 1.06-1.34; \(p = 0.004\)).

Interestingly, this relatively high cure rate for the tetracycline treatment was an unexpected result in the absence of unsupervised administration. The authors suggest that in higher prevalence settings, greater transmission and reinfection rates operate, and that reinfection might not be clinically distinguishable from treatment failure.\(^{133}\)

It is possible, therefore, in lower prevalence settings that studies are likely to report better cure rates regardless of the antibiotic used. In these circumstances with both treatment regimes achieving high cure rates, and given the high cost of azithromycin, the continued use of tetracycline in the routine treatment of active trachoma might be more cost effective. The use of azithromycin, however, might be justifiable in the treatment of trachoma where prevalence is hyperendemic, and the cost and availability are not important factors, such as in Australia, where a government subsidy reduces the cost of the drug.

### 2.15.4 Treatment intervals/distribution strategies

At the time this study was being conducted WHO guidelines were to mass treat communities with antibiotics if the prevalence of TF in children was \(\geq 20\%\), or the
prevalence of TI in children was \( \geq 5\% \). If the TF prevalence in children was found to be between 5 and 20\%, targeted distribution (members of all families in which a case of TF was diagnosed) of antibiotics was the preferred recommendation.\(^{134}\) However, following the publication of more recent data, WHO simplified its criteria, recommending that mass treatment be instituted when the assessed prevalence of TF in children was found to be \( \geq 10\% \), with targeted treatment for TF levels in children of \( < 10\% \).\(^{134}\)

The optimal interval for the treatment of trachoma in endemic communities and the appropriate target groups is not yet settled.\(^{117}\) Annual treatment has been advocated\(^{135}\) and several clinical trials have used a one-year follow-up in assessing efficacy.\(^{74,132}\) Studies in Morocco comparing the results after one year of a single dose with two doses given six months apart, showed that the latter dosage achieved better results at one year. This is not surprising given that this was only six months after the second treatment.\(^{136}\) More recent trials show mixed results, depending, in part on how the results were assessed: whether by clinical assessment, lab testing, or both. For example, Holm et al. studied two distribution strategies in Nepal: mass treatment of children, or targeted treatment of children with clinical signs of trachoma, plus household members.\(^{10}\) While the prevalence of active trachoma was reduced on average by one third six months after azithromycin distribution, infection in subjects that showed clinical signs of trachoma at baseline was reduced by about half.\(^{10}\) However, a smaller longitudinal study of a community in the same country that involved three successive annual treatments of azithromycin showed virtual elimination of infection, and a significant reduction of active trachoma from about 40\% to less than 5\%.\(^{14}\) In the Rombo district of Tanzania, subjects were treated with a single dose of azithromycin, and followed over a 24-month period. While infection declined to almost undetectable levels, the active trachoma prevalence showed a significant reduction in all age groups at two months, but then gradually stabilised over the next several months, without further decline.\(^{13}\)

Although many researchers clearly feel that an appropriate azithromycin strategy can bring infection levels down to very low levels—and the data often, though not always support this conclusion—trachoma prevalence levels do not always follow. This is in part because of the inflammatory nature of the disease. It should however be noted that short-term assessments are not likely predictors of long-term realities; those studies that follow communities over several years are much more likely to provide
data from which long-term strategies can be devised. Jha et al, noted in their study, for example, that 12 months after azithromycin administration, they could find no effect on trachoma prevalence due to the antibiotic.\(^{(137)}\)

A recent paper\(^{(116)}\) has mathematically modelled the effect of azithromycin treatment and optimal frequency of re-treatment on its ability to reduce or eliminate trachoma. The model shows that when only children are treated and no other interventions implemented, annual treatment is adequate in areas with an intermediate prevalence (\(\leq 35\%\) prevalence in children). In hyperendemic areas (\(\geq 50\%\) prevalence in children), in the absence of other interventions, six monthly treatments are preferable, though WHO recently revised guidelines recommend three annual treatments before reassessing whether to halt or continue antibiotic administration.\(^{(134)}\)

However, there are several assumptions implicit in this model. These include universal (100\%) coverage, a homogenous distribution of the disease (i.e., no significant clustering), a 95\% treatment efficacy, and a static (non-mobile) population. Clearly, this model would have very limited applicability to Australia, where the mobility of Aboriginal populations would guarantee a significant influx of inhabitants shortly after any antibiotic administration, there is very high clustering, and problems with simply reaching high coverage rates.

In addition, data from a number of studies confirm the importance of the household or family unit in the transmission of trachoma.\(^{(91)}\) Because of the highly infectious nature of trachoma it is probably better, therefore, until further studies are undertaken, that all family members and not just the affected members be treated, and the SAFE strategy be implemented in its entirety.\(^{(5)}\)

### 2.15.5 Benefits of azithromycin

Azithromycin benefits include:

- If given as a single oral dose ensures complete treatment
- Is absorbed within a few hours
- Has a high degree of safety with a few side effects characterised by gastrointestinal symptoms, usually mild to moderate, which disappear over a short period\(^{(101,135)}\)
- The Australian Drug Evaluation Committee has reported that azithromycin can be used by pregnant and lactating women.\(^{(138)}\)
• Assists with the control of most respiratory, skin, and genital infections. One study has shown that it assists with all three malarial indices.\(^{(139)}\)

2.15.6 Disadvantages of azithromycin

Azithromycin disadvantages include cost and bacterial resistance. A number of authors\(^{(74,133,135)}\) have pointed to the high cost of azithromycin as mitigating against its use. A high cost reduces access to this treatment by many target populations. Personnel and organisational costs are also involved if it is considered necessary to administer oral azithromycin by direct observation.

The possible development of bacterial resistance with widespread use of azithromycin is considered to be slight given its unusual pharmacokinetics,\(^{(129)}\) however, the issue of resistance is not completely resolved. An Australian study, which evaluated the effect of azithromycin treatment on trachoma, also monitored the effect on the carriage and antimicrobial resistance profiles of pneumococci. It showed that azithromycin allowed the growth and transmission of pre-existing azithromycin resistant strains.\(^{(140)}\) On the other hand, other results lead to the conclusion that the prevalence of azithromycin-resistant pneumococci remains low.\(^{(141,142)}\)

Preliminary findings from a study in Nepal to determine the secondary effects of mass treatment of children of \(\leq\) 10 years of age show that the treatment had several short-term benefits, including a reduction in diarrhoea and impetigo. There was no azithromycin-resistant pneumococcus detected at baseline in the studied group, although one child carried resistant organisms at day ten. However, azithromycin-resistant pneumococci were detected in children who had received two previous doses of azithromycin. The investigators considered the absence of the short-term emergence of macrolide-resistant pneumococci after one mass treatment to be encouraging.\(^{(143)}\) Continuing surveillance is important and studies in communities with a higher baseline prevalence of macrolide-resistant pneumococci are warranted.

2.15.7 Family-based treatment

In Australia, the family or living unit has been recommended as the target for treatment.\(^{(50)}\) This is consistent with the notion of trachoma as a ‘disease of the crèche’. Compared to community-based treatment, family-based treatment reduces the number of people to be treated, and thus minimises the risk of bacterial resistance.
Even in hyperendemic areas there will be some families without trachoma. Family-based treatment is more cost and resource effective. However, it is also recognised that where prevalence is high, treatment of the entire community might be simpler, as it obviates the necessity of examining members of all the families.

2.16 Australian Experience

In Australia, azithromycin has been shown to be effective in reducing the rate of active trachoma in a number of Aboriginal communities. In the Katherine region of the Northern Territory, a trachoma treatment program was implemented using azithromycin in conjunction with a health promotion program. The treatment protocol was based on the WHO guidelines, but only children were treated and not adults. The results demonstrated a fall in prevalence rates from 49% in 1995, to 19% in 1996 post-treatment. Azithromycin programs have also been introduced in other communities with positive results. In the Pilbara, a 95% resolution of active trachoma was found in children examined six to eight weeks after azithromycin treatment. The prevalence of trachoma in these children before and after treatment was not reported.

An unpublished study, undertaken in 1998 by Ewald and Hall, investigated the effect of community trachoma intervention on the prevalence of infection in a large central Australian Aboriginal community. A single dose of azithromycin was dispensed to all members of the households with cases of active trachoma found during the initial screening. The prevalence of infectious trachoma in children was 40% (95%, CI 32-40%) before and 33% (95%, CI 26-40%) seven months after the intervention; the difference was not significant. Although there were high participation rates in the census and screening and popular community support for the project, the lack of impact on infectious trachoma prevalence was, in part, attributed to limited uptake of treatment and a high degree of population movement in and out of the study community. The investigators did not monitor the number of antibiotic doses consumed and considered that this was a factor in failing to achieve better outcomes. This study was later published. Studies, which have treated with single observed doses, achieved better results.
2.17 Facial Cleanliness

Facial cleanliness protects against trachoma,\(^{(91)}\) therefore, interventions which encourage facial cleanliness and not just facial washing, especially for pre-school and school children, are very important. Four studies\(^{(79,87,90,91)}\) have considered the impact of frequency of face washing.

In Mexico an early study\(^{(90)}\) found that children whose faces were reported to be washed more than seven times a week had a significantly lower risk of contracting active trachoma compared to those for whom face washing was reported less often. However, the two villages surveyed were significantly different at baseline and the relative risk was calculated from pooled data, which can lead to misleading results, as the populations are different. Studies from Brazil\(^{(87)}\) and Malawi,\(^{(79)}\) however, failed to show any association between the number of times faces were washed and the prevalence of active trachoma. These and other studies, have been criticised on the grounds that self-reporting of face-washing parameters can lead to invalid conclusions, because bias can exist,\(^{(15)}\) and will most likely lead to an overestimation of the amount of face washing. A study in central Tanzania showed a positive effect of face-washing frequency and facial cleanliness on trachoma prevalence, although it was overall facial cleanliness that had a significant effect on prevalence, and not merely how often the face was washed.\(^{(91)}\) An unclean face, when defined by general appearance, was the presence of dirt, dust, or crustling on the cheeks and forehead. The study also found that handkerchief use and towel use also appeared protective of active trachoma. Munoz and West\(^{(45)}\) later raised doubts about the face-washing aspects of this study, citing validity problems with self-reporting. Further research considered the specific elements of an unclean face related to trachoma in children: flies on the face, nasal discharge, food on the face, and dust. Flies on the face and nasal discharge significantly increased the risk twofold.\(^{(145)}\)

Although not showing a direct association with frequency of face washing, these studies suggest that children with clean faces are less likely to have trachoma, and that face washing might reduce the likelihood of re-infection or transmission of the infection to others. Another study in Tanzania tested whether a participatory strategy to improve face-washing behaviour would reduce trachoma.\(^{(146,147)}\) Over a twelve-month period this strategy was successful in achieving an almost sevenfold improvement in the prevalence of clean faces (from 4% to 27%). Facial cleanliness
(defined as having discharge from only one or neither eye, or no nasal discharge or flies on the face) was assessed on two days for each survey. There was also a correlation with objective evidence of face washing based on the use of invisible fluorescent cream applied to the forehead.\(^{(147)}\)

An intervention trial involving the effect of face washing on active trachoma in children following mass antibiotic treatment was conducted in three pairs of villages in Tanzania. The study found that children from villages using the face-cleaning strategies and tetracycline intervention, not only had cleaner faces, but also had reduced odds of trachoma (OR 0.81, 95% CI 0.42-1.59), when compared with children from the villages who just received antibiotic treatment.\(^{(148)}\) (No levels of significance were reported.) One year afterward, baseline children in the intervention villages were more likely to have sustained clean faces than those in the control villages. While there was no difference in the prevalence of all active trachoma cases (TF and TI) between intervention and control villages, face washing was associated with a lower prevalence of severe trachoma (TI).

When all participants from intervention and control villages were pooled and confounding factors controlled for, children who had a sustained clean face were less likely to have active trachoma than those who ever had a dirty face. The face-washing intervention strategy had a modest impact in increasing the percentage of children with clean faces in two of the three intervention villages, demonstrating that face washing and facial cleanliness are not necessarily the same thing, though both can be considered aspects of facial cleanliness. The trial indicated, after controlling for confounders, that children who had a sustained clean face were less at risk of trachoma than those who had dirty faces.\(^{(148)}\)

There is, therefore, some evidence to support the assumption that promoting clean faces will assist the reduction of trachoma.\(^{(89)}\) Health-promotion activities and community participation are crucial for the successful implementation of clean-face strategies. The improvement of personal and community hygiene practices are not simply a question of improved access to water; they also require a change in the attitude towards water and its use, with a household or community decision for approval for new practices. This requires health and public education efforts in conjunction with community development projects.\(^{(114)}\)

A clinical trial was conducted over a study period of three years, in which self-help groups of villagers were established and worked with the broader community to
advise and educate about the good hygiene practice and prevention of trachoma. The trial managed to reduce the prevalence of trachoma by 62%, while reduction in the control community was negligible.\(^{(149)}\) However, in another clinical trial a health-education program administered in conjunction with a mass treatment campaign did not reduce trachoma prevalence.\(^{(150)}\) Therefore, the effect of the education strategies cannot be compared directly between the studies due to the difference in administrative methods, i.e., the first was a self-help program; the latter was not.

Whilst the factors that predict a sustained clean face have yet to be determined, the results provide sufficient support to justify the WHO emphasis on facial cleanliness. A recent survey shows that there is a sound basis for implementing combined trachoma control interventions. These interventions would include behavioural change strategies through education, and take into account the availability of water and adequate sanitation to encourage improved overall hygiene practices, secondary to organised antibiotic treatment campaigns.\(^{(151)}\)

Defining facial cleanliness measures more accurately with regard to the risk of contracting trachoma and quantifying methods of keeping faces clean, especially when individuals harbour active infection will be key items in the success of the ‘F’ component of the SAFE strategy. At present there are still substantial errors in measuring both. There is no doubt that face washing is an effective tool in reducing the levels of trachoma; however, how it should be accomplished is still far from certain.

### 2.18 Environmental Improvements

There are sufficient grounds to accept that trachoma is a disease of poverty and communal underdevelopment, as well as of poor personal and community hygiene.\(^{(8)}\) Because of the interrelationship of risk factors associated with trachoma, it will only be eliminated successfully in the long term in many cases if appropriately targeted, community-based interventions are implemented.\(^{(152)}\)

The association between personal and environmental sanitation, hygiene and trachoma transmission has been discussed previously. The findings of various studies and research provide comprehensive evidence of causal relationships, which support a comprehensive range of interventions directed towards environmental improvements,
and which must be used to guide the implementation of the ‘E’ component of the SAFE strategy.

Having stated this proposition, many studies suffer the limitations of methodological inadequacy.\(^{(4)}\) Many do not control for the effect of confounding variables, or ensure that sampling is representative of the population under investigation. Most information about environmental risk factors comes from observational studies, though some data are available from intervention studies. Only two of the latter have sought to investigate the effect of a specific change on transmission of trachoma while controlling for potentially confounding variables.\(^{(148,153)}\)

The validity of both observational and intervention studies can be affected by several factors. The main bias might arise because environmental risk factors, such as water availability, and the presence of latrines and waste disposal, tend to occur together in the same families and confound each other. This has the risk of leading toward an overestimation of the association between environmental risk factors and trachoma prevalence.\(^{(4)}\)

Some of the potential methodological problems of observational studies might make interpretation of the data difficult.\(^{(15)}\) The main problem areas concern:

- **Lack of adequate controls**—the comparability of groups needs to be established at baseline and follow-up
- **Seasonal variations** need to be accounted for
- **Failure to account for trachoma’s tendency to cluster in households** when undertaking analyses at the individual level
- **Confounding variables**, such as age and gender not being taken into account. The inclusion of adults in a study may have a diluting effect on prevalence estimates, as the presence of inflammatory trachoma is usually higher in children.\(^{(4)}\)
- **Validity and reliability of survey methods**—inter-observer variation needs to be examined to determine the reliability of results. Behaviour-related variables require careful and specific definition to permit repeatable measurements.
- **Reliance on questionnaire and self-reporting techniques** that can lead to bias, exaggeration, and over reporting
• Studying risk factors that are more directly related to the transmission mechanisms, such as fly density or facial cleanliness\(^{(154-156)}\) might reduce confounding variables. Studies that assess these risk factors and the outcome on a community, rather than on an individual household basis\(^{(91,149,153)}\) would be expected to be more accurate, and hopefully more comparable with other studies.

Studies that used adequate methodology to provide evidence-based conclusions used the following components:

- Random selection for inclusion of study participants
- Age stratification, or an age eligibility
- Analysed confounders
- Described exposure to risk factors
- Defined the outcome in terms of measures
- Analysed the significance of the results
- Used an adequate sample size to permit detection of a significant relative risk and calculation of the odds ratio.

Of these studies, four were clinical trials and 16 were observational surveys. Parameters analysed in these studies include water availability, garbage collection, absence of latrine/toilet, frequency of face washing, facial cleanliness, personal hygiene, fly density, presence of animals inside the house, and indoor air quality.\(^{(4)}\) In summary, the studies showed the relationships described in the following sections.

2.18.1 Water

There is a close association between a poor water supply and limited access to water with the increased prevalence of trachoma. Studies assessing the impact of water supply on trachoma are mainly investigations that compare water availability between communities. The impact of water availability on trachoma can be related to the distance between the water supply and the household, the quantity of water brought into the house, how the water is used (hygiene practices), and the quality of the water (water source). These are discussed below.
A reduction in the risk of trachoma is consistently associated with better access to water.\(^{(92)}\) The distance to water can place constraints on its use and, hence, in hygiene practices and trachoma prevalence.\(^{(78,80,87,118)}\) Tielsch et al.\(^{(79)}\) found that a distance of more than 60 minutes’ walk to the water source increased the risk of trachoma by two-and-a-half times. Other studies have also found that the more distant the water source,\(^{(157,158)}\) the higher the risk of having active trachoma. In a six-year follow-up study of risk factors for trachoma, it was found that children who lived more than two hours distance from water were more likely to have severe trachoma at both study periods—1989 and 1995.\(^{(158)}\) However, some studies have shown this not to have any significant effect,\(^{(159)}\) possibly because of the how the water is used, not how much is available. A study undertaken in Ethiopia\(^{(96)}\) found that people living more than fifteen, but less than thirty minutes’ walk from a water source had less active trachoma.

It has also been reported that per-capita consumption of water is reasonably constant between households when the round trip to the water source is thirty minutes or less—equivalent to a round trip of two kilometres. This ‘water use plateau’ effect\(^{(160)}\) has been documented in East, West, and southern Africa, Asia, and Central America, and shows that once this level of availability is reached, bringing the water source closer has little influence on consumption unless the water is provided in the house or in the yard. This might in part explain the inconsistent results in the studies examining the effect of distance to water on the prevalence of trachoma, though, in the author’s opinion, this variable is probably too indirect and complex to be of much utility.

Kupka et al. found that the quantity of water brought into a house was independent of the distance to the source.\(^{(159)}\) Children from households with a greater quantity of water had less active trachoma. Nevertheless, it is the pattern of water consumption and water utilisation that is of particular importance.\(^{(87)}\) West et al.,\(^{(43,157)}\) as well as Bailey et al.,\(^{(161)}\) have shown that under controlled conditions, families with trachoma use less water for washing children than those families without trachoma. Low water consumption (less than 5000 litres/person/month in the household) was significantly associated with increased risk of trachoma, independent of the water source being inside or outside a residence, or whether there was no piped water at the residence.\(^{(87)}\)
The quality of water is to an extent determined by its source, such as deep wells, piped water, and tank water. The studies that have considered this factor are limited and not recent. In Malawi, the prevalence of trachoma was highest amongst those drawing their water supply from unprotected wells,\(^{(79)}\) but in Mexico, trachoma was not associated with quality of the water, in this case using water previously used by others for washing.\(^{(90)}\)

The relationship between water supply and trachoma is complex and the provision of water or easier access to water does not automatically lead to hygiene improvements, or change the way the water is used.\(^{(146)}\) However, it does facilitate better hygiene practices and cleanliness, and reduces the time taken to collect water. It is important not only to provide access to water, but also to implement strategies to change water-use behaviour.

Water usage varies between households in a number ways, but of relevance to the transmission of trachoma is the frequency of bathing, face washing, and washing of clothes. Taylor et al. showed no association with trachoma and the frequency of clothes washing, nor with the frequency of general bathing, when the study was controlled for face washing.\(^{(90)}\) However, an early (1967) Australian study reported a positive effect when children were bathed daily.\(^{(162)}\)

Two studies that examined the frequency of face washing found it to have a protective effect against trachoma.\(^{(90,91)}\) However, this was not replicated by findings in a study in Malawi\(^{(79)}\) nor in Mexico.\(^{(163)}\) A methodological problem, which could explain inconsistent prediction of the frequency of face washing as a risk factor, is that evidence of the number of times a child’s face is washed comes from self-reporting, and many mothers would be aware that face washing is a desirable practice, so there may be a tendency to over report.\(^{(79)}\)

West et al.\(^{(148)}\) undertook a face-washing intervention program, following a mass, topical antibiotic treatment program, in Kongwa, Tanzania. After controlling for confounders, the results demonstrated that children who had a sustained clean face were less likely to be at risk of trachoma.

Facial cleanliness was reported by five studies to be inversely associated with the prevalence of trachoma in children\(^{(89,91,145,157,158)}\) and as non-significant by another study,\(^{(154)}\) the median protective effect being 41%. The relationship between frequency of face washing, facial cleanliness, and trachoma might be affected by other hygiene-related factors, such as the use of shared or dirty cloths for face
drying.\textsuperscript{(164)} It should be clear then that the desired outcome is facial cleanliness, rather than facial washing.

\subsection*{2.18.2 Hygiene}

Hygiene practices appear to be a much more important factor than water availability per se, though poor personal and community hygiene is often a consequence of limited access to water. Nose blowing and the use of a towel for face drying have shown a protective factor in at least one study,\textsuperscript{(91)} but, if used by several family members, the use of towels or handkerchiefs can enhance transmission.\textsuperscript{(165)} In the study by Taylor et al. \textsuperscript{(91)} the use of handkerchiefs for nose blowing and towels for face drying showed a protective effect with regard to trachoma. These results most likely reflect families with better hygiene practices overall.\textsuperscript{(45)} It should be noted that the sharing of towels and sleeping quarters and crowded living areas are also associated with an increased risk of trachoma.\textsuperscript{(166)}

One potential source of infection is nasal and ocular secretions, especially in children.\textsuperscript{(64,167)} Contact with pre-school aged children, who typically have the highest prevalence of infection, leads to an increased exposure and risk of trachoma.\textsuperscript{(90,104)} It is logical to assume that reducing secretions would also reduce the prevalence of trachoma, but the self-reported frequency and quality of washing can be biased, and in certain cases not reflect its real association.\textsuperscript{(79,87)} In the Tanzania study\textsuperscript{(91)} however, children having flies on the face and nasal discharge had a twofold increased risk of active trachoma compared with children who did not have these signs.\textsuperscript{(145)} Once again, it appears to be a matter of cleanliness and not washing that is important to reduce the likelihood of auto-reinfection or transmission of infection to others.\textsuperscript{(45)}

\subsection*{2.18.3 Crowding}

Evidence for the effect of crowding on the prevalence of trachoma is inconclusive. An early study by Dawson et al. \textsuperscript{(42)} reported a significant positive relationship between the number of people within a household and the prevalence of trachoma. Another early study also reported a positive correlation between the numbers of people per sleeping area and active trachoma prevalence,\textsuperscript{(168)} though did not show a significant relationship with the number of people living in the household. Ballard et al.\textsuperscript{(41)} did, however, suggest that there is a four-times greater likelihood of children having trachoma if there are more than nine people living in a household. A
A longitudinal study in a Gambian village showed that sharing a bedroom was a significant factor for the acquisition of trachoma, and an increasing trend in severity of the disease the greater the number of people in the same living space.\textsuperscript{99} An additional study found that children sharing a room with five or more people were nearly 1.5 times more likely to have trachoma (95\%, CI 1.03 – 1.75) as compared to those who shared a sleeping area with less than five people.\textsuperscript{146}

In contrast, an unpublished Australian study revealed a non-significant reduction in trachoma prevalence in association with a 15\% reduction in the number of people per household, though 15\% is a relatively small number.\textsuperscript{19} An additional study in Gambia showed a non-significant relationship between trachoma levels and the number of people sleeping in a room.\textsuperscript{85} Tielsch et al.\textsuperscript{79} investigated the effect of crowding on trachoma but found no significant association with the number of people sleeping in a room or living in a house. However, a strong association was found with the presence of siblings with trachoma living in the same household, with an odds ratio of 4.2 (95\%, CI 3.7-4.8). Thus it would seem logical to conclude that close physical contact with affected family members, as would happen in large families that have more preschool-aged children and share small sleeping areas, is more of a risk factor than having a large family per se\textsuperscript{101} or crowded housing facilities.

2.18.4 Flies

In trachoma-endemic areas, flies are frequently seen around the face and eyes of children, where they feed on mucus and discharge. Flies were one of the earliest risk factors noted for trachoma\textsuperscript{45} and their ability to act as physical vectors has been demonstrated in laboratory conditions.\textsuperscript{170} Moreover, very recently, the last of Barnett’s four criteria, modelled after Koch’s postulates,\textsuperscript{171} (criteria previously used to prove arthropods are disease-transmitting) have been fulfilled for the synanthropic fly, \textit{Musca sorbens}.\textsuperscript{172}

A study in The Gambia\textsuperscript{153} has shown a strong relationship between flies and the transmission of trachoma. In this study, fly control resulted in 75\% fewer new cases of trachoma in the intervention villages compared to the control villages. There was also a 61\% decrease in point prevalence of trachoma in the intervention villages, a comparable result to that of West’s study\textsuperscript{148} in Tanzania.

Although there has been some controversy as to the importance of the role of flies in the transmission and prevalence of trachoma, recent studies\textsuperscript{173,174} have clearly
shown that flies can be an important vector. The secretions of the eyes of infected persons contain the infective agent *C. trachomatis*. Emerson et al., using PCR techniques, identified *C. Trachomatis* on 2/395 flies (*Musca sorbens*) caught from the eyes of swab-positive children—suggesting that it is possible for wild-caught flies to act as vectors in the prevalence of trachoma.

A recent study examined whether there was a consistent relationship between fly populations and the presence of trachoma in three Aboriginal communities in North Western Australia. The study confirmed the presence of bush flies in the surveyed communities; peak fly numbers were consistent across the communities and were greatest in the wet season, the purported peak season for trachoma.

When the fly population density is reduced, at least when combined with concomitant antibiotic therapy, a reduction in the prevalence of active trachoma has been observed. Various studies have shown that ‘unclean environments’ (i.e., uncollected garbage or excreta) also foster the proliferation or attraction of flies. However, the methods used in studies that estimate the size of the fly population might be unreliable, and hyperendemic trachoma has been reported in communities with low fly densities and in the absence of flies.

While it is clear that flies have a role in the transmission of trachoma, there is nothing to suggest that they are likely to be the most important source of infection. It must be noted that even if flies are an important mode of transmission, they are not essential to the transmission or presence of trachoma.

### 2.18.5 Climate

A paradoxical effect exists between climate and the presence of trachoma: there is a notably greater prevalence in dry, arid climates, yet this does not account for the presence of trachoma in humid or tropical climates. Few studies, though, have examined the effect of seasonal variation associated with climate in regard to trachoma. In Nepal, a multivariate regression study demonstrated a 20% difference in the prevalence of trachoma (TF or TI) between spring and fall, with the highest prevalence found during spring. In northwestern Australia, one study conducted in three Aboriginal communities showed a significant increase in both trachoma and bush flies during the rainy season (summer) in two of the communities. The authors suggest that sustained rain causes an increase in the bush fly population, which is a suspected vector for *C. trachomatis*, and could be
responsible for the increase in trachoma prevalence. However, this was a small-scale study, with no rainfall data, and only two sampling points during the year, which might lead to an incomplete picture of events.

The inherent difficulty in analysing the unique effect of climate is the inability to control it. The effects of the climate are, however, abundant and strongly related to the availability of fresh water, the ability to maintain a hygienic living environment through adequate waste disposal, and the presence of flies, though the effect of flies is inconsistent and inadequately measured.

2.18.6 Cattle and Animals

Cattle herding, rather than the presence of cattle, seemed to be a risk factor in the Tanzanian study, though it is considered that rather than being causal it could be a marker for other socio-economic factors. Ownership of cattle is often a measure of wealth and might demonstrate a higher socio-economic status and better living standards and hygiene practices, whereas children that herd cattle live a more traditional way of life and might be part of the poorer groups in society. People who maintain a more traditional lifestyle also keep cattle close to the residential dwelling, attracting flies through the presence of dung. Most likely, it is the level of flies associated with the proximity of cattle dung to humans that will determine whether cattle are a risk factor.

The necessity for interventions addressing animal care would be determined by the assessment of their presence on a targeted community, how they are managed, and the role that they have in family and community life. While cattle are an important issue in African studies, they are irrelevant in studies of Aboriginal communities, as they are not closely associated with the economy or lifestyle of this particular population.

2.18.7 Waste and Garbage

Flies, particularly *M. sorbens*, are attracted by and breed in exposed human waste. Pit latrines, even when full and unscreened, have been shown to have a protective effect against trachoma in households in Egypt—studies in Australia, Malawi, and Ethiopia support this conclusion. In Tanzania, Taylor et al. found the presence of a latrine in a household reduced the risk of having severe trachoma infection. The presence of a latrine was also reported to be significant by five
studies that have investigated this parameter, with a median reduction of trachoma prevalence by 28%\textsuperscript{(181)}.

The presence and use of latrines might be a marker for families with better hygiene practices, as well as showing a diminished fly population around the house. The study in Egypt\textsuperscript{(44)} showed that the presence of a latrine indicated the presence of other measures of higher socio-economic status, including higher occupational status, more land, and ownership of more, large farm animals. The presence of functioning toilets was shown to be important in an Australian study, particularly when house populations were high, though the toilets were not always well accepted (i.e., used in preference to latrines)\textsuperscript{(88)}.

Appropriate management of animal waste might also have a positive effect on the reduction of the presence of flies. Cattle dung attracts flies. By reducing dung volumes through the use of dung beetles, fly levels can be reduced\textsuperscript{(173)}. Frequent collection of garbage also showed a median protective effect of 69% in two studies\textsuperscript{(87,166)}.

2.18.8 Dust

Trachoma is particularly common and severe in countries with hot, dry and dusty climates\textsuperscript{(157)}. Even though there appears to be an association between dusty environments and trachoma, there are few studies that specifically examine the impact of dust as a risk factor for trachoma. Salim and Sheikh\textsuperscript{(183)}, in their study of the prevalence and distribution of trachoma in Sudan, postulate that one of the factors explaining the high prevalence of trachoma in northern Sudan is irritation of eyes by dust particles. This leads to excessive watering and discharge, and consequent rubbing with the fingers. This is certainly a plausible explanation, but whether this is a significant factor—even in Australia—remains to be seen.

The 1976 ophthalmological survey\textsuperscript{(78)} in the Northern Territory of Australia analysed prevalence rates in Aboriginal communities in respect of a range of environmental conditions. The communities surveyed were grouped by criteria of locality, climate, and dwellings. The highest rates of prevalence were found in the communities located in areas where the climate was dry and dusty.
2.18.9 Smoke

Traditional cooking usually creates smoke in the room, which tends to reduce the number of flies. Sleeping next to a cooking fire produced a negative effect (odds of contracting trachoma) in two studies,\(^{(91,157)}\) whereas cooking in a central room had a protective effect in another.\(^{(166)}\) However, the use of a central room for cooking and sleeping might have influenced the results, because it suggests crowding, which also plays a role in the transmission of trachoma.

2.19 Conclusions Regarding the ‘F’ and ‘E’ Components of SAFE

Whilst there is good evidence that children with sustained clean faces are less likely to be at risk of trachoma, the results of an intervention based on the promotion of face washing show that on its own this had limited success.\(^{(148)}\) Other studies have shown that the presence of an adequate water supply is associated with a reduced community prevalence of active trachoma; however, this is only part of what is required and not the whole answer.\(^{(92)}\) Latrines appear to be associated with a lower prevalence of active trachoma, and the evidence that flies are vectors of trachoma has recently been strengthened by a pilot intervention study.\(^{(153)}\)

Although the studies discussed in this section provide evidence for specific tactics regarding trachoma control, they are insufficient by themselves when implementing the ‘F’ and ‘E’ components of the SAFE strategy. Rather, the evidence supports a combination of strategies and interventions. Interventions, which address garbage and waste disposal, fly density, the provision of good access to water, and functioning health facilities will help to reduce the transmission of Chlamydia infection in a community that is being administered an antibiotic.
CHAPTER 3
BACKGROUND

3.1 Anangu Pitjantjatjara Lands

There are nine major communities within the AP Lands. Historically, the AP land rights were only granted in 1991, and this is a problem as the lands are straddled over pre-existing state boundaries. The administering and owning authority is the Anangu Pitjantjatjara Council, with an office at Umuwa.

3.1.1 Location, geography, and climate

The Anangu Pitjantjatjara (AP) Lands are situated in the far northwest of South Australia (SA) (see Figure 3) and comprise 10,190,000 hectares of arid and semi-arid land. The AP Lands are an isolated geographical area, with the nearest regional centre (Alice Springs) being 750 kilometres away. Like the rest of the AP Lands, the study communities Pipalyatjara and Mimili are located in dry and dusty areas, classified as desert, where there are no permanent streams and where evaporation exceeds precipitation. They are located approximately 400 kilometres apart in remote areas in the northwest part of South Australia (Figure 3). The AP lands are an indigenous protected area with extraordinary biodiversity and play host to two threatened vertebrate species and one of the most diverse reptile species populations, many of which hold significant cultural importance.184
Figure 4 is an aerial shot of Pipalyatjara, taken early in the study: note the dry, dusty conditions. Figure 5 shows part of another community within the AP lands, and was taken shortly after a ‘hundred-year rainfall’ event; substantial greening has taken place.

Figure 4. Aerial shot of Pipalyatjara (typical dry, dusty conditions) (Courtesy NHC).

Figure 5. Aerial shot of another community in the AP lands after the ‘one-hundred-year’ rain event. (Courtesy NHC)
Rainfall in the region is low and unpredictable,\(^{(185)}\) with the wet season between December and February. The average annual rainfall is 275 mm (10.9 inches), with a monthly rainfall range of 0-380 mm (0-15 inches). Temperatures are higher than in southern regions, the average annual maximum temperature is about 27 °C and the average annual minimum temperature is 11.8 °C. Temperatures range greatly between 43.5 °C on summer days to -7.6 °C on winter nights.\(^{(186)}\) This dry, dusty desert climate has been associated with increased trachoma prevalence in previous studies.\(^{(78,182)}\)

### 3.1.2 Population

In 1999 the population of the AP Lands was 2,638\(^{(187)}\) (Figure 7), which is nearly...
double the 1985 population of 1,459 people. The population profile shows features of both a high growth rate and excess premature mortality.

The distribution is characteristic of that found in developing countries and contrasts sharply with that of the non-indigenous Australian population (Figure 8).

![Figure 8: Percentage indigenous and non-indigenous population by age at July 2001.](image)

Aboriginal people on AP Lands die much younger than the non-indigenous population; life expectancy has been estimated to be up to 19 years less compared to the non-indigenous population. Infant mortality and low birth weight is also quoted to be double that of other Australians. The four primary health conditions that account for the majority of indigenous deaths are cardiovascular, respiratory, and endocrine diseases and deaths due to injury or poisoning, these latter causes being most prevalent in young adults.

### 3.1.3 Communities

Studies have shown that there is a significant gap between the living standards of Indigenous and non-Indigenous Australians, in terms of disposable income, infrastructure, and service provision. The average income per person in the AP lands is estimated at AU $14,167—this is 47% lower than the average estimated
income across Australia and 25% lower than income received from government welfare per head of the population. The biggest employer in the AP Lands is the Community Development Employment Projects (CDEP) scheme, which employs some 850 paid workers in the region; this supplies the primary source of community income. Workers participating in the scheme forfeit their unemployment benefits for the opportunity to earn an income in return for working in their own community.

The CDEP is a major component of the Commonwealth Government Aboriginal Employment Development Policy (AEDP), which aims to achieve both employment and income equity between Aboriginal and non-Aboriginal Australians. Although the CEDP program has made a substantial difference with regard to income and living conditions for the Aboriginal communities located within the AP lands, it is still a long way from achieving its goals.

Low socio-economic status is associated with higher rates of communicable and chronic diseases. Previous studies have shown that communities with poorer living conditions and low levels of income have a higher prevalence of trachoma; both of these disadvantages are evident in AP communities.

3.1.4 Study settings

Most Aboriginal people in the Pipalyatjara (population: 359) and Mimili (population: 289) communities live in impoverished circumstances. Income is low, there are few employment opportunities, and although educational services are available, many children do not attend school regularly or stay in school long enough to achieve more than a basic education. Most families are in a situation in which they cannot afford to buy enough food and personal health items to maintain a healthy lifestyle, and instead are living a subsistence lifestyle.

The physical and living conditions are equally impoverished and not all members of the communities have access to even the most basic of housing. For those that do have houses, they are often poorly functioning and do not provide adequate health hardware or a healthy living environment. There are also difficulties in establishing adequate housing and health hardware, such as water supply and sewerage, and provision of health services. These circumstances are not dissimilar to those found in other remote, rural Aboriginal communities.

A recent assessment of the performance of critical healthy living practices in over 700 houses representing 20 communities from three states of Australia found that the
percentage of houses functioning over nine critical living practices assessed was poor. They varied from 3% (Improving nutrition: ability to store and prepare food) to 44% (Safety: structurally safe). Only 40% of houses were found to have power, water, and safety services connected and safe, with even less at 29% having working showers, and 37% possessing flush toilets that worked.

3.2 The Australian Health System

In Australia, both public and private suppliers deliver health services. Private health insurance is optional and receives a 30% subsidy from the Commonwealth government for those who purchase private health insurance. Medicare is the universal health insurance for all citizens and permanent residents administered by the government to provide health services. Health services covered by Medicare include inpatient and outpatient services in public hospitals, such as nursing care, optometry, and some specialized dentistry. Even though the health system provides good coverage, not all people are able to access the services they need, especially those in remote locations such as the AP Lands. A full range of services is not available in some regions, which requires referral to regional centres and extensive travelling time for patients. Associated with providing health services in remote locations are increased costs, and difficulties recruiting well-trained and qualified health-service providers. Also due to the comparatively high prevalence of chronic disease, the demand for health services is comparable to that of a much larger population.

The majority of funding for health-service provisions in the AP Lands comes from Commonwealth/Federal and State grants through the Nganampa Health Council. The primary sources of ongoing funding grants are the Commonwealth Department of Health and Aged Care, and the South Australian Department of Human Services; this accounts for 72% of income. Supplementary income is provided through government programs, private grants, and also some support from within the AP communities themselves.

3.3 Nganampa Health Council Inc.

The Nganampa Health Council (NHC) is an Anangu (Aboriginal-) controlled community health organisation, providing a range of programs to all people on the
Nganampa Health was formed in 1983, and is responsible for the provision of health services in the AP Lands. As the NHC is self-controlled, they internally prioritise the rationing of health funds based on the expressed needs of the Anangu people, to cover the various health and environment related programs.

There are six major health clinics across the AP Lands, one each in Mimili and Pipalyatjara, and an additional three health-worker stations in smaller communities. The mission of the NHC is to improve the health status of Anangu people and deliver a comprehensive primary health care service to residents of the AP Lands. NHC provides primary and some secondary health care services on the AP Lands, but specialist services are only available off the lands in urban centres.

The Ngangkari, traditional healers, are important members of the NHC team. Traditional views about the aetiology of illness, and appropriate means of treatment and care, are strongly held by many Anangu. Certain diseases and conditions, such as trachoma, are considered to be ‘associated’ with non-indigenous people and their lifestyles, and are therefore capable of being treated by non-indigenous medicines and methods. Other illnesses are considered best-treated using traditional indigenous methods. (185)

### 3.4 Regional Programs

The NHC provides a range of regional programs (189) to meet the needs of AP communities, such as delivering aged and disability care, dental programs, training for Anangu health workers, health promotion, immunisation, STD control, HIV prevention, and programs specifically for women’s health care.

Part of the Nganampa health strategy is also to promote and facilitate healthy living conditions and practices. A major program delivered across the AP Lands concerns public and environmental health, and is called Uwankara Palyanyku Kanyintjaku (UPK). (192) Its main goal is to prevent the spread of infectious diseases, by developing, implementing, and monitoring public health at both a regional and local community level, and promoting the linkage between good living conditions and low morbidity.

A prime focus is to improve housing and health hardware that includes showers, toilets, and washing machines. The other areas of the program address water and its...
harvest and storage, energy, dog health, regional stores, and the Eye Health Project. UPK is now used nationally and internationally as a model for improving environmental health in developing communities, and provides a framework for developments on the AP Lands. The guiding principles for program design include providing a healthy physical environment, promoting access to functioning health hardware, and increasing people’s capacity to access health hardware on an affordable, ongoing basis.\(^{192}\)

National guidelines for improving the living environment for safety, health, quality control, and sustainability were developed from the outcomes of the UPK. The National Indigenous Housing Guide, endorsed by the Aboriginal and Torres Strait Islander Commission (ATSIC), outlines the nine healthy living practices and is the official government framework for appropriate indigenous housing. ATSIC is Australia’s national policymaking and service delivery agency for Indigenous people, and is an independent statutory authority that embodies the principles of Indigenous self-determination.\(^{197}\) (Due to recent governmental policy changes, it seems likely that ATSIC will not survive, however.)

The nine healthy living practices of the National Indigenous Housing Guide are as follows\(^{195}\):

- Washing people
- Washing clothes and bedding
- Removing waste safely
- Improving nutrition
- Reducing crowding
- Reducing negative contact between people and animals, vermin or insects
- Reducing the negative impact of dust
- Controlling temperature of the living environment
- Reducing trauma around the house and living environment.
CHAPTER 4
MATERIALS AND METHODS

4.1 Study Design

The study was a longitudinal, population-based prevalence survey undertaken in the AP Lands of Central Australia, and conducted over a period of two-and-one-half years between March 1999 and September 2001. Two aboriginal communities were targeted for the survey: Pipalyatjara and Mimili. The communities were comparable in size, age, gender structure, and environment.

The Nganampa Health Council (NHC) has a population registry that is updated regularly to include all the names that an individual might be known by, gender, date of birth, Medicare number (Australian government health insurance scheme), and dwelling place of all the community residents.

Two main categories are used in this registry: ‘permanent residents’ are individuals that spend six months or more in a given community; individuals spending less than six months in a community are considered ‘visitors’. Individual residential status can change from year to year or as a result of the high mobility of the population between communities.

It has been documented by the NHC that mobility is a problem when attempting the follow-up of individuals and family units after an intervention. As a result, health initiatives are now undertaken on a community level rather than the individual level, which would be more normal in traditional public health. With this in mind, baseline data were collected during five separate visits over a 17-month period, to ensure that most people in the communities were reached. All registered residents of the communities were eligible for examination.

In order to reach a large proportion of the population and obtain increased coverage, people who were examined at the first five visits were considered part of the baseline examination in order to determine the prevalence and risk factors for trachoma.

The study protocol was approved by the Human Research and Ethics Committee of the Royal Victorian Eye and Ear Hospital (project # 99/366H), and by the community elders, as well as by an appointed committee of the NHC representing the Anangu people.
4.2 Study Settings

The two participating communities have already been described. However it is useful to say that since the NHC already had a wealth of environmental data and planned environmental interventions for Pipalyatjara, this community was selected as the intervention community where SAFE-related activities would take place. Mimili has a similar population composition as well as climate. It served as the control community, where only SAF-related activities were planned, as funding was not available for the E component to be implemented in this community at the time of the study. This enabled us to evaluate the impact of environmental interventions on the prevalence of trachoma.

4.3 Recruitment

At the beginning of the study, information sessions were conducted with the Aboriginal Health Workers (AHW) and residents in both communities. These sessions covered community strategies\(^2\) and primary health-care issues\(^3\) required for trachoma control. Authorization was then obtained from community elders and special interest groups to implement the study; ethical approval was also granted by the NHC. Based upon the information given, individuals had the choice to participate; therefore recruitment was by voluntary self-selection. Written consent was not obtained at an individual level, but consent was implied by choosing to participate, and by prior authorization of the community representatives. All residents in the community at the time of the examinations were eligible to participate in the study.

Examinations were conducted in the company of an AHW and often with a community nurse, in the school, clinic, store, and houses. Every effort was made to try to locate all the individuals in the population registry. These included, but were not limited to, securing special permission to examine people in a mourning camp (‘sorry’ camp) or driving hundreds of kilometres to neighbouring communities. When this was not possible, a note was made as to the cause of non-participation, e.g., patient in Darwin, in prison, refused examination, etc.

4.4 Surveys

A total of eight visits were conducted in order to collect field data in both communities. The months of March, June, and November 1999; and April and August
2000 constituted the baseline collection period. August 2000 was also the intervention visit in which azithromycin was distributed and when health promotion activities were initiated. A further three visits to collect post-intervention data were conducted in December 2000, and February and September 2001.

4.5 Examinations

Examinations recorded the presence of trachoma in each eye according to WHO recommendations and current grading scheme for trachoma, to include TF, TI, TS, TT, and CO (see Table 3). No subject was examined twice in one visit. The examination included the use of adequate lighting and binocular loupes. For the purpose of this thesis and in order to avoid the effects of any potential misclassification, particularly of TI in adults, an active case of trachoma was defined as having TF in either or both eyes. The author, a medical practitioner, conducted all examinations, and unlike many other examiners in published studies, was already a trained ophthalmologist with experience in developing settings, such as Mexico and Papua New Guinea, and familiar with the trachoma. In addition, the author received additional training by Prof. Hugh Taylor, a noted trachoma expert. Training was conducted through the use of slides and with actual patients in field settings.

During the length of the study, photos were taken of subjects, starting with visit 1, and the grading of trachoma from these photos also assessed by Prof Taylor in batches, the first session being conducted after visit 3. There was 100% agreement in grading for children < 15 years old (therefore a Kappa of 1). This was performed to monitor possible longitudinal drift, which was not detected for the children. More grading would have been conducted but for the fact that the camera and several rolls of film were mislaid. During visit 8, Prof. Taylor and the author conducted joint examinations in which 200 pairs of eyes were examined. After each had assessed a subject, the results were logged and assessments compared. With regard to masking, each examiner made a separate assessment for each subject that was recorded, though there was occasional discussion regarding assessments during the sessions after each of the gradings had been recorded. This could have resulted in a small amount of interobserver agreement bias.

Overall, the agreement was 94%, with all the disagreements centred on nine observations in adults who had TF or TI—i.e., complete agreement regarding children
The interobserver Kappa statistic for adults, for TF assessment was 0.81; for TI assessment it was 0.62.

Examinations also recorded a description of facial cleanliness. Absolute facial cleanliness was defined as the total absence of eye and nasal discharge. Partial facial cleanliness was defined as having either eye or nasal discharge, but not both. A dirty face had both eye and nasal discharge; the quality of discharge was also recorded as clear, abundant, or mucopurulent.

### 4.6 Training

Ms Cindy Cole, the principal NHC Health educator conducted a one-week training course for AHWs from the communities forming part of the AP Lands in March of 1999. This course was based on the so-called ‘blue book’ of the World Health Organization, as well as the ‘green’ book. The ‘green’ book includes information on the disease and its modes of infection, elements of the SAFE strategy, and how to identify if trachoma is a problem in the community. The ‘blue’ book teaches health care workers how to examine for and identify clinical symptoms of trachoma infection.

The aim of the course was to train AHWs in examination procedures and accurate classification of trachoma, as well as to aid in the development of culturally appropriate health-promotion tools. During the course, AHWs spent considerable time examining slides depicting the signs of trachoma and learned how to classify them accordingly. The course was considered to be a skills-transfer session that was separate from examinations conducted, and results gathered by, the author for his thesis work.

As a result of this course, the AHW and the NHC adopted the following simplified working definition of trachoma in order to help comprehension by indigenous people:

> Trachoma is an infectious disease, which can be spread from person to person by using or sharing towels by many people living together and when their face is dirty (runny nose and sticky eyes). This disease hurts your eyelids, causing scarring, and the eyelashes turn inward and scratch the eye. That is usually very painful and leaves a scar in the window of the eye (cornea) and this can make you blind.
This definition was created after the one-week course given by this author, and is based on the WHO ‘green’\(^{(2)}\) and ‘blue’\(^{(3)}\) books. The Pitjantjara translation is as follows:

\[
\]

One of the participants, Mrs. Jennifer Summerfield, a local artist and an Assistant Health Educator, created a painting that was used to produce posters as health promotion instruments;\(^{(5)}\) the painting was her own concept, and not initiated by the author, but fully supported by him (Figure 9).

![Figure 9: Trachoma painting.](image)

The painting can be described as follows: In the centre there is the shape of an eye. The pupil represents the instructor, while the iris represents Umwa, the administrative and training centre. The eyelashes represent the AHWs learning about trachoma and general eye health, while the footprints represent the AHWs going back to their communities—a flower shape in the four corners. The petals of these flowers represent members of the community surrounding the AHWs who now are talking to
them about trachoma and the ways to prevent it in their communities. The smaller red eyes represent blind and painful eyes, while the white dots signify follicles found in trachoma. The elongated thin ‘worm-like’ structures represent scarring tissue in various degrees in the tarsal conjunctiva. Finally, somewhat hidden towards the corners, are the acronyms TF, TI, TT, TS, and CO.

4.6.1 Radio messages

Discussions between the author and NHC personnel about encouraging community members to participate led to the concept of their producing a series of jingles broadcast on local radio to promote healthy living practices and to encourage members of the communities to go to the clinic for eye examinations. Two main themes, ‘To Stop Trachoma’ and ‘Trachoma Eye Doctor Visits’, were broadcast. These themes and their associated messages are listed below for interest, followed by their English translations.

To Stop Trachoma

*Rubbish bin nyuntumpa pati kanyinma.*
Keep your rubbish bins closed.

*Tjinguru nyuntu kuru pilki tjinguru kura pika, ara tjukaruru kilinikikutu.*
If you have sticky eyes or sore eyes, go to the clinic.

*Tjitji nyuntumpa yunpa kilina kanyinma rawangku.*
Keep your child’s face clean.

*Munu nyuntumpa yunpa kilina kanyinma tjinguru mungawinkinguru munu tjintu katu paltjinma, kapi tjupartjara.*
Keep your faces really clean with soap and water at least twice a day.

*Nyuntumpa tjitji mulya rawangku nyuulpungama.*
Blow your child’s nose frequently.

*Towela waltja waltjangku kanyinma. Towela nyuntumpa kilini kanyinma.*
Try to use one towel per person. Keep your towel clean.
Trachoma Kuru Dakata Visits

*Trachoma kuru dakata kunyu Pipalyatjara nyinaku, Monday August 28th-nguru, Friday 1st September-kutu. Ara kilinikikutu kuru nyakula palyantjaku.*

The Trachoma eye doctor will be in Pipalyatjara from Monday August 28th to Friday 1st September. Go to the clinic to have your eyes examined and treated.

*Trachoma kuru dakata kunyu Mimilila nyinaku, Monday September 4th-nguru, Friday September 8th-kutu. Ara kilinikikutu kuru nyakula palyantjaku.*

The Trachoma eye doctor will be in Mimili from Monday September 4th to Friday 8th September. Go to the clinic to have your eyes examined and treated.

4.7 Health Intervention

A registry of all the cases requiring corrective surgery was kept to immediately refer urgent cases to a regional hospital to have the WHO recommended corrective lid surgery, as per current best practice NHC guidelines and the Australian health system. This registry was kept by the NHC clinic and there was discussion of the referred cases between the author and the treating ophthalmologist in Alice Springs.

On the final visit of the baseline data collection, antibiotics were distributed to treat all the individuals in the population registry of the study communities who were present. The antibiotics were administered by the author and a trained health worker. The antibiotic of choice was azithromycin, which has several advantages: it is used as a single dose (20 mg/kg); its efficacy and safety have been proven even in the paediatric population; and it is safe to use in pregnancy. It also eliminates the compliance problem associated with other systemic or topical antibiotics, and is the ideal tool to break the cycle of intra-family re-infection as the most important factor to prevent scarring. It should be noted that azithromycin is available for remote areas through special arrangements under the Pharmaceutical Benefits Scheme (PBS).

The extent of azithromycin treatment is primarily dictated by trachoma prevalence in the community. The options are for individual treatment, family treatment, household treatment, or community-wide treatment. In this case, the whole community was treated due to the high prevalence level, small community size, and expected cost effectiveness.
After the baseline data collection, an active Health Education Campaign was instituted with emphasis on a Facial Cleanliness campaign in schools, the program being primarily facilitated by teachers and personnel from the NHC. It was targeted at the entire community, but more specifically at school children, as they are at higher risk of developing trachoma. The campaign included a drawing designed by the teachers depicting a child washing in a bathtub—this was intended to encourage the children to bathe before coming to school. The impact of the campaign was evaluated through interviews with the teachers and community to assess change in knowledge about trachoma and prevention of disease transmission.

One of the tools used was the *Uwankara Palyanku Kanyintjaku* (A strategy for well-being) video and audiotape. The theme song of *Uwankara Palyanku Kanyitjaku* urges children to jump into the shower, and the lyrics are as follows:

Mungawinkin Mulapa  
Wari Pulka Tjitji Tjuta Pakani, Pakani, Pakani  
Soapa Towela Shampoo Kulu Kulu Mantjira  
Shower Block La-Kutu Ananyi  
(Chorus)  
Kapia Ala La  
Wari Waru Tap Kutjara Ngaranyi  
Tjitji Kapingka Kuwari Tjapara  
Inma Nyangatja Inkanyi.  

The English translation is:

Early in the morning  
Really cold time  
All the kids get up, get up, get up  
Grab the soap, towel, and shampoo  
And go to the shower block  
(Chorus)  
Turn on the water  
Hot water and cold water taps are there  
All the kids jump into the shower  
Singing this song.
Radio clips and storyboards were also developed in conjunction with the NHC as further strategies of health promotion, as described above. In addition to promoting healthy practices among those attending the health clinic for any other reason, the AHWs conducted the health education campaign at a home level.

Monitoring of the health program was conducted by a variety of individuals. The author kept in personal touch with the radio station manager to assure that the suggested broadcast frequency of the messages was being carried out, and he also interviewed teachers and nurses as a crosscheck. In addition, a Health Council worker checked that the radio messages were broadcast for the four-month period that was requested. In the schools, the teachers checked attendance lists, and reported how often children used the shower block song and video. Clinic workers reported how often information sessions occurred with the painting. No hard data was generated to specifically monitor the health program, but this author would ‘keep a pulse’ by spending time with the health workers on every visit to gauge whether the program was running smoothly, and that participants were aware of various aspects of the intervention.

4.8 Environmental Intervention

The environmental intervention consisted of road sealing; demolition of poorly built or maintained houses during the implementation phase of the project, with appropriately designed houses to be erected; rubbish collection twice a week; repairing of water-heating and air-conditioning systems; upgrades in the sewerage system; upgrades in the water lines introduced in the community and installation of rainwater tanks; all house yard fences to be bordering the roads instead of just the immediate perimeter; planting of trees, grass, and various other native plants in areas where wind and dust are prevalent; earthworks and diversions to create micro catchments and water ponding; and installing drinking-water fountains in the school and health clinic.

The road sealing process (primarily for the verges on the sides of the roads) was intended to reduce atmospheric dust levels raised by the passage of vehicles, as was much of the landscaping. Another function of the landscaping was to improve drainage, reduce flooding, and prevent generation of stagnant pools of water—much
of the precipitation tends to be sudden and heavy, depending on the season. In addition, the planting of trees and shrubs absorbs much of the rainfall that would either evaporate or pool.

Better provision of fresh water and disposal of sewage were major targets in the upgrading of the houses, as was improvement in the hot/cold water systems, and environmental controls. For the intervention to succeed, the upgrading was considered important, but even more critical was the maintenance of such systems. The latter has been noted as problem in much Aboriginal community housing.

Provision of water is a major problem in the AP lands, as many of the aquifers are being depleted from over-excessive use of the existing bores. A portion of the environmental intervention was devoted to catching more rainfall runoff and utilising it within the community. It should be noted that water drawn from bores is heavily laden with minerals, and is one of the reasons why plumbing fixtures (for example, shower heads), become easily clogged.

Figure 10 shows the earthwork construction (to prevent vehicles being driven into dusty areas and to improve drainage); Figure 11 the planting of trees.

Figure 10. Earthwork construction (courtesy NHC).

Figure 11. Planting trees (courtesy NHC).
Figure 12 shows the final result: yard fences, earthwork, and landscaping.

All these measures were intended to reduce the dust and fly population, as well as to promote appropriate water use and disposal. Unless otherwise stated, all were conducted, monitored, and evaluated by NHC and Health Habitat. Monitoring occurred on a monthly basis. The results were provided by these organisations.

The effects of these measures were inferred by comparing the prevalence of trachoma between Pipalyatjara and Mimili, where only SAF was implemented. In Mimili, due to financial constraints, no environmental interventions were scheduled to take place within the two-year time frame of this study apart from the already existing water supply. However, the SAF components of the strategy were implemented.

Prior to the environmental intervention, 16 houses in Pipalyatjara were earmarked for upgrades in various areas related to the previously mentioned nine healthy living practices. Of the nine healthy living practices, five have been identified as critical for health, namely safety (utilities, electricity, structure, and hot water); washing people (showering and washing young children); washing clothing and bedding (laundry services); removing waste safely (flush toilet; all other areas); and improving nutrition (storage, preparation, and cooking of food).

4.9 Cost of the Interventions

It is hard to break down the component costs of SAFE, because general costs covered administration, some health costs, consultant costs, but some approximations can be made. The interventions cost Australian $475,000 (US$ 625,000). In addition, state and local governments contributed Australian $1.2 million (US$ 1.6 million) to
cover such environmental improvements as landscaping, road sealing, and improvements to community housing. The surgery costs for the intervention were estimated at approximately $4,000-5,000 (US$ 5,260-6,580) for four individuals. The national government paid $25 (US$ 33) per dose of azithromycin, which does not count logistical and administrative costs. If these are included, the total cost for the antibiotics component was approximately Australian $20,000-$25,000 (US$ 26,300-33,000). The cost of the F component is difficult to estimate, but is probably not more expensive than the antibiotic component, leaving the E component as by far the most expensive to implement.

4.10 Data Collection

Data collected during the study period included information regarding critical healthy living practices, climatic parameters, and characteristics/risk factors for trachoma. Each of the critical healthy living practices was given an absolute score (pass/fail) by measuring various components that are listed in Appendix 1. The four remaining healthy living practices which are reducing crowding, reducing the negative effects of dust, temperature control, and separating people from animals, vermin, and insects, were also measured by an absolute score (Appendix 2).

Flytraps were constructed to collect flies over 6-weekly periods using dung as an attractant, to establish fly counts over a period of one year. The teachers at Pipalyatjara were responsible for maintenance of the traps and sending the packages to Dr. Ian Dadour at Perth for counting and determination of viable Chlamydia species associated with the flies. Figures 13 and 14 show the design and typical placement of the flytraps.

Figures 13 and 14. Flytrap (above) and placement in the field (right) (courtesy NHC).
Climatic parameters, such as temperature, humidity, and road traffic, were recorded daily. A weather station located onsite collected weather information, including rainfall (Figure 15). Dust monitors were checked monthly.

Figure 15. Weather station (courtesy NHC).

Traffic was continuously measured by two computerised counters strategically located in the main road of access to the community to determine potential seasonal effects that might be associated with trachoma prevalence (Figure 16).

Figure 16. Road counter (courtesy NHC).

High traffic volumes can potentially generate high dust levels, which might be associated with increased eye irritation and microtrauma by dust particles, and
excessive rubbing of eyes. The data were collected fortnightly by NHC using dust monitors. Figure 17 shows a dust monitor; Figure 18 its placement in the field.

![Dust monitor](image1.png)  ![Dust monitor in the field](image2.png)

Figure 17. Dust monitor.  Figure 18. Dust monitor in the field.
(Both courtesy NHC.)

Dust analysis was to be performed by Dr. Scott Buckingham, a biochemist with Rio Tinto.

Of the information collected at each visit, many were characteristics of and potential risk factors for trachoma. They were features of the community and the individuals assessed.
Table 4 lists and defines the variables examined.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Definition and code (where applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1 = Male, 2 = Female</td>
</tr>
<tr>
<td>Residential community Pipalyatjara/Mimili</td>
<td>Permanent residential community at time of visit, from population register 1 = Pipalyatjara, 2 = Mimili</td>
</tr>
<tr>
<td>Status Permanent/visitor</td>
<td>Residential status in community at time of visit, 1 = permanent, 2 = visitor</td>
</tr>
<tr>
<td>Examined</td>
<td>Examined at time of visit, 1 = yes, 0 = no</td>
</tr>
<tr>
<td>TF in right or left eye</td>
<td>Presence of TF 1 = yes, 0 = no</td>
</tr>
<tr>
<td>TI in right or left eye</td>
<td>Presence of TI 1 = yes, 0 = no</td>
</tr>
<tr>
<td>TS in right or left eye</td>
<td>Presence of TS 1 = yes, 0 = no</td>
</tr>
<tr>
<td>TT in right or left eye</td>
<td>Presence of TT 1 = yes, 0 = no</td>
</tr>
<tr>
<td>CO in right or left eye</td>
<td>Presence of CO 1 = yes, 0 = no</td>
</tr>
<tr>
<td>Facial cleanliness</td>
<td>Defined by absolute, partial or dirty face (see section 4.5), 1 = yes, 0 = no</td>
</tr>
<tr>
<td>Nasal discharge</td>
<td>Presence of nasal discharge, 0 = none, 1 = clear, 2 = abundant, 3 = muco-purulent</td>
</tr>
<tr>
<td>Azithromycin administered at time of examination.</td>
<td>1 = yes, 0 = no</td>
</tr>
</tbody>
</table>

Table 4. Characteristics and risk factors for trachoma

4.11 Data Coding and Description

A database was created using all the known names for an individual, as occasionally, due to the death of a person of the community, the given name might become ‘kumana’, or a forbidden name. Hence, the individual might have on occasion as many as four or more names, especially in cases where English and Pitjantjatjara names were used. A unique identification number of five digits previously assigned by the Nganampa Health Council was used for each individual. The original data were locked in a cabinet at the university department in order to ensure confidentiality.

4.12 Statistical Methods

Data were initially recorded manually. Data were then entered and managed using Microsoft Access for Office 2000®. Double-data entry was conducted and
comparisons made between data sets for inconsistencies. Statistical analysis was performed using SPSS Ver 11®. Graphs and tables were constructed using Microsoft Excel for Office 2000®.

In order to obtain a good proportion of the population and increased coverage, people who were examined during any of the first five visits were considered as baseline examination in order to determine the prevalence of trachoma. No examination was conducted in Mimili during the second visit. It was considered culturally inappropriate due to the death of a prominent elder of the community in which the entire population was sequestered in a mourning camp. Thus, the first four visits were considered as the baseline examination. The presence of a particular variable was coded as 1 if present and 0 if absent. Whether an individual had a given disease parameter at baseline was calculated initially on a probability basis by the sum presence of the disease parameter in all baseline visits divided by the total number of examinations that a particular individual had. This led to fractional probabilities sometimes, and was corrected using the following rule: if \( p < 0.5 \), \( p = 0 \); if \( p \geq 0.5 \), \( p = 1 \). The baseline prevalence for each parameter in each group was then estimated by calculating the average, using all individuals included in each study group.

To ensure that this method of estimating prevalence was sound, because the percentage of individuals examined varied with each visit, the prevalence was also estimated based on the worst grade among the baseline visits for all individuals, the grade at the time of first examination among the baseline visits, and using a random selection algorithm. In addition, a sensitivity analysis was conducted by removing the September 2000 data, since the trachoma prevalence for this visit seemed low for both communities.

Chi-square analyses were used to assess the significance of relationships between categorical variables, while two-sided t-tests were used to assess differences in mean values. Odds ratios (OR) were calculated using logistic regression models. Confidence limits of 95 percent for the prevalence rates and odds ratios were also presented. \( p < 0.05 \) was considered to be statistically significant.

Even though it was originally thought that clustering was not a significant factor, risk factors and important prevalence data was adjusted for this factor using the GEE approach (Generalized Estimating Equations),\(^{199}\) which is appropriate for longitudinal studies containing unbalanced data—non-equal time intervals. GEE model (PROC GENMOD in SAS 9.1) was used included adjustments for a potential
design effect, the presence of multiple children from the same household in the dataset.
CHAPTER 5

RESULTS

5.1 Demographics

A total of 700 people were registered by the NHC for the study during the study period, 385 (55%) in Pipalyatjara and 315 (45%) in Mimili (see section 5.2 for explanation of differences vis-à-vis population registry). Of these, 330 (47%) were male and 370 (53%) were female. The median age was 19 years (mean = 22 years; range = birth to 89 years). There was no significant difference in age (p = 0.76; Mann-Whitney U-test) or gender (chi-square = 0.98; p = 0.32) distribution between the two communities (Table 5).

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (n = 175)</td>
<td>Female (n = 210)</td>
</tr>
<tr>
<td>&lt; 1</td>
<td>14 (8%)</td>
<td>12 (6%)</td>
</tr>
<tr>
<td>1-9</td>
<td>34 (19%)</td>
<td>55 (26%)</td>
</tr>
<tr>
<td>10-14</td>
<td>22 (13%)</td>
<td>18 (9%)</td>
</tr>
<tr>
<td>15-24</td>
<td>25 (14%)</td>
<td>47 (22%)</td>
</tr>
<tr>
<td>25-34</td>
<td>36 (21%)</td>
<td>35 (17%)</td>
</tr>
<tr>
<td>35-44</td>
<td>15 (9%)</td>
<td>17 (8%)</td>
</tr>
<tr>
<td>45-54</td>
<td>14 (8%)</td>
<td>13 (6%)</td>
</tr>
<tr>
<td>55-64</td>
<td>7 (4%)</td>
<td>7 (3%)</td>
</tr>
<tr>
<td>65+</td>
<td>8 (5%)</td>
<td>6 (3%)</td>
</tr>
</tbody>
</table>

Table 5. Age and gender distribution

In Pipalyatjara, 175 (45.5%) were male and 210 (54.5%) were female, while in Mimili, 155 (49.2%) were male and 160 (50.8%) were female. Forty percent (155/385) of those registered in the study at Pipalyatjara were less than 15 years of age, while in Mimili 43% (134/315) were under 15 years of age (Table 5).

There were 41 extended families in Pipalyatjara and 36 in Mimili. The number of family subunits varied from 1 to 8 (median = 1; mean = 2). Each family unit varied in the number of individuals registered, ranging from 1 to 55, with a median of 6 (mean = 9). There were 35 households in Pipalyatjara and 29 in Mimili. The number of individuals registered in each house ranged from 1 to 41 with a median of 8 (mean = 11). (The high end of the range might seem very excessive, and indeed it is, but only
represents a theoretical maximum. On a typical evening, one might find about a quarter as many people. However, on some occasions, one can find that high number of people in a house, especially if visitors or extended family are present.) The average number of registered children aged less than 15 years per household ranged from 1 to 18 (median = 6).

5.2 Mobility

As indicated in Chapter 3, these communities have a previously well-documented high mobility pattern, which is clearly depicted in Figures 19 and 20.

![Figure 19. Population mobility profile of Pipalyatjara.](image-url)
Figure 20. Population mobility profile of Mimili.
Pipalyatjara had a changing pattern of population registered across all visits (Figure 19), while Mimili had a more stable population represented by the proportion of permanent residents and visitors to the community, as well as the change in classification of various individuals in this particular category (Figure 20).

In Pipalyatjara, there were initially 279 permanent resident and 68 visitors, whilst in Mimili the ratio was 247 to 5. At the end of the study, in Pipalyatjara there were 215 permanent residents and 32 visitors, compared to Mimili, where there were 255 and 8 respectively. The reduction in permanent residents at Pipalyatjara was mainly due to residents moving to other communities and deaths.

The NHC regularly updated the population registry, which accounted for two major ‘movement’ episodes during the study period. In visit number 3, 147 (52.5%) people in Pipalyatjara officially left the community, either by death, or because they had moved to a different community, compared to only 53 (21.4%) people in Mimili. In visit 7, there were 85 new arrivals in Pipalyatjara, compared to only 11 in Mimili. However, even between these major population registry updates, other changes in the registry occurred: in the permanent resident registry category in Pipalyatjara there was 1 arrival in each of visits 2 and 3, 2 in each of visits 4 and 5, and 9 in visit 8. In Mimili, there was 1 arrival in visit 3, 8 in visit 4, 31 in visit 5, 5 in visit 6 and 29 in visit 8. In Pipalyatjara there were 2 departures in visit 5 and 14 in visit 6.

5.3 Examination Rate

Based on the information provided by the resident Aboriginal health workers, the participation rate for those available for examination was extremely high in both communities, ranging from 98 to 99% in all age groups. The overall refusal rate among those available participants for examination was 2%.

Of the 700 registered people, 105 (15%) people never had an examination during the study period. The age group that was most affected was the 15-45 years group, followed by the group older than 45 years. One hundred and fourteen people (16%) had only one examination; 99 (14%) people had two examinations; 97 (14%) people had three examinations and 285 (41%) people had four or more examinations (Table 6).
<table>
<thead>
<tr>
<th>Number of times examined</th>
<th>Pipalyatjara (n = 385)</th>
<th>Mimili (n = 315)</th>
<th>Total (n = 700)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not examined in any visit</td>
<td>60 (16%)</td>
<td>45 (14%)</td>
<td>105 (15%)</td>
</tr>
<tr>
<td>Examined in 1 visit</td>
<td>62 (16%)</td>
<td>52 (17%)</td>
<td>114 (16%)</td>
</tr>
<tr>
<td>Examined in 2 visits</td>
<td>68 (18%)</td>
<td>31 (10%)</td>
<td>99 (14%)</td>
</tr>
<tr>
<td>Examined in 3 visits</td>
<td>59 (15%)</td>
<td>38 (12%)</td>
<td>97 (14%)</td>
</tr>
<tr>
<td>Examined in 4 visits</td>
<td>47 (12%)</td>
<td>35 (11%)</td>
<td>82 (12%)</td>
</tr>
<tr>
<td>Examined in 5 visits</td>
<td>34 (9%)</td>
<td>40 (13%)</td>
<td>74 (11%)</td>
</tr>
<tr>
<td>Examined in 6 visits</td>
<td>40 (10%)</td>
<td>41 (13%)</td>
<td>81 (12%)</td>
</tr>
<tr>
<td>Examined in 7 visits</td>
<td>12 (3%)</td>
<td>33 (11%)</td>
<td>45 (6%)</td>
</tr>
<tr>
<td>Examined in 8 visits</td>
<td>3 (1%)</td>
<td>-</td>
<td>3 (0.4%)</td>
</tr>
</tbody>
</table>

Table 6: Examination rates in Pipalyatjara and Mimili.

The average number of examinations per person was 3 (median = 3; SD = 2.2; range 0 to 8). Of those examined on four or more visits, 47% were less than 15 years of age. Although there were only seven examinations conducted in Mimili compared to eight examinations in Pipalyatjara, the mean number of examinations per person was higher in Mimili (mean = 3.3, SD = 2.3; range: 0 to 7 examinations) when compared with Pipalyatjara (mean = 2.8; SD = 2.1; range: 0 to 8 examinations). This difference was statistically significant (p = 0.005; Mann-Whitney U-test), but probably has no clinical significance regarding the reporting of trachoma prevalence.

When comparing people who had at least one examination with those who never had an examination, there was no statistically significant difference in age observed (Mann-Whitney U test, p = 0.67), gender (chi-square = 0.91, p = 0.34), or between communities (chi-square = 0.23, p = 0.63).

A further indicator of high mobility is the overall examination rate. At any given visit, a significant number of people were not available for examination (never less than 29% available for exam; maximum of 79% available for exam). Although classified as permanent residents, these would be away for short or long periods of time for reasons such as health, education, family, etc. The average examination rate
of all community residents during the visits of this study was 49%, ranging from 28% to 69%. The average examination rate in Mimili (61%; range 44% to 71%) was higher when compared with Pipalyatjara (43%; range 21% to 71%) (Tables 7 and 8).

<table>
<thead>
<tr>
<th>Visits</th>
<th>Total</th>
<th>Age &lt; 15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Registered</td>
<td>No. Examined</td>
</tr>
<tr>
<td>Visit 1</td>
<td>348</td>
<td>74 (21%)</td>
</tr>
<tr>
<td>Visit 2</td>
<td>349</td>
<td>97 (28%)</td>
</tr>
<tr>
<td>Visit 3</td>
<td>351</td>
<td>157 (45%)</td>
</tr>
<tr>
<td>Visit 4</td>
<td>166</td>
<td>59 (36%)</td>
</tr>
<tr>
<td>Visit 5</td>
<td>167</td>
<td>90 (54%)</td>
</tr>
<tr>
<td>Visit 6</td>
<td>167</td>
<td>86 (52%)</td>
</tr>
<tr>
<td>Visit 7</td>
<td>236</td>
<td>83 (35%)</td>
</tr>
<tr>
<td>Visit 8</td>
<td>247</td>
<td>176 (71%)</td>
</tr>
</tbody>
</table>

Table 7. Examination rates in Pipalyatjara

<table>
<thead>
<tr>
<th>Visits</th>
<th>Total</th>
<th>Age &lt; 15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. Registered</td>
<td>No. Examined</td>
</tr>
<tr>
<td>Visit 1</td>
<td>252</td>
<td>123 (49%)</td>
</tr>
<tr>
<td>Visit 2</td>
<td>252</td>
<td>0</td>
</tr>
<tr>
<td>Visit 3</td>
<td>253</td>
<td>169 (67%)</td>
</tr>
<tr>
<td>Visit 4</td>
<td>207</td>
<td>91 (44%)</td>
</tr>
<tr>
<td>Visit 5</td>
<td>236</td>
<td>168 (71%)</td>
</tr>
<tr>
<td>Visit 6</td>
<td>240</td>
<td>155 (65%)</td>
</tr>
<tr>
<td>Visit 7</td>
<td>231</td>
<td>145 (63%)</td>
</tr>
<tr>
<td>Visit 8</td>
<td>263</td>
<td>174 (66%)</td>
</tr>
</tbody>
</table>

Table 8. Examination rates in Mimili.
This difference was statistically significant ($p = 0.03$).

There was no examination conducted in visit 2 in Mimili, as it was considered culturally inappropriate due to the death of a prominent elder of the community in which the entire population was sequestered in a ‘sorry’ or mourning camp.

Examination rates varied widely between age groups on every visit, with those less than 15 years of age and those 45 years of age or over more likely to be available for examination (see Figures 21a and b).

![Figures 21a and b. Examination rate by age.](image)

As seen in Figures 22 and b, the examination rate for those under 15 years of age was similar across the seven visits in Mimili (mean = 74%), while in Pipalyatjara, there was a more variable examination rate (mean = 50%) in the same age group, reflecting the nature of the mobile population registry, as none of the eight visits were conducted during school holidays, football tournaments, or other events when a significant proportion of the population might be expected to be away.

![Figures 22 a and b. Examination rates by visit for children less than 15 years of age](image)
Of the 700 people registered in this study, 289 (41%) were less than 15 years of age (40% in Pipalyatjara and 43% in Mimili). Of those children younger than 15 years of age, only 9% never had an examination in any of the visits when compared with 16% in those aged 15 years or older. Also, of those children younger than 15 years of age, 53% had four or more examinations compared with only 36% in people aged 15 years or older.

The average examination rate for children younger than 15 years of age (median = 4; range 0 to 8 examinations) was significantly higher than for those people aged 15 years or older (median = 3, range = 0 to 7 examinations; p < 0.001, Mann Whitney U test). Because of the higher examination rate and because they account for 42% of the permanent residents (40.5% in Pipalyatjara and 43% in Mimili), only children younger than 15 years of age were included in the analyses. This also reflects the nature of the trachoma diseases as reported in the literature, where the burden of active trachoma is usually found in children.

Of those less than 15 years of age, 42 (15%) were visitors and were excluded from the analysis. Of the remaining 247, 119 (48%) were registered in Pipalyatjara, and 128 (52%) were registered in Mimili. Of these, 177 (72%) children had at least one examination at baseline; 86 (49%) from Pipalyatjara, and 91 (51%) from Mimili.

The mean examination rate for those aged 45 years and older was 52% (range 27% to 74%). The people least likely to be available for examination were those between 25 and 44 years of age (mean = 43%; range 16% to 70%).
The examination rate for permanent residents in both communities was higher across all age groups when compared with the total population (Figures 23a and b), which includes visitors.

It also varied from visit to visit. In Mimili, both permanent residents and the total population had almost identical examination rates as there were only a few visitors registered, while Pipalyatjara exhibited more variable examination rates between both categories, as there were more visitors registered.

In Pipalyatjara, the examination rate varied in each visit between genders, but these differences were not statistically significant (p=0.83): the examination rate of males ranged from 48% to 90% with a median of 56%, while in females, it ranged from 35% to 100% with a median of 62% (Figures 24a and b).
In Mimili there were no differences observed in examination rates between genders, with males ranging from 75% to 79% (median: 77%) and females ranging from 68% to 85% (median: 81%).

5.4 Risk Factors

5.4.1 Facial cleanliness

The overall prevalence of an absolutely or partially clean face was 39% (95% CI: 34%, 44%) in children under 15 years of age, while children aged 10 years or older had a higher likelihood (OR: 1.2; 95% CI: 1.07, 1.3) of having an absolutely or partially clean face compared with children less than 10 years of age (see Table 9).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. at risk</td>
<td>Prevalence</td>
<td>No. at risk</td>
<td>Prevalence</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>17% (1)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>33% (1)</td>
<td>3</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>32% (8)</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>35% (9)</td>
<td>36</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>16</td>
<td>50% (8)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>40% (4)</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>36% (17)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>36% (14)</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>36% (31)</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 9. Prevalence of an absolutely/partially clean face in children at baseline exam

This difference was statistically significant. There was no significant difference in the prevalence of an absolutely or partially clean face between genders (OR: 1.02; 95% CI: 0.92, 1.1). The prevalence of an absolutely or partially clean face in children was 36% (95% CI: 28%, 44%) in Pipalyatjara, and 42% (95% CI: 36%, 48%) in Mimili. This difference was not statistically significant (OR: 1.1; 95% CI: 0.96, 1.2).
The overall prevalence of an absolutely clean face was 27% (95% CI: 22%, 31%) in children under 15 years of age (Table 10).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. at risk</td>
<td>Prevalence</td>
<td>No. at risk</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>17% (1)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>33% (1)</td>
<td>3</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>16% (4)</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>30% (8)</td>
<td>36</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>16</td>
<td>50% (8)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>40% (4)</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>28% (13)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>33% (13)</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>30% (26)</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 10. Prevalence of an absolutely clean face in children at baseline examination

Children aged 10 years or older had a significantly higher rate of an absolutely clean face when compared with children less than 10 years of age (OR: 1.3; 95% CI: 1.2, 1.4). No significant difference in the prevalence of an absolutely clean face was observed among genders (OR: 1.0; 95% CI: 0.93, 1.1). The prevalence of an absolutely clean face in Pipalyatjara was 30% (95% CI: 23%, 37%) and 23% (95% CI: 18%, 28%) in Mimili, but this difference was not statistically significant (OR: 1.1; 95% CI: 0.98, 1.2).
The prevalence of facial cleanliness was associated with age (Figure 25).

![Bar chart showing facial cleanliness by age group]

Figure 25. Baseline prevalence of facial cleanliness by age.

Children aged 1 to 9 years had higher risk of having a dirty face when compared with children less than one year old, and with children 10 years of age and older. Only 33% of children aged 1 to 9 years had an absolutely or partially clean face when compared with 42% in those aged less than one year, and 51% in those 10 years of age or older.

5.4.2 Nasal discharge

Of the 177 children included in this analysis, 68% (95% CI: 63%, 72%) had some degree of nasal discharge at baseline examination; 20% (95% CI: 15%, 25%) of children had clear discharge; 41% (95% CI: 35%, 46%) had abundant discharge; and 7% (95% CI: 4%, 10%) had mucopurulent discharge.

The overall prevalence of abundant or mucopurulent discharge in this study population was 48% (95% CI: 43%, 53%) (Table 11).
<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clear</td>
<td>Abundant</td>
<td>Muco-purulent</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>0% (0)</td>
<td>67% (4)</td>
<td>0% (0)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0% (0)</td>
<td>33% (1)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>28% (7)</td>
<td>28% (7)</td>
<td>24% (6)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12% (3)</td>
<td>38% (10)</td>
<td>12% (3)</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>6% (1)</td>
<td>38% (6)</td>
<td>0% (0)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10% (1)</td>
<td>40% (4)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>17% (8)</td>
<td>36% (17)</td>
<td>13% (6)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10% (4)</td>
<td>38% (15)</td>
<td>8% (3)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>14% (12)</td>
<td>37% (32)</td>
<td>10% (9)</td>
</tr>
</tbody>
</table>

Table 11. Prevalence of nasal discharge in children at baseline examination
Children under 10 years of age had a small but significantly higher risk of having any degree of nasal discharge (OR: 1.3; 1.1, 1.4) and also mucopurulent discharge (OR: 1.1; 95% CI: 1.04, 1.2) when compared with children 10 years of age or older. No statistically significant difference was observed in the prevalence of degree of nasal discharge between genders (OR: 1.03; 95% CI: 0.94, 1.1). There was a significantly higher prevalence of any degree of nasal discharge observed in children living in Mimili when compared with children living in Pipalyatjara (OR: 1.14; 95% CI: 1.04, 1.3) (Table 11).

Presence of nasal discharge was significantly associated with age. The prevalence of nasal discharge was higher in children aged less than 10 years, compared with children 10 years of age and older.

Of the 177 children included at the baseline analysis, 12% of children aged 1 to 9 years had mucopurulent discharge compared to none of the children less than one year of age or aged 10 years or older (Figure 26).

![Figure 26. Prevalence of nasal discharge by age](image-url)

### 5.5 Prevalence of Active Trachoma

As stated in chapter 3, the highest burden of active trachoma prevalence is generally found in children less than 10 years of age. Later on in life it is mostly in females due to their traditional role as caretakers, whilst male children beyond that
age generally have a much lower prevalence of active trachoma and consequently secondary complications. However, some studies have found that in Aboriginal communities this trend is not as strong, as male children stay at home for longer periods and for more years, as there is no traditional farming or other activities to take them away. It has also been seen that long-term complications have similar prevalence rates between genders in Aboriginal communities.

For this reason, we investigated the age-specific prevalence of TF to determine a cut-off point in which we determined that this prevalence significantly drops and to investigate any significant difference between genders. Although many studies are reported in the literature with TF or TI denoting active trachoma prevalence, we chose to report active trachoma as TF only, because the prevalence of trachoma is very high, small numbers of those individuals with TI can have spurious effects when added to the TF results (see Discussion), and the prevalence of TI after the intervention approached zero.

As seen in Table 12, the burden of TF is seen in those aged 1-9 (51%; 95% CI = 37, 65), however, significantly hyperendemic levels are still observed in those between 10 and 14 years of age.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. at risk</td>
<td>TF</td>
<td>No. at risk</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>67% (4)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>33% (1)</td>
<td>3</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>52% (13)</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>44% (11)</td>
<td>36</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>16</td>
<td>23% (4)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>32% (3)</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>45% (21)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>38% (15)</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>42% (36)</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 12. Prevalence of TF in children at baseline examination
There was no significant difference between genders: a higher prevalence of TF among males was observed in this study when compared with females, but this difference was not statistically significant (OR=1.1; 95% CI: 0.96, 1.2). There was no statistical significant difference in the prevalence of TF between the two communities (OR =1.0; 95% CI: 0.9, 1.2).

The overall prevalence of TF in children less than 15 years of age in this study population was 43% (95% CI: 37%, 48%) (Table 12). Children under 10 years of age had a significantly higher risk of developing TF when compared with children over 10 years of age (OR: 1.3; 95% CI: 1.1, 1.4).

The overall prevalence of TI in children under 15 years of age was 8% (95% CI: 5.5% 11%). The prevalence of TI was higher in females when compared with males, but this difference was not statistically significant (OR: 1.06, 95% CI: 1.0, 1.12). No significant difference in the prevalence of TI was observed between communities (OR: 1.0; 95% CI: 0.96, 1.1). The prevalence of TI was 9% (95% CI: 5.6%, 13%) for those less than 10 years of age compared to 8% (95% CI: 2.5%, 13%) in those aged 10 years or older (Table 13).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. at risk</td>
<td>TI</td>
<td>No. at risk</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>0% (0)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>0% (0)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>25</td>
<td>8% (2)</td>
<td>25</td>
</tr>
<tr>
<td>1-9</td>
<td>Female</td>
<td>26</td>
<td>12% (3)</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>16</td>
<td>0% (0)</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>20% (2)</td>
<td>12</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>47</td>
<td>4% (2)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>13% (5)</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>8% (7)</td>
<td>91</td>
</tr>
</tbody>
</table>

Table 13. Prevalence of TI in children at baseline examination

If one considers inflammatory trachoma as including TF or TI (sometimes in the literature, this is often reported as TF + TI), the overall prevalence was 51%
(95% CI: 45%, 57%) (Table 14).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. at risk</td>
<td>TF or TI</td>
<td>No. at risk</td>
<td>TF or TI</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male 6</td>
<td>67% (4)</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Female 3</td>
<td>33% (1)</td>
<td>3</td>
<td>0% (0)</td>
</tr>
<tr>
<td>1-9</td>
<td>Male 25</td>
<td>60% (15)</td>
<td>25</td>
<td>68% (17)</td>
</tr>
<tr>
<td></td>
<td>Female 26</td>
<td>54% (14)</td>
<td>36</td>
<td>61% (22)</td>
</tr>
<tr>
<td>10-14</td>
<td>Male 16</td>
<td>25% (4)</td>
<td>15</td>
<td>40% (6)</td>
</tr>
<tr>
<td></td>
<td>Female 10</td>
<td>50% (5)</td>
<td>12</td>
<td>25% (3)</td>
</tr>
<tr>
<td>Total</td>
<td>Male 47</td>
<td>49% (23)</td>
<td>40</td>
<td>58% (23)</td>
</tr>
<tr>
<td></td>
<td>Female 39</td>
<td>51% (20)</td>
<td>51</td>
<td>49% (25)</td>
</tr>
<tr>
<td></td>
<td>Combined 86</td>
<td>50% (43)</td>
<td>91</td>
<td>53% (48)</td>
</tr>
</tbody>
</table>

Table 14. Prevalence of TF or TI in children at baseline examination

Children less than 10 years of age were at a 1.3 times higher risk of having TF or TI (95% CI: 1.1, 1.4) compared to children 10 years of age or older. No statistically significant difference in the prevalence of TF or TI was observed between genders or between the communities. The prevalence of TF trended with age (Figure 27).
Children aged 1 to 9 years of age had a higher prevalence of TF; 51% of children aged 1 to 9 years had TF compared with 42% of those aged less than one year and 26% of children aged 10 years and older.

There was no statistically significant difference in the prevalence of TF (43%; 95% CI: 37%, 48%) or a combination of TF or TI (51%; 95% CI: 45%, 56%) in children < 15 years old.

The baseline prevalence of active trachoma in each visit (data adjusted for clustering) is presented in Figure 28.

![Figure 28. Baseline prevalence of trachoma by visit adjusted for clustering (error bars are confidence limits).](image)

Although trachoma prevalence varied in both communities in each visit, a lower prevalence was observed in visit 4 compared with visits 1, 2, 3, and 5. The overall prevalence of trachoma was 49%, 56%, 48%, 29%, and 40% at visits 1, 2, 3, 4, and 5 respectively. Visits 1 and 4 were conducted in autumn one year apart, yet different prevalence rates were observed (49% versus 29%), whilst visits 3 and 5 were conducted in early spring also one year apart, but presenting more similar prevalence rates (48% versus 40%). These data are not simply explained by seasonal influence, or other factors, such as the implementation of the health program.

Figure 29 shows the time-plotted trachoma prevalence for both communities with significant rainfall data added. (The threshold for inclusion of rainfall points was set at ≥ 50 mm per month.) No obvious correlation was seen between significant rainfall and trachoma prevalence.
Figure 29. Time-plotted trachoma prevalence for both communities with significant rainfall co-plotted. (Rainfall key: Pipalyatjara; Mimili.)

5.6 Prevalence of TT, CO, and TS

No children aged 15 years of less had corneal opacities or TT. There were 3 people that had corneal opacities in the total population; 2 males aged 80 years and one female aged 58 years. The 2 males had previous lid repair and the female had trichiasis. There were 2 females, aged 54 and 74 years, who had TT without corneal opacity. The overall prevalence of TS in children aged 15 years and younger was 5% (95% CI: 3.4, 6.6). Of the 9 children who had TS, 4 lived in Pipalyatjara, and 5 in Mimili.

5.7 Prevalence Based on Different Methods

Several methods for estimating the prevalence of trachoma were investigated in this study. Prevalence based on the average of the baseline examinations was compared with four other methods: prevalence estimated from (a) the worst grade; (b) the grade at the time first examination among the five baseline visits; (c) employment of an algorithm that selected visits at random; and (d) a sensitivity analysis that removed the September 2000 data, because it seemed low. Figure 30 shows the results for (a), (b), and (c), as well as the average baseline grade.
Figure 30. Prevalence of active trachoma, any degree of nasal discharge, and absolutely or partially clean face, based on four different methods of estimation.

When the September 1999 data was removed from the baseline data set, the results for trachoma prevalence were as follows: (a) Pipalyatjara—44.4% (95% CI: 35.9, 52.8); Mimili—47.4% (95% CI: 40.7, 54.1).

The overall prevalence of trachoma based on the average of the baseline examination was 43% (95% CI: 37%, 48%), and was similar to the prevalence estimated based on the grade at the time of first examination (47%, 95% CI: 40%, 54%), and using random visits (41.8%, 95% CI: 34.2, 48.8), but lower than the prevalence estimated based on the worst grade of the baseline visits (67%, 95% CI: 60%, 74%).

The overall prevalence of absolutely or partially clean face based on the average and first examination was 26% (95% CI: 22%, 31%) and 31% (95% CI: 24%, 38%) respectively, whereas the prevalence of absolutely or partially clean face based on the worst grade was only 12% (95% CI: 7%, 17%). A similar trend was also observed in the prevalence of any degree of nasal discharge.
5.8 Analysis of Risk Factors

From Figure 30, prevalence estimated using the worst grade in any of the baseline examinations appears to be an overestimate of the true prevalence. It is interesting to note that the prevalence rate estimated based on the average of the baseline examination and the grade at the time of first examination produced similar rates.

Considering the complexity involved in assessing risk factors for the prevalence of active trachoma using average rates, the grade at the time of first examination was used in order to assess these risk factors.

Age, gender, place of residence, status of facial cleanliness, degree of nasal discharge, and number of people registered as living in each household were included in the univariate analysis to identify factors significantly associated with the prevalence of TF. Of these, age (chi-square: 10.9, p = 0.004), status of facial cleanliness (chi-square: 9.8, p < 0.007) and degree of nasal discharge (chi-square: 17.8, p < 0.001) were significantly associated with prevalence of TF. Gender (chi-square: 0.01, p = 0.95), place of residence area (chi-square: 1.0, p = 0.32) and number of people living in household (chi-square: 0.43, p = 0.51) were not significantly
associated with the prevalence of TF in the univariate analysis (Table 15).

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Trachoma</th>
<th>No trachoma</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (in years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1</td>
<td>3 (3.6%)</td>
<td>9 (9.6%)</td>
<td>0.004*</td>
</tr>
<tr>
<td>1 – 9</td>
<td>63 (75.9%)</td>
<td>49 (52.1%)</td>
<td></td>
</tr>
<tr>
<td>≥ 10</td>
<td>17 (20.5%)</td>
<td>36 (38.3%)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>41 (49.4%)</td>
<td>46 (48.9%)</td>
<td>0.95</td>
</tr>
<tr>
<td>Female</td>
<td>42 (46.7%)</td>
<td>48 (53.3%)</td>
<td></td>
</tr>
<tr>
<td><strong>Residence</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipalyatjara</td>
<td>37 (44.6%)</td>
<td>49 (52.1%)</td>
<td>0.32</td>
</tr>
<tr>
<td>Mimili</td>
<td>46 (55.4%)</td>
<td>45 (47.9%)</td>
<td></td>
</tr>
<tr>
<td><strong>Facial cleanliness</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolutely clean</td>
<td>6 (7.2%)</td>
<td>21 (22.3%)</td>
<td>0.007*</td>
</tr>
<tr>
<td>Partially clean</td>
<td>11 (13.3%)</td>
<td>17 (18.1%)</td>
<td></td>
</tr>
<tr>
<td>Dirty</td>
<td>66 (79.5%)</td>
<td>56 (59.6%)</td>
<td></td>
</tr>
<tr>
<td><strong>Nasal discharge</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>8 (9.6%)</td>
<td>33 (35.1%)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Clear</td>
<td>18 (21.7%)</td>
<td>18 (19.1%)</td>
<td></td>
</tr>
<tr>
<td>Abundant</td>
<td>47 (56.6%)</td>
<td>41 (43.6%)</td>
<td></td>
</tr>
<tr>
<td>Mucopurulent</td>
<td>10 (12.0%)</td>
<td>2 (2.1%)</td>
<td></td>
</tr>
<tr>
<td><strong>Number of people in household</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10</td>
<td>13 (15.7%)</td>
<td>18 (19.1%)</td>
<td>0.51</td>
</tr>
<tr>
<td>10 – 15</td>
<td>18 (21.7%)</td>
<td>21 (22.3%)</td>
<td></td>
</tr>
<tr>
<td>≥ 15</td>
<td>52 (62.7%)</td>
<td>55 (58.5%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 15: Univariate risk factors for prevalence of TF. *Significant
All these factors were also included in the multivariate model to identify the independent risk factors (Table 16), which was adjusted for number of baseline examinations and clustering employing the GEE approach, using TF, and TF or TI data.

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>TF</th>
<th></th>
<th>TF or TI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>p value</td>
<td>OR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Age (in years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 1 year</td>
<td>0.8 (0.2, 3.8)</td>
<td>0.80</td>
<td>0.5 (0.1, 2.1)</td>
<td>0.36</td>
</tr>
<tr>
<td>1 - 9 years</td>
<td>2.0 (1.0, 4.1)</td>
<td>0.045*</td>
<td>1.9 (0.99, 3.6)</td>
<td>0.06</td>
</tr>
<tr>
<td>10 - 14 years</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipalyatjara</td>
<td>1.0</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Mimili</td>
<td>0.7 (0.5, 1.1)</td>
<td>0.10</td>
<td>0.7 (0.5, 1.2)</td>
<td>0.24</td>
</tr>
<tr>
<td>Facial cleanliness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolutely or partially clean face</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dirty face</td>
<td>1.4 (0.8, 2.2)</td>
<td>0.23</td>
<td>2.2 (1.3, 3.7)</td>
<td>0.002*</td>
</tr>
<tr>
<td>Nasal discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1.0</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Clear</td>
<td>3.5 (1.4, 8.8)</td>
<td>0.008*</td>
<td>3.7 (1.3, 11.1)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Abundant</td>
<td>4.5 (1.6, 12.2)</td>
<td>0.003*</td>
<td>3.3 (1.3, 8.3)</td>
<td>0.01*</td>
</tr>
<tr>
<td>Mucopurulent</td>
<td>15.8 (3.2, 77.2)</td>
<td>&lt; 0.001*</td>
<td>6.7 (1.6, 27.5)</td>
<td>0.009*</td>
</tr>
<tr>
<td>&gt; 15 people living in an household</td>
<td>1.1 (0.6, 1.9)</td>
<td>0.71</td>
<td>1.4 (0.9, 2.2)</td>
<td>0.16</td>
</tr>
<tr>
<td>&lt; 15 people living in an household</td>
<td>1.0</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 16. Multivariate risk factors for prevalence of TF using GEE method of adjusting for number of baseline examinations and household clusters, for TF, and TF or TI data. *Significant

When the TI prevalence data are added to the TF data and analysed (TF or TI), the differences in the risk factors show a complex result: children aged 1-9 years no
longer show a significant association with trachoma (though the change is small); the association with a dirty face becomes highly significant (OR: 2.2, 95% CI: 1.3, 3.7); and the associations with nasal discharge factors become less significant.

For the TF only model, children aged 1 to 9 years (OR: 2.0, 95% CI: 1.0, 4.1), and some degree of nasal discharge, clear (OR: 3.5, 95% CI: 1.4, 8.8), abundant (OR: 4.5, 95% CI: 1.6, 12.2), and mucopurulent (OR: 15.8, 95% CI: 3.2, 77.2) were all significantly associated with a higher risk of developing TF.

Of the 177 children, 122 (69%) presented with both facial signs (eye and nasal discharge), 28 (16%) with only one sign (either nasal or eye discharge), and 27 (15%) with no facial signs. Children with both facial signs were 4.1 times, whilst those with only one facial sign were 2.3 times more likely to develop TF when compared to children who presented with no facial signs. Of the 66 children who had TF when both signs were present, 77% (51/66) of them were in the 1 to 9 years of age group.

### 5.9 Housing Surveys

There were 41 extended families in Pipalyatjara and 36 in Mimili. The number of family subunits varied from 1 to 8 (median = 1; mean = 2). Each family unit varied in the number of individuals, ranging from 1 to 55 with a median of 6 (mean = 9). There were 35 households in Pipalyatjara and 29 in Mimili. The number of individuals in each house ranged from 1 to 41 with a median of 8 (mean = 11). The average number of children aged less than 15 years per household ranged from 1 to 18 (median = 6).

In terms of safety—utilities, electricity, structure, and hot water—substantial improvements were noted in all items (only 18% of houses met the hot-water safety passing score at baseline). In terms of the number of houses in which net improvements occurred as a result of the intervention, the figures were 38%, 25%, 25%, and 77% for the four factors respectively (see Figure 30).

With regard to washing people, there was a big improvement in the usage of hot water (77%), offset against a reduction in shower and bath function and usage (28% and 17% respectively). In terms of washing children (perhaps one of the most important factors), the improvement was modest—about 18%. A small increase in the score for washing clothes and bedding was recorded (6%). Use of a properly flushing toilet increased by 25%, and there was a large increase in removal of waste from all
other areas (29%), but no houses at either survey reached the minimum passing score. No change was also seen in food handling—another problem area in which no houses reached the minimum score to pass. About 65% of all houses showed an improvement in the score of the ‘reduce the impact of crowding’ healthy living practice, and reducing the impact of animals, vermin, and dustmites, all had modest gains of 10-20% in terms of score, even though few houses reached passing scores on these items except for dustmites. The availability of affordable heating and cooling devices improved moderately, as did warming houses in cold conditions (gains of 10-20%), but the reverse situation (cooling houses in warm conditions) did not change. Dust conditions improved slightly (< 5%), but the results were disappointing given the amount of effort put into this area.

To summarize, for the nine healthy living practices outlined in the National Indigenous Housing Guide, these were the estimated changes using categories of no change (none); small (<10%), medium (10-20%), or large (>20%):

1. Washing people—small
2. Washing clothes and bedding—small
3. Removing waste safely—large
4. Improving nutrition—none
5. Reducing crowding—small
6. Reducing negative contact between people and animals, vermin, or insects—medium
7. Reducing the negative impact of dust—small
8. Controlling temperature of the living environment—medium
9. Reducing trauma around the house and living environment—small

5.10 Post-intervention

As stated in the methodology section, Pipalyatjara was the intervention community where the full SAFE strategy was implemented, whilst Mimili was the control community where only SAF was implemented (section 4.2 p56). Figure 31 shows the difference between Surveys 1 and 2 (pre-intervention, and post-intervention, approximately 12 months) at Pipalyatjara regarding the state of the healthy living practices.
Figure 31. Critical healthy living practices in Pipalyatjara in Survey 1 versus Survey 2

5.10.1 Trachoma prevalence

The prevalence of active trachoma by age and gender distribution at 3, 6, and 12 months post-intervention is shown in Tables 17 and 18 for Pipalyatjara and Mimili.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Baseline*</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. at risk</td>
<td>TF</td>
<td>No. at risk</td>
<td>TF</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>4 (67%)</td>
<td>3</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>1 (33%)</td>
<td>1</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>13 (52%)</td>
<td>13</td>
<td>2 (15%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>11 (44%)</td>
<td>10</td>
<td>3 (30%)</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>16</td>
<td>4 (23%)</td>
<td>4</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>3 (32%)</td>
<td>3</td>
<td>1 (33%)</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>21 (45%)</td>
<td>20</td>
<td>2 (10%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>15 (38%)</td>
<td>14</td>
<td>5 (36%)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>38 (42%)</td>
<td>34</td>
<td>7 (21%)</td>
</tr>
</tbody>
</table>

Table 17: Prevalence of TF in children in Pipalyatjara post-intervention

*Estimated based on average of five baseline visits
Table 18. Prevalence of TF in children in Mimili post-intervention

*Estimated based on average of five baseline visits

The prevalence of active trachoma was drastically reduced at 6 and 12 months for those children aged 10 years or older in both Pipalyatjara and Mimili. Most likely this is because older children are less prone to reinfect each other. Figure 32 shows the overall level of trachoma prevalence for children during the study, with confidence limits adjusted for clustering.

![Prevalence of TF in children for the entire study. Confidence limits (error bars) are adjusted for clustering.](image-url)
No children aged 10 years or older had active trachoma at 12 months post-intervention in Pipalyatjara and only one out of 21 (5%) children in Mimili had active trachoma at 12 months. In Pipalyatjara, 48% of children between 1 to 9 years of age had TF at baseline but the prevalence was reduced to 22%, 19%, and 20% at 3, 6, and 12 months post-intervention, respectively. In Mimili 53% had TF at baseline, which was reduced to 22%, 27% and 35% at the same post-intervention time periods.

Adjusting the trachoma prevalence data for clustering (compared to the raw data) led to small differences in the confidence limits except for a few data points, as shown in Table 19.

<table>
<thead>
<tr>
<th>Visit Number</th>
<th>Pipalyatjara Unadjusted</th>
<th>Pipalyatjara Adjusted</th>
<th>Mimili Unadjusted</th>
<th>Mimili Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>± 8.2</td>
<td>± 7.5</td>
<td>± 6.1</td>
<td>± 5.7</td>
</tr>
<tr>
<td>2</td>
<td>± 6.6</td>
<td>± 7.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>± 7.7</td>
<td>± 7.0</td>
<td>± 6.1</td>
<td>± 4.9</td>
</tr>
<tr>
<td>4</td>
<td>± 10.7</td>
<td>± 10.5</td>
<td>± 6.6</td>
<td>± 4.8</td>
</tr>
<tr>
<td>5</td>
<td>± 9.7</td>
<td>± 9.3</td>
<td>± 6.1</td>
<td>± 6.5</td>
</tr>
<tr>
<td>6</td>
<td>± 9.2</td>
<td>± 7.4</td>
<td>± 5.6</td>
<td>± 5.2</td>
</tr>
<tr>
<td>7</td>
<td>± 8.7</td>
<td>± 6.1</td>
<td>± 5.6</td>
<td>± 3.6</td>
</tr>
<tr>
<td>8</td>
<td>± 6.1</td>
<td>± 2.2</td>
<td>± 5.6</td>
<td>± 7.4</td>
</tr>
</tbody>
</table>

Table 19. Differences in confidence limits data for TF trachoma prevalence at both communities, unadjusted, and adjusted for clustering using the GEE approach.

Because of the mobility issues, particularly at Pipalyatjara, a further analysis was conducted to obtain a more accurate picture of the pre- and post- trachoma prevalence. Figure 33 shows the trachoma prevalence obtained by using only those children who were present at both baseline and follow-up examinations. The data are also adjusted for clustering.
Table 20 shows this data in terms of the prevalence figures and confidence limits.

<table>
<thead>
<tr>
<th>Point in intervention</th>
<th>Pipalyatjara</th>
<th>Mimili</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>41.5% (95% CI: 33.2, 49.8)</td>
<td>43.5% (95% CI: 38.8, 48.2)</td>
</tr>
<tr>
<td>+3 Months</td>
<td>21.2% (95% CI: 5.4, 37.0)</td>
<td>18.2% (95% CI: 7.3, 29.1)</td>
</tr>
<tr>
<td>+6 Months</td>
<td>20.0% (95% CI: 6.9, 33.1)</td>
<td>18.2% (95% CI: 10.2, 26.2)</td>
</tr>
<tr>
<td>+12 Months</td>
<td>20.0% (95% CI: 16.7, 43.3)</td>
<td>30.0% (95% CI: 16.7, 43.3%)</td>
</tr>
</tbody>
</table>

Table 20. Pre- and post-intervention trachoma prevalence data adjusted for clustering, and using individuals present at baseline and post-intervention examinations.

The prevalence of active trachoma at baseline was 42% in Pipalyatjara and 44% in Mimili. After the intervention, the prevalence of active trachoma was halved in both Pipalyatjara and in Mimili. The prevalence of active trachoma in Pipalyatjara decreased from 42% at baseline to 21%, 20% and 20% at 3, 6, and 12 months post-intervention, respectively. In Mimili the prevalence of active trachoma was reduced from 44% at baseline to 18% and 18% at 3 and 6 months respectively, but increased to 30% at 12 months (Figure 33).
### 5.10.2 Nasal discharge

The prevalence of any degree of nasal discharge in children under 15 years of age was reduced significantly in both Pipalyatjara and in Mimili after the intervention (Figure 34).

![Graph showing the degree of nasal discharge by visit in Pipalyatjara and Mimili.](image)

**Figure 34. Degree of nasal discharge by visit**

The prevalence of any degree of nasal discharge at baseline in Pipalyatjara was 62%, which was reduced to 35%, 31%, and 23% at 3, 6, and 12 months.
post-intervention, respectively (Table 21).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Baseline*</th>
<th>Month 3</th>
<th>Month 6</th>
<th>Month 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. at risk</td>
<td>Nasal discharge</td>
<td>No. at risk</td>
<td>Nasal discharge</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>4 (67%)</td>
<td>3</td>
<td>3 (100%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>1 (33%)</td>
<td>1</td>
<td>1 (100%)</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>20 (80%)</td>
<td>13</td>
<td>5 (38%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>15 (58%)</td>
<td>10</td>
<td>3 (30%)</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>16</td>
<td>7 (44%)</td>
<td>4</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>5 (50%)</td>
<td>3</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>31 (66%)</td>
<td>20</td>
<td>8 (40%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>22 (56%)</td>
<td>14</td>
<td>4 (29%)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>53 (62%)</td>
<td>34</td>
<td>12 (35%)</td>
</tr>
</tbody>
</table>

Table 21. Degree of nasal discharge in children in Pipalyatjara
*Estimated based on average of five baseline visits

The prevalence of any degree of nasal discharge in Mimili was 76%, 32%, 30%, and 9% at baseline, 3, 6, and 12 months post-intervention, respectively (Table 22).

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Gender</th>
<th>Baseline*</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. at risk</td>
<td>Nasal discharge</td>
<td>No. at risk</td>
<td>Nasal discharge</td>
<td>No. at risk</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>0</td>
<td>--</td>
<td>2</td>
<td>1 (50%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>3 (100%)</td>
<td>2</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>1-9</td>
<td>Male</td>
<td>25</td>
<td>22 (88%)</td>
<td>19</td>
<td>9 (47%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>36</td>
<td>28 (78%)</td>
<td>31</td>
<td>13 (42%)</td>
</tr>
<tr>
<td>10-14</td>
<td>Male</td>
<td>15</td>
<td>10 (67%)</td>
<td>9</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12</td>
<td>6 (50%)</td>
<td>8</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>40</td>
<td>32 (80%)</td>
<td>30</td>
<td>10 (33%)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>51</td>
<td>37 (73%)</td>
<td>41</td>
<td>13 (32%)</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>91</td>
<td>69 (76%)</td>
<td>71</td>
<td>23 (32%)</td>
</tr>
</tbody>
</table>

Table 22. Degree of nasal discharge in children in Mimili
*Estimated based on average of five baseline visits
The prevalence of mucopurulent discharge was 10%, 6%, 0%, and 6% in Pipalyatjara, whilst it was 4%, 3%, 1%, and 2% in Mimili during baseline, and at 3, 6, and 12 months post-intervention, respectively.

The prevalence of any degree of nasal discharge in children aged 10 years and older was 46% and 59% in Pipalyatjara and Mimili, respectively. After the intervention none of them had any degree of nasal discharge at 12 months in this age group in either Pipalyatjara or Mimili.

Prevalence of any degree of nasal discharge in children aged 1-9 years was 69%, 35%, 38%, and 24% in Pipalyatjara, and 75%, 44%, 34%, and 10% in Mimili during baseline, and at 3, 6, and 12 months post-intervention, respectively. Prevalence of any degree of nasal discharge in children aged less than one year was 56%, 100%, 33%, and 50% in Pipalyatjara, and 100%, 25%, 60%, and 28% in Mimili during baseline and at 3, 6, and 12 months post-intervention visits 6, 7 and 8, respectively. There were no significant differences in the prevalence of any degree of nasal discharge between genders in both pre- and post-intervention in either Pipalyatjara or in Mimili.

5.10.3 Facial cleanliness

The prevalence of an absolutely or partially clean face in children under 15 years of age was increased significantly in both Pipalyatjara and in Mimili after the intervention. The prevalence of an absolutely or partially clean face at baseline in Pipalyatjara was 36%, which increased to 91%, 83%, and 88% at 3, 6, and 12 months post-intervention, respectively (Table 23), while the prevalence of an absolutely or partially clean face in Mimili was 42%, 87%, 92%, and 97% during baseline and at 3, 6, and 12 months post-intervention, respectively (Table 24).
<table>
<thead>
<tr>
<th>Age group</th>
<th>Gender</th>
<th>Baseline*</th>
<th>3 Months</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>Partial or absolutely clean</td>
<td>Absolutely clean</td>
<td>N</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>6</td>
<td>1 (17%)</td>
<td>1 (17%)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>1 (17%)</td>
<td>1 (17%)</td>
<td>1</td>
</tr>
<tr>
<td>1 to 9</td>
<td>Male</td>
<td>25</td>
<td>8 (32%)</td>
<td>4 (16%)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>26</td>
<td>9 (35%)</td>
<td>8 (31%)</td>
<td>10</td>
</tr>
<tr>
<td>10 to 14</td>
<td>Male</td>
<td>16</td>
<td>8 (50%)</td>
<td>8 (50%)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>10</td>
<td>4 (40%)</td>
<td>4 (40%)</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>47</td>
<td>17 (36%)</td>
<td>13 (28%)</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>39</td>
<td>14 (36%)</td>
<td>13 (33%)</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>86</td>
<td>31 (36%)</td>
<td>26 (30%)</td>
<td>34</td>
</tr>
</tbody>
</table>

Table 23. Prevalence of facial cleanliness in Pipalyatjara

*Estimated based on average of five baseline visits
<table>
<thead>
<tr>
<th>Age group</th>
<th>Gender</th>
<th>Baseline*</th>
<th>Month 3</th>
<th>Month 6</th>
<th>Month 12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>Partial or absolutely clean</td>
<td>Absolutely clean</td>
<td>N</td>
</tr>
<tr>
<td>&lt;1</td>
<td>Male</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>3</td>
<td>3 (100%)</td>
<td>0 (0%)</td>
<td>2</td>
</tr>
<tr>
<td>1 to 9</td>
<td>Male</td>
<td>25</td>
<td>8 (32%)</td>
<td>4 (16%)</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>36</td>
<td>12 (33%)</td>
<td>6 (17%)</td>
<td>31</td>
</tr>
<tr>
<td>10 to 14</td>
<td>Male</td>
<td>15</td>
<td>8 (53%)</td>
<td>5 (33%)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12</td>
<td>7 (58%)</td>
<td>6 (50%)</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>Male</td>
<td>40</td>
<td>16 (40%)</td>
<td>9 (23%)</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>51</td>
<td>22 (43%)</td>
<td>12 (24%)</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Combined</td>
<td>91</td>
<td>38 (42%)</td>
<td>21 (23%)</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 24. Prevalence of facial cleanliness in Mimili

*Estimated based on average of five baseline visits
At baseline, 64% and 58% had a dirty face in Pipalyatjara and Mimili, respectively, whereas after the intervention, only 9%, 17%, and 12% in Pipalyatjara and 13%, 8%, and 3% in Mimili had a dirty face at 3, 6, and 12 months post-intervention, respectively (Figure 35).

![Presence of facial signs at baseline and follow-up](image)

Figure 35. Presence of facial signs at baseline and follow-up

The prevalence of an absolutely or partially clean face in children aged 10 years and older was 46% and 56% in Pipalyatjara and Mimili, respectively. After the intervention, none of them had a dirty face in this age group in either Pipalyatjara or Mimili (Tables 23 and 24). There was no significant difference in the prevalence of facial signs between genders in both Pipalyatjara and Mimili in all visits.

Of those children presenting with both facial signs, 54% (66/122) had TF compared with 39% (11/28) with only one sign, and 22% (6/27) presenting with no signs.

### 5.11 Post-Intervention Summary by Age Group

#### 5.11.1 Trachoma prevalence

Three months after the antibiotic administration, the overall trachoma prevalence for the children had been approximately halved, and this maintained through the six-month point post-intervention. At Pipalyatjara, for the 10-14 year-olds, trachoma was completely resolved three months post-intervention, and stayed the same through the
12-month point. At Mimili, there was substantial reduction in the trachoma prevalence, and by the 12-month point, only one individual still had symptoms of the disease. For the < 1 year-olds, there was a substantial reduction in trachoma prevalence at Pipalyatjara, with a gradual rise thereafter. At Mimili, there was complete resolution of the disease at 3 months post-intervention, but a small rise thereafter.

For the 1-9 year-olds, the situation was more complex. At Pipalyatjara, three months post-intervention, the prevalence of trachoma for males was almost zero, and remained the same through 12 months post-intervention. For females, there was approximately a halving of trachoma prevalence at three months, which did not change through 12 months post-intervention. At Mimili, there was a very substantial reduction in trachoma prevalence for males 3 months into the intervention that rose slightly through 12 months post-intervention. For females, the initial reduction in trachoma prevalence was less than for males, followed by a large rise at the 12-month point post-intervention.

5.11.2 Facial cleanliness

For the 10-14 year-olds, at three months into the intervention, all faces were absolutely clean at both communities, and stayed that way throughout the intervention. For the < 1 year-olds, faces remained mostly dirty at Pipalyatjara throughout the intervention, but gradually improved at Mimili. For the 1-9 year-olds at both communities, absolutely clean faces prevailed at the 3-month point, post-intervention, reaching about 65% at Pipalyatjara, and 90% by the 12-month point at Mimili.

5.11.3 Nasal discharge

For the 10-14 year-olds, there was no nasal discharge post-intervention at Pipalyatjara, and virtually none at Mimili. For the < 1 year-olds, there was a substantial improvement in nasal discharge at Mimili, but no real improvement at Pipalyatjara by the 12-month point, compared to the baseline situation. For the 1-9 year-olds, the number of individuals with nasal discharge dropped dramatically over the course of the intervention, with the result at Mimili slightly better than at Pipalyatjara by the 12-month point: 10% nasal discharge at Mimili; 25% nasal discharge at Pipalyatjara.
5.12 Environmental Data

According to the weather data, the wind blew between the south and east about 70% of the time, and where possible, trees and bushes were planted in a southeasterly direction relative to buildings and houses. Rainfall in the AP lands had been above average since the mid-nineties (270 mm; 10.7 inches), and for the years of the study was exceptional (data for Pipalyatjara—1999: 447 mm; 2000: 326 mm; 2001: 610 mm; data for Marla [see below for description of Marla]—1999: 276 mm; 2000: 298 mm; 2001: 389 mm). In fact, the rain was so intense during several periods of 2001 that extensive flooding was caused at Pipalyatjara, and food had to be flown in by helicopter. Nevertheless, the mounding, and other landscaping improvements helped channel some of the water to irrigate the trees, bushes, and grass, which was one of the goals of the environmental project. Unfortunately, though, these same rain events interfered substantially with collection of dust data, and flies.

Mimili has no weather station, though there are two weather stations, both within about 120 km: Ernabella to the northwest, and Marla to the southeast. Marla was chosen as the weather station to compare rainfall data with Pipalyatjara as data was incomplete at Ernabella for the years 1999-2001.

It was important to determine whether Mimili has a significantly different climate compared to Pipalyatjara and this was performed using historical data from the Giles weather station, which is 120 km southeast of Pipalyatjara, compared to Marla. The data showed that Mimili is about 2-3°C cooler (mean monthly maximum and minimum temperatures) and receives about 85% less rainfall on average, compared to Pipalyatjara.

Figure 36 shows the rainfall data for Pipalyatjara for the years of the study,
Comparing rainfall totals for the years 1999, 2000, and 2001, Marla had 62%, 78%, and 64% less rain respectively than Pipalyatjara. Figure 38 shows the temperature data for the same period at Pipalyatjara.
Figure 38. Mean maximum and minimum temperatures at Pipalyatjara for the years 1999, 2000, and 2001.

Although historically, the climate at Mimili is slightly cooler and drier compared to Pipalyatjara, for the years of the study, which were unusual with regard to rainfall, Pipalyatjara was significantly wetter; however, rain generally fell at the same periods of time during the year.

There were problems with the flytraps. The children at the Pipalyatjara community wrecked many of the traps by playing with them and throwing stones at them. In addition, the teachers quickly grew tired of servicing the traps. Only one set of packages was analysed, and according to Dr. Dadour, only one fly possibly had *Chlamydia*. This meant that it was not possible to obtain any seasonal fly counts, though it is likely that any data collected for 2001 would probably have been non-typical for the season.

The dust traps also were problematic: rainfall caused collection problems, insects clogged the funnels, and the children at Pipalyatjara again used the devices for target practice. Nevertheless, some early analysis indicated that there were substantial differences between locations just outside of the community, where dust levels were higher, and that sites near unsealed roads tended to have higher dust levels. After road sealing, it was expected that dust levels would drop, but this could not be checked.
Traffic data showed that there were two daily peak maxima: late morning, and late afternoon. However, no patterns over longer terms could be discerned. Average traffic speed was about 35 kph.
CHAPTER 6
DISCUSSION

6.1 Summary of Findings

6.1.1 Overview

This study was a longitudinal, prospective, population-based prevalence survey undertaken in the AP (Anangu Pitjantjatjara) Lands of Central Australia, and conducted over a period of two-and-one-half years between March of 1999 and September of 2001. The study targeted two Aboriginal communities, Pipalyatjara and Mimili, which were comparable in distribution of the variables of size, age, gender, sociological structure (e.g., family size, governing structure, and facilities), and climate. Pipalyatjara served as the intervention community in which SAFE-related activities took place, while Mimili served as the control community in which only SAF-related activities were planned due to budgetary constraints.

A total of eight visits were conducted in order to collect field data in both communities. The months of March, June, and November 1999, as well as April and August of 2000 constituted the baseline collection period. August 2000 was also the intervention visit in which azithromycin was distributed and when health promotion activities, as well as environmental interventions were initiated. A further three visits to collect post-intervention data were conducted in December 2000, and February and September 2001.

About 85% of the registered participants in the study were examined at least once, and as many as 41% were examined four times. Mobility and to minor extent, the morbidity factors (not specifically documented) of the populations complicated the examination process. These factors were more significant in Pipalyatjara, resulting in significantly more examinations per person on average in Mimili than in Pipalyatjara (3.3 vs. 2.8 respectively).

The data generated from this survey provided an insight into four critical issues relevant to the global initiatives of eradicating trachoma:

1. The rates of trachoma prevalence in the two communities, especially children, before and after the intervention.
2. Epidemiological data for the assessment of trends and patterns.
3. The risk factors for TF and TF or TI in the context of the study sites.
4. A controlled comparison between two matched sites, one receiving the E component (in addition to SAF); the other receiving only the SAF components.

6.1.2 Significant findings

The prevalence rate of active trachoma found in this study is comparable to rates derived from recent and some old studies in Australian Aboriginal communities conducted in Central Australia. (Changes in the WHO grading system could have resulted in some errors in reclassifying older data (largely pre-1990 data), particularly TI and TF.) In children less than fifteen years of age, the pre-intervention prevalence of TF (Trachomatous Follicular) averaged 41.5% in Pipalyatjara after adjustment for clustering, and 43.5% in Mimili, it being highest in children aged one to nine years in both communities: Pipalyatjara (48%); Mimili (53%). The prevalence of TI (Trachomatous inflammation Intense) was lower than that of TF, with a combined average of 8% for Pipalyatjara and 9% for Mimili, however, the age distribution was similar, with peak prevalence in the 1-9 year-old group. These results confirm that trachoma is still hyperendemic in these communities in Central Australia, a situation that has not significantly changed in many decades.

After the SAFE interventions were initiated, the prevalence of active trachoma in children under 15 years of age at Pipalyatjara decreased from 41.5% at baseline to 21%, 20%, and 22% during the three post-intervention visits at 3, 6, and 12 months respectively (adjustments made for clustering, and using only those children who had baseline as well as follow-up examinations). In Mimili where only SAF was instituted, the prevalence was reduced by a similar amount, from 43.5% at baseline to 18% and 18% at post-intervention visits at 3 and 6 months respectively, but increased to 30% during post-intervention visit 12 months. This halving of the prevalence in both communities is a substantial achievement.

In the 1-9 year-old group, there was a substantial difference between the pre-intervention and post-intervention TF prevalence by community, and gender. At Pipalyatjara, clinically active trachoma almost disappeared for the males at 3 months into the intervention, while for females TF prevalence was only halved. The situation was the same at the 12-month point. At Mimili, the pattern was similar by gender, though overall, the reduction in active trachoma was far less than that achieved at Pipalyatjara.
For all children, implementing the E component of SAFE at Pipalyatjara did not apparently result in any short-term difference in overall trachoma reduction compared to the SAF-alone strategy at Mimili. However, at the last post-intervention visit the prevalence in children at Pipalyatjara was 20% versus 30% at Mimili, despite slightly lower levels of facial cleanliness at Pipalyatjara (Figure 33). Although not a significant difference, this trend is heartening, suggesting that the E component was effective, though chance, or other factors could also have caused this result.

It is likely that several factors interplayed to provide the overall result of the interventions. First, the high mobility of the study population, especially at Pipalyatjara, (overnight stays within the community and between the two and other communities), could have caused more or less reinfection than one would see in a less-mobile population. (This is supposition; no lab tests were conducted.) The fact that a small, but significant percentage of the population did not receive azithromycin at the time of intervention due to absence likely increased trachoma prevalence to some extent. If another antibiotic administration had taken place after 3-6 months later to catch these individuals, this might have provided a counter-effect. Finally, because the environmental changes instituted at Pipalyatjara were not under the control of the author, the situation was somewhat frustrating. For example, in the healthy living practices, only absolute scores for pass or fail were considered.

Facial cleanliness in the under-fifteen age group was thought to be one of the most important risk factors prior to carrying out the study, but when an analysis was carried out, after adjusting for clustering and baseline examinations, it was only significant in the case or TF or TI; for TF alone, it was not significant. When determined at baseline using the criterion of an absolutely clean face, its overall prevalence was 30% at Pipalyatjara and 23% at Mimili. Partially clean faces were 6% and 19% respectively. After the intervention, absolute facial cleanliness increased to 65% and 89% respectively in the communities. Since attention to implementing the devised face cleanliness strategies was strong in both communities, these are significant improvements. It also demonstrates that it is possible to instil and possibly sustain new habits in such communities.

An almost threefold decrease from the baseline value of 61% regarding nasal discharge at Pipalyatjara was observed, while at Mimili, the drop was even more dramatic, from 75% to 9%. Although abundant discharge had disappeared by the time of the last visit of the intervention at both study sites, at Pipalyatjara the level of clear
discharge, which fluctuated throughout the intervention, appeared unchanged. Again, these results highlight the success of the interventions, although it should be noted that overall performance at Mimili was significantly better, for reasons that will be discussed later.

6.2 Mobility

One of the most fundamental difficulties encountered in this study was mobility of the registered participants in both communities. Mobility of Aboriginal people was a well known phenomenon prior to the design of the study.\(^\text{24,76}\) To counter this effect, several visits were planned to establish satisfactory baseline values of factors prior to starting the intervention. Nevertheless, the varying patterns of participation rates (vide infra) caused another set of problems. For example, how does one determine an average baseline without unfairly weighting the data from individuals that were examined multiple times, and what does one do with individuals who were absent for long periods of time. The comprehensive database used to track individuals easily separated visitors from residents, although it was not uncommon for visitors to become residents and vice versa. In this study, visitors were discounted as far as comparison of pre- and post-intervention parameters were concerned, and comparisons made simply on a permanent resident basis.

If one inspects the data from Figures 19 and 20, two items become readily apparent. First there is a considerable difference in mobility between the two communities—the population of Pipalyatjara is considerably more mobile than Mimili. Second, for the Pipalyatjara community, the turnover of the population is substantial. One potential problem resulting from this is that post-intervention assessments at 3 and 6 months (trachoma prevalence, facial cleanliness, and nasal discharge parameters) could have been seriously under- or overestimated. For example, for the 1-9 year-olds at Pipalyatjara, the numbers examined at baseline (average), 3, 6, and 12 months post-intervention were 51, 23, 26, and 46, respectively. Given that TF is most prevalent in this age group, which is why, in part, the study focused mostly on children under the age of fifteen, this mobility problem could affect the accuracy of the data—some of the outlying results determined in this study could be due in large part to the population turnover rather than other specific factors.
In order to make a more accurate presentation of pre- and post-intervention parameters, it is necessary to at least weed out those participants in the pre-intervention stage who were not present in the post-intervention stages, and vice versa. This was accomplished for TF prevalence and showed (Figure 33), in comparison to the dataset (Figure 32) in which no such adjustments had been made (though both had been adjusted for clustering) that the post-intervention differences were slightly less, though more noticeably at the 12-month point. Predictably, the former dataset higher confidence limits (larger confidence interval), because the sample numbers were smaller.

Few studies have documented mobility or taken it into account, in part because it is not a major issue in some parts of the world. In Africa, where large sample studies are more the norm—in comparison to Australia—some groups are becoming more aware of the problem, and have reported population turnovers for longitudinal studies lasting 2-2.5 years in the region of 20-25%.\(^{(13,200)}\) While population turnover is not the same parameter as mobility, it does provide an indication of the extent of the factor. Some research groups have reported statistics but not chosen to publish how this was dealt with,\(^{(200)}\) while others have decided to segregate post-intervention immigrants in terms of analysis.\(^{(13)}\) With large sample numbers there are more options; with the small numbers in this study, rigorous analysis of children subgroups in this fashion is precluded—the final numbers become too small to analyse.

In a small community in which six-month absences are very common, and the population turnover is close to or exceeds 50% in a longitudinal study, such as Pipalyatjara, it is not clear whether an improved study design might yield more precise results. For example, one option might be to survey a single time for baseline determination of prevalence parameters, aiming for as high participation as possible, and simply follow this group longitudinally, and ignore any newcomers—whether they are visitors, returning residents, new residents, or births. With a smaller group of children, one might be able to include lab exams, which would yield additional information. Another option might be survey quarterly in one year for baseline determination and then follow the entire community at 3-month intervals following an intervention. Comparisons could be made against average baseline determinations, or matched times of the year, to eliminate any seasonally related effects. Both options could be combined in a single study to provide different ways of looking at the population dynamic.
Many of the previous trachoma studies of Australian Aboriginals cited in the literature acknowledge mobility as a factor. However, only the authors of one study\(^{24}\) have specifically identified mobility per se as a factor that can aggravate attempts to reduce the hyperendemicity typically associated with the indigenous populations in the central regions of Australia. This should be obvious, because the transmission of infectious diseases by mobile people—index cases of epidemics equating to passengers in a jet aircraft, for instance—has already been well-established. The author’s study, though, is the first of its kind to document the mobility factor in considerable detail. From this study, it is not hard, after scrutinising the pattern of movement, to posit the argument that if the SAF program were extended to all Aboriginal communities in the area under NHC control (or even further afield), the prevalence of trachoma could be further reduced with a relatively modest investment. Ewald et al.\(^{24}\) have also advocated a similar regional approach to the control of trachoma in a remote area near Alice Springs, despite the failure of their intervention to significantly reduce trachoma prevalence in one largely Aboriginal dominant (90%) indigenous community. Johnson and Mak,\(^{201}\) whose area of successful intervention—the Kimberly region that borders the subject territory described by Ewald’s study—suggest trachoma control should be under the auspices of the State and Territory departments to improve coordination of interventions.

### 6.3 Examination Rates

Two other SAFE-type programs to the author’s knowledge have been implemented in Australia, one in the Kimberley region of western Australia,\(^{201}\) and the other\(^{24}\) adjoining it, some 300 km from Alice Springs. These studies were published after the study itself was being completed. While no detailed examination rates were reported for either study, the participation rate in the latter varied from 49-83% for under 13-year-olds (only 24% were examined three times versus 32% for adults). In a previous study of the same region, the author and his colleagues found that despite a 50% absence of registered residents during the study period, his group was able to achieve an overall examination rate of 75%.\(^{202}\) In two other trachoma surveys of Aboriginals in Australia, researchers reported participation rates of 54% or 74%\(^{8}\) (calculated on the basis of projected census data and populations lists respectively) and 61-100%\(^{76}\) (varying response rate according to age group). Clearly
the maximal participation rate of 85% of those registered and over 98% of those available for examination in this study (14% of registered participants at Mimili were never examined, while the figure for Pipalyatjara was 16%) compares very favourably with these other studies, and might even be superior. Nevertheless, it is acknowledged that the participatory rates of certain age groups, particularly at the 3- and 6-month post-intervention points, could have been better.

The advantage of multiple examinations over a relatively long period of time versus a one-time “snapshot” type of examination is that it allows one to probe and better define characteristics of the disease with regard to population variables and longitudinally related factors such as seasons. This approach also provides more accurate data, especially with regard to establishing trachoma prevalence and risk factors. It is, in addition, the only reliable method to enable a high participatory rate when the subject population is highly mobile. Comparing the two communities, the examination rate increased at Pipalyatjara with time (with the exception of the 6-month post-intervention visit), while the rates at Mimili were relatively constant (see Figures 21a and b). This contrast is reflected in the significantly different mean number of examinations per person (higher by 0.5 for Mimili), and the 18% significantly higher average examination rate for residents at Mimili. Again, these statistics underscore the finding that the population at Mimili is less mobile.

With regard to age, children under the age of fifteen were generally more available for examination at both communities compared to adults, although at Mimili, about 25% more on average were examined per visit. There are no known specific reasons for this disparity, such as school holidays or sporting events, suggesting that the children at Pipalyatjara were more peripatetic than their Mimili counterparts. In terms of overall examination rates, the important point to note is that children under fifteen were screened one third more often than the segment of the population aged fifteen years or more (this was statistically significant), with a mean examination rate of 66%. This is critical, since the study focused on the age group that was most likely to harbour active trachoma. However, it was noted that by the third visit to Pipalyatjara, adult examination rates had noticeably climbed, even though they rarely approached the higher numbers observed at Mimili. No significant differences in examination rates between genders were found for either community.
6.4 Clustering, Crowding, and Grouping

Like many infectious diseases, the prevalence of active trachoma (best classified as TF + TI) in many undeveloped countries, especially Africa, has been described as clustered, at the community, or even subcommunity level.\(^{(43)}\) Moreover, evidence has been steadily mounting that even at the household level there is a clustering tendency, manifested by two or more siblings showing clinical symptoms. Marx,\(^{(81)}\) in reviewing the early literature on social factors and trachoma lists such countries as The Gambia, South Africa, Malawi, and Saudi Arabia where researchers found a clustering tendency. However, most studies are not aimed at studying clustering per se, so confounding variables and sampling schema usually prevented extensive statistical analysis. In Australia, reports from many surveys and interventions mention crowding as a general socioeconomic factor, but do not discuss clustering at all.\(^{(24,76,100)}\) Ewald et al.\(^{(24)}\) elaborated a little further and pointed out that in their studied community, the density of persons/house was about three times the national average, although they did not outline a similar figure for persons per bedroom.

In this study, the number of persons registered to a household was investigated and extensively analysed by univariate analysis to see if it was a risk factor, however, no significant correlations to trachoma prevalence were established. The data have also been scrutinized to see if number of children per household was a factor, but again, no pattern emerged. One possible reason for the failure to observe significance in these types of crowding situations at the household level is that most children and many adults tend to visit one another and frequently sleep over in different houses. This is a phenomenon well-documented in the UPK study by Pholeros et al.,\(^{(88)}\) and quantified by Ewald et al.\(^{(24)}\) at 13-17% for under 13-year-olds concurrently living in more than one house in their studied Aboriginal communities. In other words, the classic ‘household’ paradigm that is the norm in a more developed community does not apply to the Aboriginal community. Moreover, the number of households inhabited by a small number of individuals, including children, is low. These (and the large mobility factor) are the major reasons why a community-wide intervention was adopted, rather than the typical household-level targeted interventions tried in many other countries. Because of the mobility of the inhabitants at the community level, the traditional meaning of the epidemiological term ‘cluster’ was thought to have less relevance in Pipalyatjara or Mimili. For example, from the mapping studies of the
communities almost two-thirds of families at Pipalyatjara had at least one child with trachoma, and this statistic did not change by 12 months into the intervention. A similar pattern was observed at Mimili, except that the percentage of families having at least one child with trachoma was a little higher. Because these children would typically be found in different houses fairly frequently, the mapping data represent a constantly moving target. Ewald et al. (personal communication) did note some tendency toward clustering in some of the surveys of the subunits of their larger Aboriginal communities. However, they also agreed this is not the classic clustering one describes in the epidemiological literature. It is noteworthy that the Kimberley intervention, which uses a protocol of azithromycin treatment for children aged 1-5 years, and identified cases plus household contacts who have trachoma (age 5-16 years), has been very successful. This suggests that this is a good strategy even in cases of high intra- and inter-community mobility, provided it is a continuous and not one-time intervention.

Despite the general opinion that clustering was not a significant factor in this study, both pre- and post-intervention TF trachoma prevalence data, as well as the multivariate risk factors using both TF and TF or TI data were subjected to a GEE approach that accounted for this factor at the household level. (The risk factors were also adjusted for number of baseline examinations.) For the trachoma prevalence data, the result was only a small change, indicating that clustering was not a significant factor. For the risk factors, the changes were more profound, but might have related more to the adjustments for number of baseline examinations; these are discussed in more detail in section 6.10.

6.5 Determination of Baseline Prevalence

6.5.1 Variation of baseline prevalence data

The period of time from which the baseline data were drawn—March 1999 through September 2000—showed considerable variation using prevalence data adjusted for clustering. One way of comparing pre- and post-intervention prevalence data, is to average it; in addition, the baseline prevalence of the major parameters is required to make comparisons with other studies. The appropriateness of the averaging method is the subject of the next section, but an even more fundamental question has to be asked: Is it appropriate to average the baseline data at all? For
example, is there a cyclical pattern to the data, or is there an unknown factor that is affecting this longitudinal data?

Although many researchers think that trachoma prevalence does have a seasonal variation (depending upon the geographical area studied), the few studies that have been performed are not conclusive, in the author’s opinion. For example, in Nepal, Holm et al. surveyed four wards at two times of the year for baseline trachoma prevalence data—late March and early December—and found a reduction from 28.5% to 19.3%.(10) This is probably the best study to date on the subject of seasonality, and while the sample numbers were sufficiently large for the change to be meaningful, but the authors did not consider other factors besides season that might account for the difference, and the surveys were not six months apart.

Reinhards et al.’s studies in Morocco during the 50s and 60s are often quoted as showing evidence for trachoma seasonality, but in fact, the only conclusive fact one can draw is that conjunctivitis probably has a seasonal component that interacts with trachoma.(178) The studies are flawed by today’s standards, and the methodology employed makes it difficult to compare these results with more contemporary ones.

In northwestern Australia, da Cruz et al. suggested that based upon bush fly counts and trachoma prevalence determined by the simplified WHO methodology in three Aboriginal communities during February and July, a definite seasonal correlation existed.(177) The study used small samples though, and no rainfall data was presented to delineate the wet/dry seasons.

Based on the results, which present the most complete set of climate and trachoma prevalence data to date in Australia, no obvious correlation between season and rainfall was observed. For example, one period of high trachoma prevalence lasted six months from March through September 1999 (winter), and the low prevalence point of April 2000 that followed in fall were both preceded by long periods of significant rainfall at both communities. If Reinhards et al. suggestion of a seasonal-related conjunctivitis(178) that might exacerbate trachoma prevalence is assumed, by inspecting Figure 29 one might think that the spike in trachoma prevalence in September 2000, when pollen counts are starting to rise, could be due to such a possibility. However, while the prevalence in September 1999 is similarly high, it also had been high for several months prior to this month. It can be argued therefore, that the trachoma prevalence variation is probably not due to any seasonal or short-term climate change, but the result of other unknown factors. (Though one could always
assert that there were insufficient sampling points to make these determinations.) This lends some justification to using the average method for calculating the baseline prevalence of major parameters in this longitudinal study, though it also questions the veracity of seasonal influences on trachoma prevalence cited in the literature.

Other possibilities could include one or a combination of the following, which are not typically described in the literature:

1. The mobility factor at Pipalyatjara works in favour of individuals there (less chance of infection), because it takes them away from a high-risk infection area.

2. The water could be contaminated at one community with bacteria that might predispose an individual chlamydial infection. This possibility was examined by researchers at the University of Newcastle and rejected (they also examined waste water), though it should be noted in general that the high mineral content of the water interferes with the working of appliances and the flow of hot and cold water because of deposits.

3. One community could be hosting a more virulent strain of Chlamydia. Although researchers have demonstrated differences in strains between coastal and more interior Aboriginal communities in the Northern Territory, (58) it remains unknown whether the communities are far enough apart geographically for this possibility to occur.

4. Combinations of factors are at work at different times. For example, a strong wind blowing for a period of time raising dust levels, in conjunction with a higher than normal level of conjunctivitis.

6.5.2 Use of different baseline measurements

Since the focus of this study centred primarily on children under fifteen years of age, it was important to examine as many children who were registered for the study as possible at each visit. At Mimili, the percentage seen at each visit was fairly constant—in the 65%-80% range. At Pipalyatjara, though, the variability was considerable due to the more mobile population, and was in the range 25-75%. The lowest numbers were mostly recorded at the five baseline visits. Therefore, it became important to be assured that the average method used to calculate the baseline prevalence of the measured parameters was, in fact, valid. As described in the
Methods section, parameters were assessed by averaging, and crosschecked by using worst grade, grade at first exam, and random selection of visits.

In general, the prevalence rates of the major parameters measured at first exam were about 10-15% higher than averaged rates. Worst-grade rates were 50-100% in the adverse direction compared to averaged rates, which clearly could be a very misleading method to use. Most of the earlier and more contemporary surveys in Australia and Africa typically compare to, or could be graded worse, than first exam rates. Since a relatively low percentage of the population is examined at a visit, as a result, these studies tend to over- or underestimate the prevalence of trachoma and associated factors by varying degrees. The fact that in our study, first-exam and averaged rates were typically about 10% different is reassuring as far as the methodology of the examinations are concerned, and the use of averaged rates no doubt improved the accuracy of the parameters measured. Another method, which employed a random selection of visits to produce the baseline data, showed results within 1-2% of the averaged rates for trachoma and degree of nasal discharge prevalence, but 10% higher for facial cleanliness.

Because of the variation in trachoma prevalence during the baseline visits, and of particular concern, the September 2000 data, which seemed on the low side, a sensitivity analysis was conducted by omitting this data. The result was an increase of about 3% averaged for both communities, which showed that its contribution to the baseline data set does not unduly influence the average.

### 6.6 Effect of Absentees on Assessing Prevalence

Although the refusal rates in this study were extremely low (2% overall), approximately 15% (105 people) of those registered for the study as visitors or permanent residents were not examined. Although their trachoma status was not known, the assumption was made that depending upon their age, they had a similar trachoma prevalence to the examined groups. Slightly more than 41% of the 700 enrolled participants had four or more exams of which 47% (approximately 134 people) were under the age of fifteen. There were also significant differences between the communities regarding examination unavailability at any given time, which averaged 39% at Mimili and 57% for Pipalyatjara. The least available age group for both sites was the 25-44 year cohort.
The absence of potential participants in this study served to reduce the sample size, which reduces the power of the statistical analyses in general. In particular, since trachoma is most common and readily diagnosed in children, the absence of children can skew the results of a study toward an artifactually low prevalence rate. However, the relatively high participation rate for this group, plus the fact that much of the data was averaged, which improved the accuracy of prevalence assessment, mitigated this problem. More problematic is that the data for Pipalyatjara has a higher variance compared to the data for Mimili, which most likely reflects the mobility problem already discussed, but possibly other factors more associated with this community.

6.7 Prevalence of TF and TI

6.7.1 The WHO grading system

One of the problems in comparing more recent with much older trachoma prevalence data is the fact that the simplified WHO grading system became the gold standard for clinical diagnosis around 1988. Prior to this time there was no standard classification scheme, so researchers who use older survey data have had to reclassify TF and TI. Although the WHO scheme is a much-simplified five-sign categorisation, it avoids grading particular signs by their severity, and deletes well-known signs, such as Herbert’s Pits, papillae, and pannus. However, confusion still exists among researchers as to whether TI is a sign of active trachoma. Given the fact that the inflammatory response can persist for several weeks or months after initial or a recurrent infection, this is no small matter. This is why some authors combine TF and TI in their prevalence rates.\(^{204-206}\)

In addition, some investigators believe that because TI can be so difficult to diagnose—and therefore TF as well—due to the conjunctival thickening, it does not necessarily mean that patients do not have trachoma. If they did not, it would be hard to explain why the scarring of tissue often progresses in severity and eventually produces TT. This process, though, could in part, also be due to a prolonged autoimmune phenomenon. In elderly individuals who also have the problem of tissue laxity, they are also likely to have ectropion and/or ptosis.

Another problem with the classification is that the clinical diagnosis of TF requires five or more follicles of at least 0.5 mm diameter. Clearly, on this basis, some cases of TF will be missed, leading to an underestimate of trachoma prevalence. This
kind of problem has led some investigators to subclassify TF during their research studies. For example, Solomon et al. note(52): ‘To overcome this problem, in our own research programs, follicular trachomatous inflammation is graded as absent (0), present (1), or mild (M, one to four follicles in the central part of the upper tarsal conjunctiva).’ Unfortunately, this kind of detailed data is rarely published in large studies. Moreover, as these same and other authors have pointed out, ophthalmic diseases caused by other pathogens, such as conjunctivitis, can be counted as TF, especially when no laboratory tests are carried out. Both these problems were undoubtedly present in the study, though it is likely that they affected < 5% of the data, in the author’s opinion.

6.7.2 TF/TI Prevalence surveys in Australia

Several researchers have attempted to compare older surveys with more recent ones they have carried out. Despite the fact that considerable effort has been put into reinterpretting the data, which were based upon older classification schemes, caution should be applied in any comparison to surveys carried in the 1990s or later. This is an attempt to compare ‘apples versus oranges’ to ‘apples versus apples’.

In the Northern Territory, trachoma prevalence (assumed to be TF + TI) for children (age unknown) declined in the ‘Top End’ from about 78-91% during the period 1955-1964 to about 5-15% in 1985.(207) In the more central part of the territory, it has declined far less, from about 90-100% to around 37-69%. (In the author’s opinion, the older prevalence numbers are almost certainly overestimates, because of grading problems.) Stocks et al.(76) reported prevalence rates in the years 1976, 1985, and 1990 for Aboriginal communities in central/South Australia—the same communities as this author examined—(TF + TI) as 13%, 15%, and 22% for the age groups 0-4, 5-9, and 10-19 (author’s estimates of averages from the paper). But a more accurate early nineties survey(17) found TF prevalence to be in the 18-38% range for children, the highest peaks occurring in the 2-9 year-old groups. TI rates for the 0-1 year-old group were about 10%, declining substantially for older children, and again rising in mature adults. More recent studies(24) estimating infectious trachoma prevalence (presumably TF) in children aged thirteen years or younger at 40% suggest that prevalence is on the rise in this area. Another recent report concerning East Arnhem in 2002 detailed an overall prevalence of active trachoma in children aged 4-15 years as 26%, with a range of 17%-38% in seven communities.(83) This apparently
surprised the CDC in the Northern Territory as they had thought that in the mid nineties, the prevalence was < 5%.

In western Australia, trachoma prevalence in Aboriginals was reported in one study to be correlated with distance from the coast. Reported rates in children under five years of age varied from 12%-25% in coastal communities, 50%-63% in semi-arid areas, and 52%-98% in arid areas (the Pilbara region). Other investigators of Aboriginal populations in western Australia have found TF rates in children aged 5-15 years of about 25% at roughly the same time period (1990), which is considerably lower, even if one presumes that children under five years of age are probably more likely to have a higher prevalence. Another study of communities in the eastern Goldfields and Kimberley regions comparing 1977 with 1984-85 TF prevalence data in 0-9 year-olds showed a reduction of 26% to 9%. The 1985 data seem on the low side, but since examination procedures were not reported at all, there is no way to know if under-estimation occurred. (For example, from the author’s study, trachoma prevalence estimated from a single screening was 10-30% higher compared to prevalence estimated over several visits.)

6.7.3 Prevalence of TF and TI in this study

The overall prevalence of TF in children less than 15 years of age, pre-intervention, averaged 42% in Pipalyatjara and 44% in Mimili. The highest prevalence was found in children aged one to nine years in both Pipalyatjara (51%) and Mimili (54%). The prevalence of TI determined in this study was considerably lower than that of TF, with a combined average of 8% for Pipalyatjara and 9% for Mimili. However, the age distribution was similar, with peak prevalence in the 1-9 year-old group.

6.7.4 Comparisons with other reported studies

Compared against older surveys (except for the report by Meredith et al.) the active trachoma prevalence rate for children determined in this study is considerably higher—nearly two-fold. However, the results are relatively in line with more recent studies conducted during or since 1999 in central/South Australia: 36%, and 40% among children under 13 years old. Nevertheless, the prevalence of TF is still higher than either of these studies. Most likely, the results reported here reflect better assessment of actual rates due to more extensive assessment and involvement of a
higher percentage of the population. In addition, anecdotal reports suggest that many of the other studies used inadequate evaluation techniques (diagnosis without loupes or adequate light) and did not seek out children if they were not present in school at the time of the visit. The Stocks et al. study\(^\text{17}\) also suffered from the decision to combine adult data with those of children, which results in a considerable underestimate of TF prevalence. Since active trachoma is largely a crèche disease and can be difficult to diagnose properly in adults due to inflammation if the individual has been exposed to the disease in childhood, only children should be included in active trachoma statistics. Inclusion of adults normally tends to underestimate the total prevalence.

Another possibility is that the current study’s data reflect a selection bias inasmuch as those with eye problems might be more motivated to participate in the study. This is because the study included a significant educational component with messages translated into Aboriginal languages and illustrated by Aboriginal artists. However, this possibility should be discounted due to the very low refusal rate and the fact that every effort was made to examine all those present available for examination.

While the prevalence of TI reported in this study agrees with several other studies in the region in which TI is reported separately, other investigators have consistently found a peak TI prevalence in children under one year old, while in this study the age distribution of TI matched that of TF, peaking in the 1-9 year old group. The discrepancy could be due to increased availability of medical care and improved hygiene practices, or could represent a grading inconsistency between the studies. For example, obscuration of the large tarsal vessels by tarsal plate scarring with diffuse fibrosis, or formation of a fibrovascular membrane are known to confound diagnosis of TI, although these phenomena are more commonly found in elderly victims of trachoma. In addition, dust or smoke irritation—certainly a factor in many central Australian Aboriginal communities—might also confuse the grading of inflammatory trachoma.

In various regions of Africa, historically reported levels of TI in children have often been much higher than in Australia, typically 15-20\(^\text{,148}\), which leads to more severe symptoms, an increased morbidity, and sequelae. Finally, as noted in the literature review, current levels of prevalence of trachoma in Australia are difficult to determine with any accuracy owing to the highly mobile lifestyle of the population. The prevalence of trachoma in the Aboriginal population can easily be underestimated.
as fewer children are available for study as a direct result of living within a highly mobile community, as was amply demonstrated in Pipalyatjara. Another consideration is the large fluctuations in the rates themselves, which are not uncommon in multi-year longitudinal studies and most likely represent the seasonal and cultural vagaries of movement between rooms, houses, and communities. It is important, nonetheless, to note that WHO defines hyperendemicity as 20% prevalence or greater, and nearly all published studies from Central Australia exceed this value. Thus, although there is wide variation in the actual prevalence between studies, the majority of researchers agree that trachoma is still hyperendemic in Central Australia. It is, therefore, still a Public Health problem. With this in mind, the author continues to advocate for a concerted program between all interested parties to cover all the communities of the AP Lands for the SAFE strategy, and which can be extended to other communities adopting housing-for-health strategies previously discussed.

6.7.5 Pre-intervention: age, gender, and other variables

In this study we included children up to 15 years old, because the prevalence of active trachoma is still high, and preliminary data suggested that in the communities studied, 15 years of age was a good cut-off point. However, in many other studies, data are reported for children up to 9 years old as in many parts of the world prevalence falls off considerably after 9 years of age. In Africa, for example, where for cultural reasons, children tend to leave the dense family living quarters, they suffer fewer reinfections as a result. In Aboriginal communities this is less true, because most male Aboriginal teenagers do not go hunting or look after cattle, but tend to stay within the family unit, and hence are more closely in contact with pools of infection.

In our study, the odds of children in the 1-9 age category contracting TF compared to children older than ten years was significantly higher at an odds ratio of 2.0. This result is not unexpected. However, what is noteworthy is that at Mimili, the prevalence of TF was nearly double for children under ten years of age compared to the 10-14 year-olds. At Pipalyatjara this ratio was nearly three-and-a-half times. This suggests that the mobility factor at Pipalyatjara might be responsible for the difference, though other factors could explain this finding.

Recent data published by West et al.(1) confirm that of Solomon et al.(68) in establishing that very young children (≥ 2 years old) are major reservoirs of infection. In terms of this study, trachoma prevalence was high for the < 1 yr-old group at
Pipalyatjara, but zero for the same group at Mimili (though far less children were involved). As the study progressed and this group aged, there could have been some impact to raise the baseline trachoma prevalence levels, but comparing the data for the 1-9 year-olds, there was not a larger spike observed at Pipalyatjara; indeed, a far larger spike in September 2001, just prior to azithromycin administration was observed for Mimili. Therefore, it seems doubtful that this very young age group had a significant impact in terms of the longitudinal aspect of the study. Taylor and Dax contend that many infants do not show clinical signs because ‘they are too immunologically immature to develop trachoma follicles’, but the data from Pipalyatjara for < 1 year-olds seems to discount this possibility.

With regard to gender, there was no significant difference in TF prevalence at either community. A slightly higher prevalence was seen with males in the 1-9 year-old group, however, in the 10-14 year-old group, the prevalence was slightly higher in males at Mimili, but the reverse at Pipalyatjara. This observed pattern is in contradiction to many studies of trachoma in children conducted in other countries, especially Africa, where TF rates for female children are higher than males. The argument is that young females act as caretakers for preschool children, and hence are more exposed to reservoirs of active disease. While in the communities studied here that is also true to some extent, other factors, such as mobility, and the presence of young male teenagers, dominate.

At the time this study was conducted, a few researchers were beginning to suspect that in some children there were cases of chlamydial infection—sometimes called a ‘quiescent infection’—without clinical symptoms present. Though in a proportion of cases this might be expected, because after infection, there is a lag of several weeks before clinical signs manifest themselves, evidence was based on early PCR results, which might have been questionable. More sophisticated PCR data, including that of Solomon et al., West et al., Burton et al., and Bird et al., however, have provided more solid evidence that infection can be present, sometimes for several months, without clinical signs. Wright and Taylor recently summarized some of these findings, though caution that due to inadequate precautions against possible specimen contamination, earlier studies should still be regarded circumspectly. The reason these findings might have significance for this study are twofold: (a) in some instances, adults harbour more of these type of infections, particularly when trachoma prevalence is hyperendemic—we principally studied children, (b) some of these types
of infection show resistance in the face of one antibiotic administration, and (c) it is unknown how infectious individuals with these types of infection are. In Kongwa, Tanzania, for example, West et al.\(^1\) noted that some 23% of individuals harboured high-load chlamydial infections, but showed no sign of the clinical disease.

This longitudinal study represented a time span of approximately two-and-a-half years, probably not long enough to be affected by overall economic factors, but likely to be impacted by weather and environmental factors. One important aspect is the difference between the rainy season, February, and the dry season, July. Da Cruz et al investigated the seasonal variation of bush flies (\textit{Musca vetustissima}) in northwestern Australia Aboriginal communities with regard to TF prevalence in pre- and primary school children, and found significant association between season and TF prevalence in two out of three communities.\(^{177}\) These investigators noted that numbers of bush flies dropped so low in the dry season that it was impossible to estimate their numbers. But they suggested that the TF variation was due to fly populations. \textit{M. vetustissima} is well known for its eye-seeking behaviour in humans, though its ability to act as a transmission vector for \textit{Chlamydia trachomatis} remains unknown.

In the communities studied there are no cattle in the area and the overall use of latrines or toilets is very good, so dung appears not to be a major factor. It was also noted by the author that since most of the children were examined indoors (in the school), few flies were recorded on the children’s faces upon examination. That is not to say the fly problem did not exist; rather that flies can only be conjectured as a major transmission vector for children outside of the school setting.

Examining the overall TF prevalence in the pre-intervention stage also showed no correlation whatsoever with season, despite rain-gauge data that confirmed seasonal, and far-above average rainfall. If association is not present with that kind of magnitude rainfall, it is certain to be absent in an average rainy season. Another factor that is thought to aggravate the epidemiology of trachoma is the presence of dust, which, according to data obtained during the pre-intervention period was confirmed as high in some locations, particularly near roads and parking areas. This problem was addressed in the SAFE intervention at Pipalyatjara, and will be discussed further.

### 6.7.6 Post-intervention: age and gender

The post-intervention data for TF do show some interesting results with regard to age and gender. Generally speaking, except for one case of active trachoma, at 12
months into the interventions, children aged 10-14 years were free from the disease. For the 1-9 year-olds, however, it still persisted to varying degrees (much more in Mimili), and overall, much more in females. At Pipalyatjara, the site of the SAFE intervention, there was only one case of active trachoma in the male subpopulation, while approximately one third of the females still had trachoma as shown by clinical assessment; at Mimili, the percentage of males and females who still had trachoma was 36% and 55% respectively, a 39% reduction and a 10% increase (male, female).

For the same age group it was also observed that a substantial rise in trachoma prevalence levels occurred from the 3-month post-intervention point to the 12-month point in Mimili (more than double), whereas at pipalyatjara, it decreased slightly. Most interesting was the finding that between the baseline levels and the 3-month post-intervention point, the decrease in trachoma prevalence was double for males, compared to females. The pattern suggests that as the intervention progressed, perhaps one underlying pool of infection—the 1-9 year-old females—became dominant regardless of the intervention site, though without lab tests, this is supposition.

Whether the E component of SAFE was solely responsible for the difference, albeit more so with males than females, remains unknown. Chance, or other factors cannot be ruled out. Burton et al. noted from their longitudinal study in The Gambia that following a mass antibiotic treatment, toward the end of the study, ‘…a small group, consisting mainly of children emerged who were infected at consecutive time points with high infection loads…. as C. trachomatis became increasingly confined to a small group of children who seemed to have difficulty in controlling the infection.’(200) In addition, researchers have noted that the clinical exam detects a much greater proportion of infection in children aged 1-5 years (78%) than in those aged 6-10 years.(209) It could also be further speculated that in these Aboriginal communities, young females probably face higher risk factors for trachoma, possibly from caretaking roles, other behaviours, or even gender-related susceptibilities that set them apart from young males. West et al. (43) noted a similar pattern from surveys of villages in Tanzania with regard to preschool females, although in our study, this pattern was not obvious in pre-intervention (baseline) examinations.
6.8 Prevalence of TS, TT, and CO

Very few members of the study population had CO (Corneal Opacity) or TT (Trachomatous Trichiasis). TS (Trachomatous Scarring) was also comparatively rare with a presence of only 5%, representing nine children less than 15 years of age. (The prevalence of TS started as early as 1 or 2 years of age and gradually increased at the age of 45 years or older when almost 95% had TS.) However, the 5% is a high percentage, even when compared to survey findings in Tanzania or Kenya. As other studies have shown, TS, TT, CO and eventual blindness increase dramatically with age as repeated infections take their toll, but are not to be expected in children. TI tends to decrease in adults, but this is likely because diagnosis of TI can be difficult in adults when there is extensive scarring. Nevertheless, the progression to TT and TS in adults suggests that repeated bouts of infection occur, and that a long history of the disease can predispose the individual to more prolonged episodes of TI from a single acute infection, due to the hypersensitivity that develops as a result of the chronic presence of Chlamydia antigen.

In the author’s opinion, there is also a potential problem with the WHO classification, as it does not account well for the severity of scarring. Thus it can be difficult to determine which individuals are at a higher risk of actually developing TT, and consequently CO.

6.9 Major Factors Associated with Assessment and Treatment of Trachoma

6.9.1 Age

As has been discussed throughout this thesis, active trachoma in a hyperendemic community starts with children younger than a year old, typically peaks (in terms of number of infections, and severity of infection as measured by TI) at about 4-5 years old, and gradually tapers off with the age of the child. By the time the child is 10-14, instead of semi-continuous and/or low-level TF infections, the child tends to experience less acute attacks, and this diminishing pattern continues into adult life. Unfortunately, the repeated attacks in childhood lead to a hypersensitivity, trichiasis, corneal scarring, and blindness if left unchecked in the adult, especially if hyperendemicity continues within a community. It is for this reason, that even if
interventions in Aboriginal communities are successful, there will be a need for corrective surgery until this older cohort dies.

6.9.2 Hygiene

Trachoma has been characterized as a disease of the rural poor, but historically was widespread in cities during the seventeenth and eighteenth centuries when hygienic conditions were so atrocious. With the general improvement of socioeconomic conditions, it has now been eliminated in developed countries, which leads some investigators to think that in the long-term the disease would be eliminated whether planned interventions were carried out or not. This not likely to be the case in all countries, especially where hyperendemic conditions prevail, though the data from Nepal is quite convincing.\textsuperscript{137} Some investigators ascribe the virtual elimination of the disease to concurrent administration of antibiotics for other diseases,\textsuperscript{82} and perhaps a threshold effect, such as the Allee effect.\textsuperscript{211} In any case, the most important factor is to eliminate the blindness that results from recurrent infections in childhood.

In terms of risk factors, hygiene is difficult to dissect into components, since many are correlated with each other, and in poorly designed studies often confound each other. Moreover, hygiene—or lack of it—is as much a function of crowding, as it is of economics, priorities in poor families, lack of education, and the social dynamics at the family and community level. Depending on environmental conditions, different hygiene practices and factors become more or less important. Thus in Mexico, lower prevalence of trachoma in children was associated with frequent face washing, and separate cloths to dry faces and blow noses,\textsuperscript{90} while in Africa, access to water is tied into personal hygiene practices, since it dictates how much water is available to the household.\textsuperscript{157} Other factors that have been identified in various geographical locales include garbage disposal, the presence of latrines, cooking fires, and personal hygiene.\textsuperscript{4} Ultimately, whatever aspects of hygiene are identified, the bottom line is to reduce transmission from person to person or vector transmission by flies. In our studies, it was determined that flies were less of a problem, and it was more important to assist the community in achieving better scores on the healthy living practices and upgrading the housing from the health hardware point of view.
6.9.3 Community

In regions of hyperendemic trachoma, most communities are relatively small units in remote areas, which leads to the consideration, does one attempt to reduce trachoma at the community level, at the household level, or employ a more classical targeted strategy of only treating those clinically diagnosed with trachoma and possible contacts? For example, arguments have been made that it does not have to be cost-prohibitive to treat entire hyperendemic communities annually with azithromycin, even without the generous programs funded by Pfizer, although there are coverage, monitoring, and compliance issues.\(^\text{(206)}\) At the same time, intervention researchers have found that health education programs have to be administered at both the community and household level to work successfully,\(^\text{(4)}\) a practice adopted in this study, but not documented in great detail in this thesis. In addition, we tried to involve the children as well as the adults, although the author is unaware of any studies that have focused on this particular aspect. One of the most critical keys to success is to utilize as many channels as possible, i.e., community meetings, intensive school programs, radio and TV messages, and walk-in policies at clinics to assist those individuals who have limited bathing or washing facilities, and in additionally, our case, visits to individual households by AHWs facilities. Finally, visits by AHWs (Aboriginal Health Workers) to individual households were made. The above studies, the mobility factor, and the WHO approach to interventions, plus the relatively small size of the communities, were the primary factors that lead us to adopt a community-based approach.

Last, it is wise to consult with elders, council members, and other prominent community leaders to achieve an endorsement, determine who has decision-making authority, and ensure that the individual components of any intervention are carried out as planned. In Tanzania, for instance, it was found that the males of the household had to endorse specific hygiene practices before their spouses could carry out any actions.\(^\text{(205)}\)

6.10 Risk factors associated with trachoma

6.10.1 Overview

Some investigators have lamented, especially with regard to earlier studies of trachoma, a lack of in-depth statistical analysis of risk factors. So, in this study, a
careful design was undertaken so that univariate, multivariate, and correlation analyses could be performed. After having established that prevalence rates of trachoma were similar based upon average baseline and first-time examinations, it was decided to utilize the latter set of data for univariate assessment of risk factors, and then develop more sophisticated multivariate GEE models to take into account clustering, and the baseline examinations, for both TF and the TF or TI datasets.

The results of univariate analysis produced the following factors in order of significance: No nasal discharge > age less than 1 year old > absolutely clean face. Due to the small numbers, the significance of factor two is doubtful. Interestingly, household person density, gender, community, and other subsets of household hygiene were not significant.

The multivariate analysis showed differences with regard to whether TF alone, or TF + TI was considered. In the former case, association with TF for age 1-9 years was significant (OR: 2.0), and nasal discharge factors were extremely significant: clear (OR: 3.5); abundant (OR: 4.5); and micropurulent (OR: 15.8). In the latter case, a dirty face was highly significant (OR: 2.2), and nasal discharge factors still remained factors, though they were less significant: clear (OR: 3.7); abundant (OR: 3.3); and micropurulent (OR: 6.7). These results demonstrate that minor alterations in how risk factors are assessed can profoundly change the outcomes when using datasets comprised of relatively small samples.

6.10.2 Age and gender

Historically, all studies have shown that active trachoma is most prevalent in children regardless of country surveyed, however, there is little uniform stratification of children by age. This sometimes makes comparison of risk factors in different countries and communities problematic. In hyperendemic areas, a general correlation also exists with age of the individual, and the frequency and type of trachoma clinically observed. Thus children exposed to repeated episodes of TF or TI do not suffer as many attacks in later life, but instead bear the sequelae in the form of TS, TT, and CO.

In our studies, younger children were twice as likely to develop TF than older children aged 10-14 years—the odds ratio of this risk factor dropped to 1.9 and became non-significant when cases of TI were added. However, it must be borne in mind that this OR calculation was made with a relatively small sample (≈ 50), and
that a subgroup of at least 130 individuals is required to permit detection of a significant OR of 3 with a power of 80% and a CI of 95%.(4) In Tanzania, West’s group has not reported a breakdown in OR for children by specific age groups, but in one study the authors showed that for preschool children at least, the odds of contracting TF were highest when a sibling already had the disease (4.8), and the child had an unclean face as well (6.8).(145) On the other hand, in The Gambia, Burton et al. found little difference in the risk association of active trachoma and different age groups of children.(200) In a later study, in Kongwa, West et al. reported an OR of 9.3 of 0-5 year olds, versus an OR of 5.6 for 6-10 year-olds, and an OR of 2.8 for 11-20 year-olds for predicting high chlamydial loads.(1) Moreover, in this same study, females had a higher odds of carrying higher bacterial loads (OR: 1.5). Unfortunately, little risk factor data have been reported in the literature for Aboriginal communities in Australia.

Various studies, particularly in Africa, have noted that adult women tend to run higher risks of contracting TF, especially when they are caretakers,(104) but there appears to be no overall consensus that young female children are more at risk than males. According to clinical and laboratory investigations carried out by West et al., female children demonstrated a higher prevalence of trachoma, but positive identification rates of Chlamydia species were equal to their male counterparts.(154) The authors of this study suggested that ‘the course of inflammatory disease in younger children and girls was longer because of more frequent transmission of Chlamydia species among these groups,’ but also admit that the methodology of their study might also be flawed.

In contrast, in western Australia, for instance, Van Buynder et al reported that males in the age group 5-18 years had the higher TF prevalence (RR for girls the same age range was 0.63),(100) but this tends to be the exception, rather than the rule. The lack of good correlation between trachoma clinical signs and Chlamydia culture identification techniques in the laboratory also makes investigation of this possible gender difference in young children difficult to resolve.

6.10.3 Facial cleanliness

The majority of more sophisticated trachoma surveys and interventions have focused on face washing procedures and assessment of facial cleanliness—indeed this was the foundation for the F component of the SAFE intervention. In terms of a
strategy to reduce trachoma prevalence (usually in combination with antibiotic administration), face washing has historically achieved mixed results. This is because some designs were flawed, or the procedure could not be carried out adequately. For example, who is the responsible party, and does there exist at various levels within the community agreement that the responsible party—usually the mother—is permitted to do so. Poor compliance, or supervision or monitoring of the procedures is also another issue.

In reviewing the literature through 2001, Bailey and Lietman said that face-washing alone interventions were virtually useless: “Unfortunately, it has been difficult to show that facial cleanliness programs substantially reduce the prevalence of trachoma in communities. Several studies have attributed changes in the prevalence of trachoma to such programs without adequately accounting for chance variation, seasonal effects, or secular trends.”(8)

However, in general, most investigators are beginning to see that facial cleanliness should probably be added as an item for assessment, not just the act of washing per se in conjunction with clinical diagnosis. One interesting observation the author personally made was that all the faces of non-indigenous children examined at schools in the study (because their parents worked in the communities) were always clean, and no child exhibited clinical symptoms of trachoma.

One current issue of contention lies in what constitutes a clean face. In this study, faces were classified as absolutely clean, partially clean, or dirty. WHO defines a clean face as the absence of eye and nasal discharge, but some researchers, notably West’s group, report a clean face as ‘having none or only one facial sign present’,(157) which makes comparisons to other studies difficult. Moreover, unlike clinical assessment of trachoma, few interobserver statistics have been published on agreement of facial cleanliness categories. West et al. published some Kappa statistics in 1991 for ocular and nasal discharge that seemed to suggest that agreement can be similar to trachoma assessment using the simplified WHO methodology,(145) though in our studies, we do not know if that is true.

In our studies, the prevalence of an absolutely clean face at baseline increased with age, from an average of 24% in the 1-9 years-old age group at Pipalyatjara and 16% at Mimili, to 42% in the 10-14 year-old age group at Pipalyatjara, and 42% at Mimili. The multivariate analysis showed that a dirty face (not absolutely or partially clean) produced odds of contracting TF at 1.4, but this more than doubled to an OR of
2.2 with high significance, when children having TI were also taken into account. At the 12-month point, post-intervention, there were no dirty faces in the two communities regarding the older children. In the 1-9 year-olds the prevalence of a clean face had risen to 65% at Pipalyatjara, and 87% at Mimili. For the children, better facial cleanliness resulted in part from the habit of face washing instilled at school through cleaning drills, but also from the reduction in infection caused by antibiotic administration. Why it did not reach 100% in either community at 12 months into the intervention was either due to reinfection, residual pockets of infection, or continuing inflammation producing clear or mucopurulent discharge.

Some similarity to our results has been reported for different age groups. For example, in Tanzania, where in 1989, prevalence of both TF and especially TI in one and two-year-olds was very high, a clean face halved the odds of having trachoma. Another study in the same region of preschool children (1-7 years-old) showed that an unclean face gave an OR of 1.3 for TF, and 1.72 for TI. In reviewing the literature, Prüss and Mariotti noted that authors of four studies reported inverse relationships between facial cleanliness and trachoma prevalence (median protective effect: 41%). But, in another study it was found that no relationship existed. While, the frequency of face washing per se was not found to be a factor in three studies, an interesting pilot research project in central Tanzania found another possibility. By employing a UV-fluorescent cream in the study, the results revealed that one of the reasons for lack of facial cleanliness is that in young children—three years of age or less—although the face was washed thoroughly at least once a day, facial signs, such as nasal discharge, could rapidly reappear. While it was noted that over the period of a year, the quality and frequency of face washing generally improved, the percentage of clean faces (assessed on a daily basis) peaked at 62% six months into the project timeline. However, it fell back to 28% at 12 months. The results demonstrate that many complex factors are associatively involved as measured by the investigators: distance to water source, season (rainy or not), and type of dwelling (tin roof or not).

In the final analysis, one has to consider that face washing is only one component of the strategies used to reduce trachoma. The important point is to create good cleanliness habits, especially with children, so that faces are periodically cleaned, whether it is once, twice, or three times a day (see section 6.10.5). Regardless of how children look, a washed face can still become dirty!
6.10.4 Nasal discharge

Nasal discharge is probably the most highly correlated factor to facial cleanliness, though other investigators have studied dust, sleep secretion, and food as well. Nasal discharge is a consequence of having active trachoma, so it also a good, but not absolute indicator of the disease. In Africa, where flies are abundant, many investigators have further examined a combination of fly density on the face with concurrent nasal discharge, the idea being that this is a handle on the fly transmission vector. In the communities we studied, the fly problem was far less significant, and it is not believed that fly transmission represents a significant vector in the transmission of trachoma. Although the fly data was very limited, both observations, and the fact that only one fly might have had *Chlamydia* according to Dr. Dadour, both support, though not prove this conclusion.

In our studies, in our attempt to further differentiate the nature of the discharge, it was classified as clear, abundant, or mucopurulent. At baseline, in the 1-9 year-old age group, overall nasal discharge levels were 78%, compared to about 50% for the 10-14 year-olds, and there was also substantially more mucopurulent and clear discharge in the younger age group. Between the communities, some variation was observed in the various parameters, but no significant differences were found. At 12 months into the interventions no nasal discharge was observed in the older children, but 10% of children in the younger age group still had a discharge of some type at Mimili, whereas it was 23% at Pipalyatjara.

Generally speaking, the worse the degree of nasal discharge, the higher the probability of being positive for TF. So, the overall numbers observed twelve months into the intervention are reflective of reduced trachoma prevalence. However, it should also be pointed out that if faces are cleaned frequently, both facial cleanliness and nasal discharge are less likely to correlate to the presence of active disease, since the symptoms are being essentially masked.

6.10.5 Risk factor relationships in pre- and post-intervention data

The risk factors thus discussed so far provide some predictive power as far as quantifying risk of contracting trachoma when a survey is carried out in a given community. But what is the long-term power of these factors to predict the epidemiology of the disease, and how do these factors correlate with findings in SAF or SAFE-type of interventions regarding the prevalence of trachoma?
In Tanzania, West et al. carried out a series of interventions with preschool children, using a face-washing strategy.\(^{(148)}\) One year into the intervention, although there was no significant change in trachoma prevalence, they noted ‘Having a clean face at two or more follow-up visits was clearly protective for both any trachoma [TF or TI] or severe trachoma’ [TI] [OR: 0.58 and 0.35 respectively]. A follow-up study conducted five years later that used the children who participated in the first intervention project (1-2 year-olds at that time) showed that while the OR was now 0.51 for both categories of trachoma (cited above), TF had dropped from 70% to 55% and TI from 33% to 25%. The 36% increase in facial cleanliness apparently did not result from the face-washing strategy, but from other long-term economic improvements.

In comparing the pre- and post-intervention data, one of the curious discoveries made and already discussed is the apparent difference between genders in the 1-9 year olds regarding TF prevalence, especially at Pipalyatjara. From the time of antibiotic administration to the 3-month post-intervention mark, it appeared that facial cleanliness improved in concert with a reduction in trachoma prevalence. However, while the trachoma prevalence in males was reduced more compared to females, the level of facial cleanliness was similar. From the 3-month post-intervention point to the 12-month point, facial cleanliness continued to improve for both genders at Mimili, but changed little at Pipalyatjara. Moreover, at Mimili, while the overall trachoma prevalence level rose modestly, it improved for males at Pipalyatjara, and changed little for females within the same community.

It should be first stressed that these are relatively small sample numbers. Clearly, though, in this age group, after the 3-month post-intervention point, it is suggested that facial cleanliness and nasal discharge no longer became good predictors of trachoma.

The literature on this subject is scant. For example, if only antibiotic administration is undertaken, then the odds ratio of having trachoma with ocular secretions does increase, at least for the first 12 months.\(^{(200)}\) With SAF- and SAFE-type interventions, though, the complexity of interactions and different possibilities of implementing the F and E components probably make such clear-cut predictions difficult. This is perhaps why that at Mimili, while facial cleanliness and nasal discharge both improved, trachoma levels still rose modestly by the 12-month point.
6.11 SAFE versus SAF

6.11.1 The environmental intervention at Pipalyatjara

The full SAFE intervention was conducted at Pipalyatjara, because the NHC (Nganampa Health Council Inc.) had already selected this community for environmental improvements. These improvements included road sealing, the creation of mounds to improve drainage and dust control, tree planting and landscaping, and upgrade of houses. This author had no input regarding the improvements, because the NHC was implementing this part of the intervention, but agreed with the goals.

During the intervention, significant changes were made in critical healthy living practices, as well as the mound, fencing, and landscaping projects to reduce dust levels around the houses, and improve drainage. The surveys for the critical healthy living practices were carried out in March 1999 (baseline) and August 2001 (approximately 11 months post-intervention).

In general, houses were scored for each item and ‘passed’ when the score reached an acceptable figure. In many cases, there were specific improvements from survey 1 to 2, but virtually all houses failed to pass but a few categories.

Overall, therefore, a considerable improvement was made, although it perhaps fell short of desirable goals in some areas. However, in terms of the current critical healthy living practices at Pipalyatjara, the community scored highly in a survey conducted by Paul Pholeros of 700 other dwellings in similar communities (personal communication).

6.11.2 Overall difference in results between SAFE and SAF

If we take the view that the two communities represent a clinical trial with one patient in each arm, despite the fact that the trachoma prevalence rose at the 12-month point post-intervention at Mimili, while it remained constant at Pipalyatjara, we cannot conclusively say that this was due to the E component. This difference, especially when adjusted for clustering, and individuals present at baseline and follow-up is not significant, and could have been due to chance, or other factors. If the intervention had followed for another year, it is possible that this difference would have been large enough to make more definitive statements. Nevertheless, the author still believes that this was a step in the right direction. Most researchers also acknowledge that trying to tease out the F and E factors of the SAFE strategy is very
challenging. West phrases this dilemma thus: ‘Part of the challenge for research in the area of “F and E” lies in the differing ecology for trachoma within the communities, which makes generalized findings and strategies difficult.’

Analysing the findings of the 1-9 year age group—the most important age group—also reveals other interesting results. First, it appears that the children at Mimili achieved better facial cleanliness than their counterparts at Pipalyatjara. As a cohort, the group at Mimili had slightly dirtier faces at the start of the intervention, and cleaner faces 12 months into the intervention. It could be surmised that because the population at Pipalyatjara is substantially more mobile, children at Mimili perhaps employed better face washing strategies as they were in school and at home a higher proportion of the time than their peripatetic cousins. However, it must be stressed that facial cleanliness is probably no longer a good predictor of trachoma prevalence, perhaps as early as three months into the intervention. One incidental set of observations made by the author underscores this point. At Mimili there were identical twin girls about 6-7 years old, presumably of the same genotype, who were exposed to the same environmental factors, and had the same dose of antibiotic. Both constantly had dirty faces, but whereas one had had several TF episodes and no lines of scarring, the other had only one or two episodes of TF but so much scarred tissue that it is likely she will develop TT a very early age. This also highlights the classification problem (see 6.12.2).

Nevertheless, the young cohort at Pipalyatjara demonstrated a much-reduced TF prevalence, on average approximately 25% less than the cohort at Mimili, despite being more mobile. The mobility factor might have predisposed the Pipalyatjara group to a much higher risk of infection, perhaps due to less face washing, and intermingling with children from neighbouring communities who were outside the area of Nganampa. For example, a community 20 km distant at the border of western Australia, and not subject to trachoma control. On the other hand, because we have so little trachoma prevalence data on communities in Central Australia, this assumption could turn out to be in error: neighbouring communities might have had a lesser trachoma prevalence, which would have meant that absentees would have been subject to less infection.

All of these factors enhance the proposition that we should extend the SAFE intervention to all communities within the AP lands. The strategy should employ an identical health program, distribute azithromycin at least once, and perhaps twice a
year, and institute a series of environmental improvements (such as was carried out at Pipalyatjara) until the disease falls below endemic levels. Making assumptions about trachoma prevalence in Aboriginal communities can turn out to be a surprise, as health authorities in the Northern Territory found out in 2002!(83)

6.11.3 The nature of the ‘E’ factor

Although considerable road and landscaping improvements were made in Pipalyatjara, this translated to only a little improvement in the dust levels around the residences, though dust levels around the community saw some improvement. Had the dust-monitoring program worked properly, it is possible that the community-wide improvement might have been characterised and a better understanding of the dust situation might have occurred. At present, whether dust is a significant risk factor in Australian Aboriginal communities still remains an unknown.

The drainage improvements helped mitigate the flooding that occurred on a few occasions, which were still extensive. However, the rainfall amounts were excessive: for example, in December 2001, 290 mm fell, which represents 48% of the rainfall that year, and 260% of the average annual rainfall recorded in previous decades. It is not known whether the bush fly population increased in proportion to the high rainfall observed during the study (compared to earlier years), but since there was no obvious correlation between rainfall and trachoma prevalence in either community, either the bush fly is not a significant C. trachomatis vector in these settings, or its numbers were insufficient to cause an effect.

Modest improvements in the housing environment and healthy living practices were observed, and although they fell short of desirable targets—a comparison with other Aboriginal housing stock showed that the housing in Pipalyatjara by 2001 was in very good shape.

Do these actual improvements constitute a viable enough E component as part of the SAFE strategy? The problem in answering these questions is that while researchers can agree that certain aspects are important—for example, water availability, latrines, reducing crowding, and the density of flies—the weighting of these and other factors remains to be established in different environments and countries, which is essentially West’s argument.(212) Moreover, many of these factors confound each other. There are also likely to be a synergistic, and possibly threshold
effects with regard to reducing trachoma prevalence when a number of environmental changes are instituted.

Some researchers have pointed out that in Aboriginal communities, crowding in houses is still too high, and that this should be a key focus. The data from Pipalyatjara indicate that crowding levels still remained high post-intervention, and although the crowding factors were not significant in the multivariate analysis, in the case of TF or TI, the risk factor did increase (OR: 1.4).

Developing population health environmental indicators to monitor environment-related health and disease trends is a relatively new science. In the Australian geographic area, for example, Sladden et al. report that nationwide, the institution and monitoring of relevant databases is progressing, but still in its infancy. We can certainly regard the healthy living practices as a step in understanding what factors are key in the ‘E’ component of trachoma interventions. However, there is no data yet to associate the current scales and scores utilized by the NHC with understanding the success or failure of an environmental intervention. For example, data from Ewald et al.’s study showed that in four healthy living practices—wash people, wash clothes, remove waste, and cook and prepare food—there were relative gains of 30-120%, though the absolute final scores were more equivalent to Pipalyatjara at the pre-intervention point. This SAFE-type of intervention did not work, though it does not necessarily prove that the intervention failed because the E component was not implemented adequately.

Regarding trachoma prevalence pre- and post-intervention, larger spikes were seen at Mimili compared to Pipalyatjara, just prior to antibiotic administration, and 12 months post-intervention. In all respects, the SAF components were similar in both communities, which begs the question, was the E component as implemented in Pipalyatjara, responsible for the difference, or was this chance? The answer to this question is not known.

Until a better understanding of what specific environmental factors make a critical contribution to a successful trachoma SAFE-style intervention is achieved, health authorities will continue to be frustrated in deciding where to allocate money.

6.11.4 Unanswered questions at Pipalyatjara and Mimili

One puzzling feature of the 1-9 year-old cohort is the gender difference with regard to the post-intervention trachoma prevalence at 12 months, plus the cleanliness
and nasal discharge factors. At Mimili, both genders made major gains in cleanliness all the way through the intervention, but while the TF prevalence in boys was reduced about 20% twelve months into the intervention, there was no change in the girls. Moreover, after the 3-month post-intervention point, the increase in trachoma prevalence was remarkably parallel for both genders. At Pipalyatjara, the reduction in TF prevalence was very substantial for the boys, but for the girls it improved only about a quarter with respect to the boys, essentially remaining stagnant after the 3-month post-intervention point.

Several hypotheses might explain the gender differences. For example, a gender-related genetic susceptibility difference to *C. trachomatis* could exist, or, on average, girls could spend more time in close proximity with each other than boys do. Daniell and Taylor raised the former possibility with regard to the higher rates of trichiasis in women in their Tanzanian study, but also raised the latter possibility in the form of sharing of hygiene practices and a common environment. Thus far, there is no biochemical evidence in the literature for a gender-related genetic predisposition, and although Courtright and West do not yet discount this theory, they allow for the possibility that the situation is the result of social dynamics, at least in Africa. However, in order for a genetic gender-based susceptibility to be in play, it should have operated at both communities, and one might have expected more similar results at both communities.

Little research has been conducted with regard to the physical size of social proximity circles in different cultures. In European cultures, there is evidence that the circle is physically smaller for girls compared to boys, but this has not been extended to all cultures. If this is true for young Aboriginal girls, this might have increased the opportunities for cross-infection. Another point raised by Hsieh et al. is their recognition of a ‘persistent’ clinical infection in children, although the authors suggest this is due to high ocular chlamydial loads rather than exogenous reinfection, which, with the publication of more PCR studies, now seems to be more the case. Interestingly, the same investigators found that in 22 children with a ‘persistent’ infection, almost half had the same *ompI* outer membrane protein genotype, implying that a more virulent strain of *C. trachomatis* might be responsible.

The idea of a more persistent, more virulent strain existing within the pool infection at Mimili is attractive, but unlikely. Since azithromycin had not been administered at either community prior to the intervention, there should be no
evolutionary pressure for *C. Trachomatis* to evolve more virulent strains there, though some researchers have hypothesized that a higher trachoma prevalence does represent more genetic diversity among chlamydial strains.\(^{(215)}\) In fact, little or no resistance to this macrolide antibiotic has been reported worldwide. In the author’s opinion, it is more likely that a proportion of young girls that have experienced prior *Chlamydia* infections are simply much more sensitive to the disease. This might manifest itself in prolonged inflammation long after the bacteria have been cleared from the body. In addition, because azithromycin has been used so successfully to clear *Chlamydia* STD-type infections, it is unlikely that reinfection is comes from extraocular sources within the body.

### 6.11.5 Comparison with other interventions in Australia

The most similar intervention to which comparisons can be made is a SAFE-type intervention made by Ewald et al in central Australia (minus surgery) in three Aboriginal communities during 1998-2000.\(^{(24)}\) The administration of azithromycin to trachoma-affected children was carried out at baseline, 7 and 21 months, at the household level, while the E-focus of the intervention centred on improving housing and reducing the level of crowding. It is difficult to draw exact conclusions, because detailed scoring data were not reported. Data published were the percentages of houses passing the minimum standards recommended under the NIHG (National Indigenous Housing Guidelines) for four critical practices. However, it does appear that the state of healthy living practices described 14 months *post*-intervention were comparable, or slightly worse than Pipalyatjara at baseline. All three communities were characterized as highly mobile.

The result, however, was a failure. The authors reported statistical analyses despite the low examination rates, and found no significant reduction in active trachoma prevalence at 7 or 21 months into the intervention. Why did this occur? In their defence, the researchers listed several factors. These included insufficient environmental improvement, too much time between antibiotic administrations, insufficient compliance (they estimated this at 70% minimum), overcrowding, and mobility of the populations. These were all contributory, but in addition, the fact that this was a targeted as opposed to community-wide intervention for antibiotic administration was probably not a wise choice, dictated as it was perhaps by cost. By contrast, the other SAFE-style intervention in the Pilbara region of Australia, which
also utilized a targeted approach for antibiotic administration, has been successful for several years.\(^{(201)}\) However, this is an ongoing intervention with environmental improvements, and azithromycin is administered biannually based upon screening.

While the examination rates in the first two rounds in Ewald et al.’s study were near 80%, they fell to 55% in round 3.\(^{(24)}\) This might have given rise to an underestimation of trachoma prevalence despite their claims that the sample sizes were adequate for the methodology of their statistical analysis. Given our results, it is entirely possible that many trachoma cases were missed, and that ‘persistent’ infections were present in the population. The point concerning time between azithromycin administrations is a key one, and for highly mobile populations, including Pipalyatjara, six-month intervals are probably advisable if funds permit, at least until trachoma prevalence falls close to endemic levels. Laming and Currie support the interval timing, but maintain that a targeted but supervised antibiotic twice-yearly administration plus a health program can work.\(^{(216)}\) According to Ewald et al.’s data, their best result was a temporary 25% reduction in trachoma, but what is important is that prevalence levels returned to baseline at some point. In the author’s opinion, this is what can happen when health and environmental programs are not continuously maintained in a community-wide sense, and antibiotic coverage is < 80%. Another point rarely discussed is that when poor regions slowly improve economically, environmental improvements automatically take place. More frequent use of antibiotics for other diseases can also reduce the prevalence of trachoma by combating \textit{C. trachomatis}.\(^{(217)}\)

### 6.12 Limitations and issues of the current study

#### 6.12.1 Comparisons with other surveys

It is always problematic when insufficient trachoma-related data are reported in a survey from which to make a comparative assessment. The two most important parameters are examination rates and how prevalence is reported by age group. Given that the bulk of the infection reservoir exists in children, data must be separated out from adults. Moreover, where possible, children should be categorized by younger and older groups. If it were possible to obtain some broad agreement on age ranges, then direct comparisons would be feasible, although the likelihood of this occurring
seems slim. In addition, reviewers of articles submitted to journals could insist at a minimum that certain data be made available.

6.12.2 Difficulties with the current classification

In the author’s opinion, while the new WHO scheme is bringing into line reported prevalence rates of trachoma in published studies—all investigators are now on ‘the same page’—it has made some determinations more problematic. In adults, it can be difficult enough for experienced examiners to determine TI in the presence of a long scarring history. Moreover, with the current reporting system it is possible to under-report cases of TI, which tends to concurrently underestimate the risk of such individuals to further scarring, TT, and ultimately, CO. Another problem with the simplified WHO classification is that an individual who has four or less follicles is not graded as having TF, which can lead to an underestimate of TF in a population.\(^{(12)}\)

6.12.3 Accuracy, precision, and utility of clinical trachoma assessment

Since complete agreement was obtained between the author and Prof. Taylor regarding the trachoma assessment of children < 15 years old during the length of the study based upon the photos, and for the interobserver sessions conducted during visit 8, for which the Kappa statistic would be 1.0, the accuracy and precision of clinical trachoma assessment for this group is likely to be relatively high and consistent. Based upon the interobserver session, the Kappa of 0.81 for the adults regarding TF assessment, would be considered almost perfect agreement,\(^{(218)}\) and higher than the results of the studies reported by Thylefors et al.,\(^{(102)}\) and Taylor et al.\(^{(103)}\) for TF assessment. For the TI assessment, a Kappa of 0.62 is regarded as substantial agreement, and while higher than the Kappa reported for TI assessment in the Thylefors et al. study,\(^{(102)}\) it is lower than that reported by Taylor et al.\(^{(103)}\) In the experience of trained clinical observers, the hardest assessment to make is TI when an adult has had a history of trachoma infections, and has some scarring. In the author’s opinion, based upon the interobserver session, the estimated prevalence of TI for adults in the study is likely to be an underestimate, while the estimated prevalence of TF is likely to be slightly high.

In the author’s opinion the training of the AHWs in examination procedures and trachoma classification was well accomplished. This lead to a good performance by the AHWs in helping with administration of the health program. In general, there was
an 80% agreement between the author and the AHW examiners with regard to WHO trachoma classification, though calculation of Kappa was not possible.

This kind of training for health workers, provided there is provision for recurrent training, saves time and money by obviating remote diagnosis (which, on a large scale, would be impossible). It allows for on-site decisions, and action, and stops too many outside visits by outside specialists, which would be disruptive.

Recent data provides for the first time an estimate of both the positive predictive value (PPV) and sensitivity of the WHO simplified grading scheme. Based upon a baseline pre-intervention sample of about 1,059 children aged < 15 years, a PPV and sensitivity of 69% and was established. The authors comment that the PPV declines with subject age within this group, with a 78% value for children < 5 years of age, and a 17% value for the 11-15 years group. As expected, the PPV also dramatically declines several months after antibiotic administration (average 10% 14 months after treatment). These results confirm the utility of clinical assessment in young children, but also highlight the potential pitfalls of assessing trachoma in older subjects with a view to treating infection.

On these grounds, baseline assessment of the 1-9 year old group in this study is likely to be a reasonable predictor of infection, but is the not the case for the 10-14 year-olds. Moreover, Bird et al.’s study suggests that trying to estimate a reinfection rate based upon the post-intervention trachoma prevalence (for example between 6 and 12 months) might not be a valid procedure.

6.12.4 Mobility

Mobility of Aboriginal communities is an established fact, and is unlikely to change. Mobility is also a factor that does complicate the establishment of a successful intervention, but it can be overcome. Aware of this complication in advance, the author was able to devise tracking procedures to document movement and monitor potential problems with examination rates.

However, it can easily be seen from this study that in order to bring down the level of trachoma endemicity in all Aboriginal communities, there needs to be a much larger coordination with different geographic areas, as movement of infected individuals into and out of areas not subject to intervention can compromise the end result. When interventions across a larger area are harmonized, the result for individual interventions will be much improved.
6.12.5 Sample sizes

As surveys and interventions go, both the communities studied here are relatively small, and when particular sub-populations are isolated for study, extensive statistical analysis is not always possible. Since the attention of interventions will focus most on the children—the active reservoir of infection—this will, on a community basis, result in small sample sizes for study. Moreover, due to the variable factors associated with Aboriginal communities, it is a challenge to group children from different communities into a cohort for analytical purposes and expect meaningful results. As a result, it is vitally important to keep the examination and study participation results as high as possible so the sample size is maximal.

6.12.6 Long-term follow-up

Limited interventions are certainly useful, but in order to bring down the level of trachoma endemicity and hopefully eradicate it at some point in the future, long-term interventions should be instituted until the level of hygiene and environment is high enough that normal health care can deal with the problem. With this in mind, the author advocates long-term follow up and care for both communities in order to better understand the dynamics of the disease in these communities, to fine-tune procedures, and further learn about the epidemiology of the disease. In particular, the effects of the interval between antibiotic dosing, the E component of SAFE, and the monitoring of health programs need further study. In retrospect, had the design of this study allowed for another year of follow-up—many recent interventions are now following up for two years—some of the unanswered questions might have been answered.

6.13 Future research

This study uncovered many interesting associations and factors in the epidemiology of trachoma within two small Aboriginal communities that have not heretofore been reported. Several lines of research could be profitably pursued to both confirm and extend our knowledge in this area that will ultimately benefit those who have trachoma:

- Mobility. Is it possible to study the mobility factor in such a way as to track individuals that do and do not have trachoma and learn more about
their infection patterns? How much potential is there for an infected child to reinfect healthy children? How significant a factor is cross-infection between communities? Can we use that knowledge to design better interventions? Vector analysis is common in other epidemiological investigations, and this author suggests, that some limited but long-terms movement tracking of individuals might yield useful results. In addition, recent epidemiological models of TB and AIDS based upon stochastics show promise in terms of developing better approaches that might be utilized for trachoma.

- **Chronic ‘persistent’ trachoma symptoms.** Our studies and others suggest that it is hard to limit the disease in young children who seem to have more intractable trachoma signs. Is there a pathological reason for this observation? Are certain Chlamydia serotypes more responsible, or is it a case of more prolonged inflammation? Research suggests that azithromycin resistance in Chlamydia strains is unlikely, but field tests in Aboriginal children are scant.

- **Gender.** Our studies suggest a gender difference regarding trachoma prevalence with time. Is it based upon social-dynamic interactions, or other factors? Can this be verified? If so, this could lead to new intervention paradigms to allow for this possibility.

- **Environment.** Unfortunately, much of the planned collection of environmental data did not work in the study. For example, it was hard to collect flies in traps for many reasons; Aboriginal children often played with rain gauges or dust traps thereby wrecking the data. Is it possible to rethink collection of this data so that several years of consecutive data could be collected?

- **Houses.** Can we better establish the yardsticks with regard to healthy living practices that will tell us at what point small, perhaps synergistic changes are likely to make a very real difference in an intervention?

- **Hygiene.** Is establishment of face-washing habits the only item to be most concerned about? Are there other specific hygiene practices that could be extracted from studies reported in the literature and tested at the communities? For example, frequency of face washing, towel sharing, frequency of laundering.
6.14 Conclusions

With a well-designed SAFE intervention, despite the mobility factor, it is possible to demonstrate substantial reductions in active trachoma within Aboriginal communities. Although researchers in the literature are still debating the frequency antibiotic administration and the necessity for SAFE-type interventions in geographic regions of the world with different levels of endemicity, with annual or biennial azithromycin administration, maintenance of health programs, and improvements in the environment, it ought to be possible to make these reductions permanent, and at least bring the trachoma prevalence down to the endemic level. Most importantly, the study demonstrated the need for involving the entire community in the intervention—adults and children—as well as training workers in examination and the epidemiology of the disease.

Interesting associations were uncovered in children with regard to the ‘E’ factor, age, and gender that point to further research to confirm and perhaps extend these ideas. The more we understand about how transmission occurs within Aboriginal communities—facts, rather than supposition or educated guesses—the more effectively interventions can be designed.

Last, the study highlights a model that could be exported under the auspices of the Nganampa Health Council to other Aboriginal communities, hopefully in concert with CERA, the Centre for Eye Research Australia—for assistance in monitoring and implementation—to treat trachoma. In the long-term, only more regional coordination of interventions will bring the prevalence of trachoma down on a region-by-region basis.
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**Appendix 1. Critical healthy living practices score sheet.**

| Pipeyalatjara | Survey No. 1 March 1999 |

**Critical Healthy Living Practices**

<table>
<thead>
<tr>
<th>House number with score</th>
<th>Houses OK score</th>
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<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25</td>
</tr>
</tbody>
</table>

### Safety

1.1: Power, water and waste services connected and safe | 4
1.2: Safe electrical system | 8
1.4: Structurally safe | 3
1.5: Hot water system OK | 3

### Washing people

2.1: Working shower | 7
2.2: Working tub or basin for young children | 7

### Washing clothes and bedding

3.1: Laundry with OR without washing machine | 6

### Removing waste safely

4.1: Working flush toilet | 4
4.2: Working waste removal from all other areas | 11
Improving nutrition

5.1: Ability to store AND prepare AND cook food

% critical HLP’s with max scores

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<table>
<thead>
<tr>
<th></th>
<th>Houses OK</th>
<th>Required score</th>
</tr>
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<tbody>
<tr>
<td>Safety</td>
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<td>Utilities</td>
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<td>Structure</td>
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<td>Hot water</td>
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<td>Shower</td>
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<td>Washing young children</td>
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<td>Bath</td>
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<td>Lights, shelves,</td>
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<td>Hot water</td>
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<tr>
<td>Washing clothes and bedding</td>
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<td>Laundry services</td>
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<td>Laundry services with w/m</td>
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<td>Laundry maintenance and use</td>
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<tr>
<td>Removing waste safely</td>
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<td>Flush toilet</td>
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<tr>
<td>All areas</td>
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children
Flush toilet AND other waste
Toilet maintenance & use

Improving nutrition
Store, prepare & cook food
Store food
Prepare food
Cook food

Pipalyatjara

Survey No. 2 August 2001

All Healthy Living Practices
House number with score

<table>
<thead>
<tr>
<th>Houses OK</th>
<th>Required score</th>
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</tbody>
</table>

Reducing crowding
Crowding

Separating people from animals, vermin, and insects
Dogs and cats
Vermin
Dustmites
Flies and mosquitoes

Reducing the negative effects of dust
Dust

Controlling temperature for health
Heating
<table>
<thead>
<tr>
<th>Category</th>
<th>Score</th>
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<tbody>
<tr>
<td>Cooling</td>
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<tr>
<td>Affordability</td>
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% critical HLPs with max score
% all HLPs with max score

NOTE: The denominator for % takes into account the number of applicable houses/HLPs

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