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Factors Associated with Emergence and Spread of Cholera Epidemics and Its Control in Sarawak, Malaysia between 1994 and 2003

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Abstract

Cholera is a water and food-borne infectious disease that continues to be a major public health problem in most Asian countries. However, reports concerning the incidence and spread of cholera in these countries are infrequently made available to the international community. Cholera is endemic in Sarawak, Malaysia. We report here the epidemiologic and demographic data obtained from nine divisions of Sarawak for the ten years from 1994 to 2003 and discuss factors associated with the emergence and spread of cholera and its control. In ten years, 1672 cholera patients were recorded. High incidence of cholera was observed during the unusually strong El Niño years of 1997 to 1998 when a very severe and prolonged drought occurred in Sarawak. Cholera is endemic in the squatter towns and coastal areas especially those along the Sarawak river estuaries. The disease subsequently spread to the rural settlements due to movement of people from the towns to the rural areas. During the dry seasons when tributary gravity fed tap waters cease to flow, rural communities rely on river water for domestic use for consumption, washing clothes and household utensils. Consequently, these practices facilitated the spread of water borne diseases such as cholera. The epidemiologic and demographic data were categorized according to ethnic group, gender, occupation, and age of the patients. Large outbreaks occurred in north Sarawak (Bintulu, Miri, and Limbang) rather than the central (Kapit, Sarikei, Sibu)

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and south (Kuching, Samarahan, Sri Aman). The indigenous people, the Orang Ulu and the Iban live in longhouses built along the rivers in the low-lying areas. Whereas the Malays live in coastal areas that eat traditional uncooked seafood causing frequent water-borne infections. Data analysis showed a high incidence of cholera among low-income laborers and rural house wives as opposed to the well paid workers from government and private sectors. Infants and non-school children were 15% of the cases. This suggests household transmission widely occurs. Two cholera cases infecting cooks in a school canteen revealed poor hygiene during food preparation resulting in 229 infections of school children. The majority of the patients were the active adult group from 19 to 59 years. This finding was typical of many food-borne outbreaks where adults gathered to attend festive parties or funeral feasts. Various intervention activities and preventive measures such as surveillance, quarantine, treatment, monitoring and improving community sanitation, and health education of poor communities were performed by the Health Department and the local authorities during and after the major 1997–99 epidemics. These measures effectively prevented the emergence and spread of further epidemics.

Keywords: cholera, epidemiological and demographic data, Epi Info

Introduction

Cholera is a serious epidemic disease and continues to be a major health problem globally. *Vibrio cholerae* serotype O1 was formerly considered as the sole etiologic agent of epidemic and pandemic cholera. In the severe form, cholera results in a profuse watery diarrhea and is often accompanied by vomiting. If untreated this leads to rapid dehydration, acidosis, circulatory collapse, and death within 12 to 24 hours. Therapy using prompt fluid replacement with adequate quantities of electrolyte solution corrects dehydration, acidosis, and hypokalemia and is the keystone to recovering from cholera [Kaper *et al.* 1995; Gunnlaugsson *et al.* 1999; Sack *et al.* 2004]. In October of 1992, a non-O1 serotype of *V. cholera* referred to as *V. cholera* O139 or the "Bengal" strain appeared in India and Bangladesh and has pandemic potential. Since that time, *V. cholerae* O1 and O139 serotypes have both been considered to be the etiologic agents of epidemic cholera [Seas and Gotuzzo 1996]. *V. cholerae* O1 and O139 serotypes produce cholera toxin that is responsible for the cholera symptoms. Both serotypes are natural habitants of the estuarine environment and cause cholera disease through consumption of contaminated seafood. The patient excretes the pathogen into the environment and a cholera epidemic begins by contaminating the environmental water or food leading to further cases. Information on cholera cases and epidemics in Asian countries except for the Bengal area is rarely communicated to the international scientific community where only two countries in Asia reported to the WHO the incidence of cholera cases in 2002 [World Health Organization 2003].

Sarawak, one of 14 states in Malaysia is located on the Island of Borneo. It is the largest state of Malaysia with an area of 124,967 square kilometers. It shares an international boundary with Kalimantan, a province under the sovereignty of Indonesia. Two thirds of the land are native tropical forests and its rivers provide the primary means of transportation. The primary rivers are the Batang Rejang, Batang Lupar, Batang Sadong and Baram that provide important modes of transportation for the rural populations from the interior of Sarawak. Using these rivers, the Sarawakians travel by express boats to the larger towns of Sibu, Miri, and Sarikei as well as to the smaller towns such as Marudi, Kanowit, Kapit and the Simunjan bazaar.

The state is divided into nine administrative divisions. Each division is subdivided into administrative districts depending on the size and population of the division (Fig. 1). A resident is the administrative head of a division and is assisted by a district officer in each district.

About 25 different ethnic groups of people make up the population of Sarawak including the Malays, Melanau, Iban, Bidayuh, Orang Ulu and others. The Iban is the largest indigenous ethnic group with a population of 603,735; followed by the Malays, 462,270; the Bidayuh, 166,756; the Orang Ulu, 117,690; and the Melanau, 112,984; and there are 537,230 people of Chinese origin [Malaysia, Department of Statistics, Sarawak 2000]. The Bidayuh also known as Dayak Darat (the Land Dayak) live in the hilly areas outside of Kuching. Among the Orang Ulu, the three main

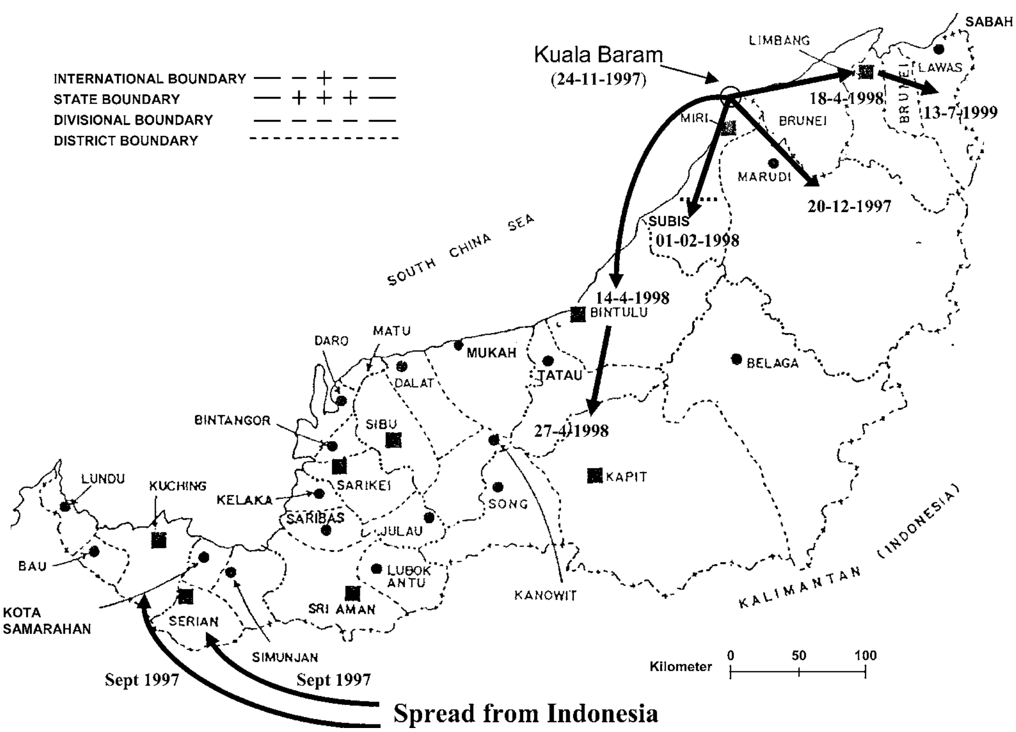

Fig. 1 Sarawak Map Showing Divisional Boundary and District Boundary and the Propagation of the Cholera Epidemic during and after the 1997–98 El Niño Period

groups are the Kayan, Kenyah, Lun Bawang and Kelabit, while other smaller groups include the Bisaya, Kejaman, Sekaran, Lahanan, Sihan, Ukit and Penan. The Sarawak peoples celebrate various festivals; among them are the Gawai Dayak, the Hari Raya, the Chinese New Year and Christmas. The Gawai Dayak is the largest celebration held on 1 June of each year to mark the completion of the rice harvest. A wine brewed from rice and yeast called *tuak* is prepared and served to guests [Malaysia, National Museum 2004].

In Sarawak, the first recorded occurrence of cholera was in 1873. The early outbreaks were accompanied by many deaths. The 1888 outbreak in Sri Aman resulted in 80 fatalities. And in 1902, 1,500 deaths were recorded. In 1910, there were 83 cholera cases with 67 deaths and the following year there were 109 cases with 77 deaths recorded. An outbreak in 1961, four divisions cumulatively reported 301 cases with 70 deaths [Yadav and Chee 1990].

In the 1990s the foci of infections were initially reported in the squatter areas around the towns along coastal areas and especially in the settlement areas along the river estuaries. The disease subsequently spread to the rural settlements due to movement of people from the towns to the rural areas. The spread of cholera occurs when people use poor hygiene and poor sewage treatment that contaminate the river water supply [Van Bergen 1996]. This occurred particularly in the squatter areas of towns and the poorer rural areas. In Sarawak, cholera is usually reported during the dry season, in the months of July and November. During the dry season, the pipe gravity feed system from streams and the rainwater storage tanks in the rural areas run dry and compel people to use river water that may be contaminated with *V. cholerae*. From November 1997 to April 1998, the drought was unusually severe and prolonged due to a strong El Niño [Buizer *et al.* 2000]. Rural populations living in the longhouses along the rivers were especially susceptible to cholera infection due to the wide dissemination of the *V. cholerae* O1 during that drought period [Malaysia, Sarawak Health Department 1998]. This association of drought with cholera epidemics has been previously reported in Malaysia [Chen 1970] and elsewhere [Samadi *et al.* 1983].

Although cholera has occurred repeatedly and has been an important cause of diarrhea in Sarawak for more than a decade, few reports on the epidemiology of cholera in Sarawak have been made to the international scientific literature. Our group recently reported contamination in the seafood marketed in Malaysia, including Sarawak, by *V. cholerae* O1 and O139 [Chen *et al.* 2004]. The study suggests a possibility that the pathogen may persist in the Malaysian aquatic environment and may be primarily responsible for the cholera epidemics in Malaysia. In this communication, we report ten years of epidemic cholera occurring in the state of Sarawak from 1994 to 2003, the factors that enhanced its spread; and the control counter measures that were successfully used by the State

Health Authorities to control cholera in recent years.

Materials and Methods

The epidemiologic and demographic data for cholera cases during the 1994–2003 period were obtained from the Information and Documentation Unit of the State Director Office in Kuching with permission from the State Director of Health for this study.

Statewide Epidemiological Data Collection

Cholera is included in the list of 25 infectious diseases that require the mandatory notification under

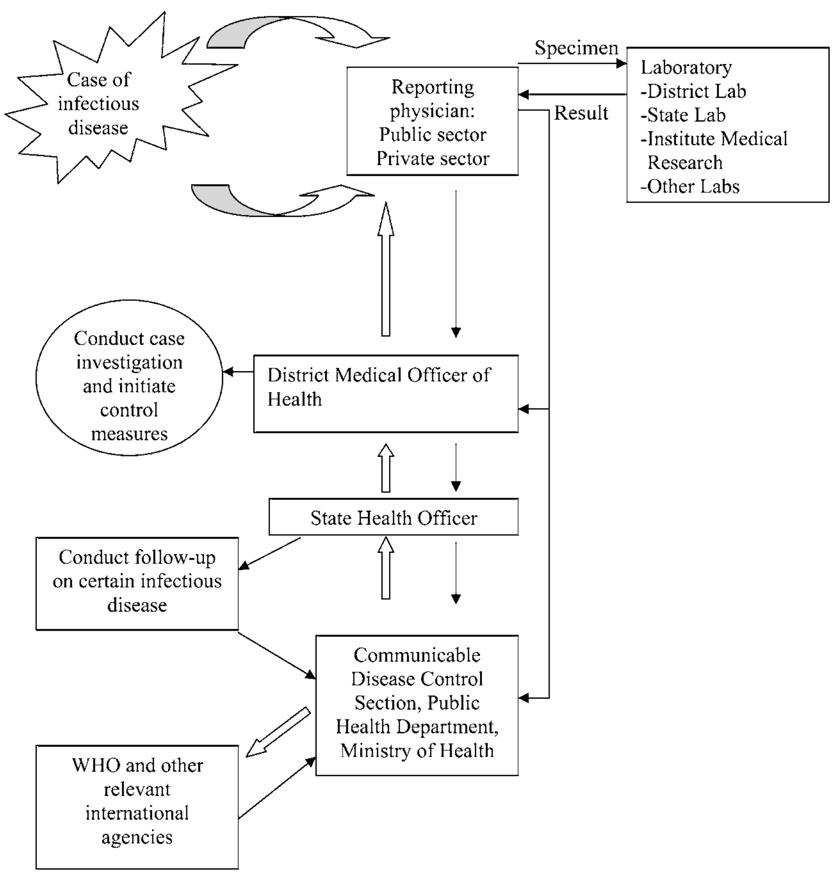

Fig. 2 Flow of Surveillance Data and Dissemination of Information
Source: [Malaysia, Ministry of Health 2004]
Notes: A small arrow, flow of Data. A large arrow, dissemination of information.

the Malaysian Prevention and Control of Infectious Diseases Act enacted in 1988. The system flowchart for disease surveillance and epidemiologic data collection for the mandatory notifiable infectious diseases is shown in Fig. 2. The Act requires all medical officers or private practitioners treating a case of infectious disease to report the case to the District Medical Officer of Health (DMOH) who is responsible for infectious disease surveillance in the district. The Health Inspector of the Infectious Disease Unit will assist the DMOH to conduct the case investigation and reporting of the infectious disease cases from health clinics, general practitioner clinics, both government and private hospital and microbiology laboratories using a prescribed notification form as provided under the Act. The data collected must be submitted in a timely manner to the State Health Office. The laboratory based surveillance system introduced recently in August 2002 compliments the mandatory notifiable disease surveillance system. It entails the reporting of specific microorganisms isolated in all public and private laboratories in Malaysia to the related health authorities as shown in Fig. 3.

When an outbreak or impending outbreak of infectious disease is suspected in a district, the DMOH activates the District Infectious Disease Control Team to carry out an investigation,

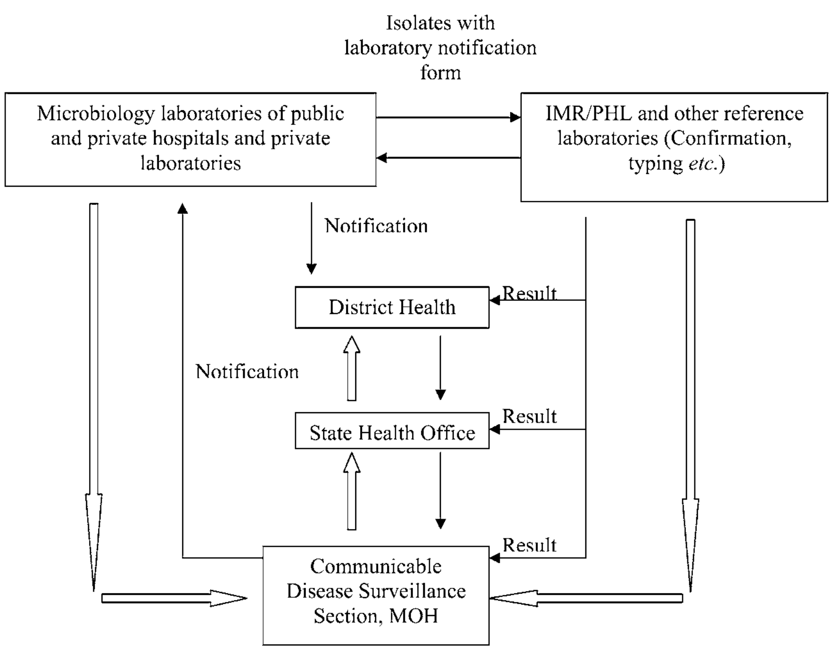

Fig. 3　Laboratory-based Surveillance Flowchart
Notes: A small arrow, data flow. A large arrow, information feedback. IMR, Institute of Medical Research. MOH, Ministry of Health. PHL, Public Health Laboratories

implements control, and institutes preventive measures. If more than one district in a division is affected, the Divisional Medical Officer of Health activates the Divisional Infectious Disease Control Team to co-ordinate the prevention and control activities at the divisional level. Likewise, if an outbreak of infectious disease involves more than one division, the State Infectious Disease Control Team would be activated to do the coordinating activities.

Laboratory Testing and Patient Diagnosis

When a cholera epidemic occurred in Sarawak, all clinically diagnosed cases of acute gastroenteritis diagnosed were screened for *V. cholerae*. Rectal swabs were transported in alkaline peptone water to the hospital laboratory and incubated at 37°C for 8 hours and then cultured on thiosulphate-citrate-bile salt agar. The presence of *V. cholerae* O1 or O139 was confirmed by slide agglutination test the following day. The first isolates of *V. cholerae* O1 or O139 were sent to the State Laboratory for reconfirmation and as a quality control of the initial isolate test at the beginning of the epidemic. All suspected cases were investigated immediately and the Health Inspector traced the primary contacts. Confirmed healthy carriers were given chemoprophylaxis and isolated in a hospital or a special isolation center until three consecutive rectal swabs were confirmed to be negative for *V. cholerae* O1 or O139. Data on confirmed cases are reported daily to the State Health Office responsible for collating the epidemiologic data. The Sarawak Health Department defined a "suspected case" as acute watery diarrhea affecting a person during an epidemic and defined a "confirmed case" as laboratory confirmed *V. cholerae* O1 or O139 infection.

Statistics

The 10 years of epidemiologic and demographic data were logged in Epi Info 6 (USD Inc. Stone Mountain, GA, USA), the software used by the Ministry of Health for epidemiological study of infectious diseases in Malaysia. The data were analyzed to show the distribution of cholera in the nine divisions of Sarawak from 1994 to 2003. The data includes incidence of the disease with respect to gender, ethnic groups, occupations and age groups.

The two-sample student t-test at a probability (p) of 0.05 or less was determined to be significant between two mean populations.

Results

In this study, we present laboratory testing-based epidemiology data on cholera in Sarawak. From

Table 1 Distribution of Cholera Cases in Sarawak from 1994 to 2003 by Division, Ethnic Groups, and Gender Composition

Category		Cholera Cases in Year										
Division/district	Population[a]	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Kuching Division	**498,221**	**52**	**16**		**14**							**82**
Kuching district	455,828	49	16		14							
Bau district	42,393	3										
Sri Aman Division	**65,587**											**0**
Sarikei Division	**138,605**		**4**			**61**						**65**
Sarikei district	59,148					1						
Bintangor district	30,812					1						
Daro district	15,951					47						
Julau district	32,694		4			12						
Sibu Division	**282,561**	**8**	**5**		**1**	**13**						**27**
Sibu district	206,274		5			7						
Dalat district	25,660	8										
Mukah district	50,627				1	6						
Kapit Division	**30,416**			**1**								**1**
Belaga district	30,416			1								
Bintulu Division	**141,082**					**171**						**171**
Bintulu district	113,837					65						
Tataw district	27,245					106						
Miri Division	**296,333**	**73**	**11**	**22**	**60**	**325**					**15**	**506**
Miri district	206,769[b]	73*	7*	22	56◆	206◆					1	
Subis dstrict	[c]					72◆						
Marudi district	89,564		4		4	47◆					14	
Limbang Division	**77,674**					**5**	**729**	**1**				**735**
Limbang district	41,413					5	40	1				
Lawas district	36,261						689					
Samarahan Division	**196,018**	**14**	**12**	**10**	**10**	**1**	**37**		**1**			**85**
Samarahan district	56,062	10	5									
Simunjan district	55,962	4	5	1	1				1			
Serian district	83,994		2	9	9	1	37					
Grand Total	**1,726,497**											**1,672**
Races												
Malays		46	22		15	70	161		1		1	316
Chinese		4			3	18	5					30
India						1						1
Melanau		22	2			48						72
Iban		54	22		47	376	5	1			13	518
Bidayuh		13		9	13	5	35					75
Other natives		7	2	23	7	41	560				1	641
Foreigners		1		1		17						19
Genders												
Male		61	27	17	46	319	160				5	635
Female		86	21	16	39	257	606	1	1		10	1,037

* and ◆: occurred as one continuous outbreak.

[a] Population in year 1998 [Malaysia, Department of Statistic Sarawak 2000].

[b] The population including the Subis district.

[c] The population including Miri and Subis districts is available and is shown above.

1994 to 2003, 1,672 cholera cases occurred. There were eight epidemics with cases ranging from 40 to 689 in five divisions, 7 small outbreaks with cases ranging from 10 to 37 in four divisions, 14 smaller outbreaks involving 3 to 9 victims, and 11 sporadic occurrences involving less than 3 victims. Table 1 summarizes the distribution of cholera cases in Sarawak from 1994 to 2003 by division, ethnic groups and gender.

In the 10 year period, the Limbang Division had the highest number of cases at 735 cases even though recording only one cholera epidemic in 2000. The next highest was in Miri with 506 cases where cholera outbreaks occurred annually from 1994 to 1998 and again in 2003. In the Miri district particularly around the Baram estuary has always been endemic for cholera. The Bintulu epidemic was similar to the Limbang epidemic with only one occurrence in 1998 and ranked third in the number of cases at 171. Like in Miri, the Samarahan Division has yearly occurrences of cholera outbreaks from 1994 to 1999 but only recorded 85 cases. In descending order for divisions, Kuching had 82 cases; Sibu, 27 cases; and interestingly there were no epidemics of cholera in Kapit and Sri Aman.

There were differences in the total number of yearly cholera patients (Fig. 4) showing remarkably high numbers during the dry El Niño period from 1997 to 1998 at 661 of 1,672 patients (40% of the 10 year total) and just after the El Niño years in 1999, 46% (776/1,672); then just 9% (147/1,672) occurred in the mild El Niño year of 1994. When El Niño was at its lowest there were even fewer cases: during 1995, 3% (48/1,672); and only 2% (33/1,672) in 1996 with no outbreaks in 2000 to 2002 and only 1% (15/1,672) in 2003.

Fig. 5 compares the yearly number of cholera cases between male and female. The cumulative

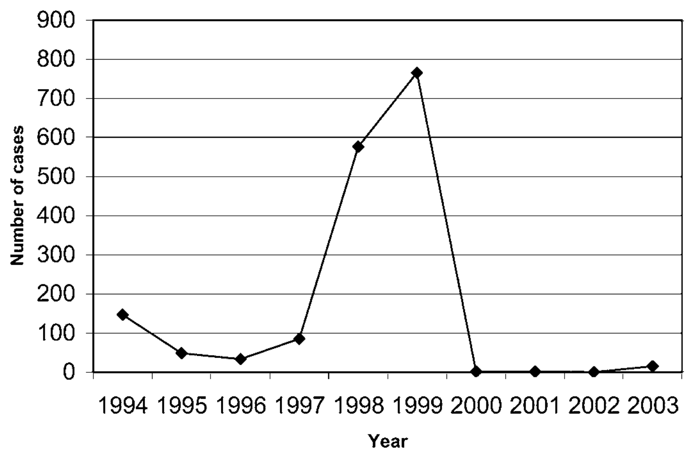

Fig. 4 Yearly Incidence of Cholera Cases from 1994 to 2003

number of cases was 1.6 times higher in females than males at 62% (1,037/1,672) females compared to 38% (635/1,672) among males. However, when incidence was compared for each year, the number of male and female patients did not significantly differ (p=0.57).

None of the ethnic groups were spared from cholera during the epidemics in the 10 year period (Fig. 6). Cholera was most prevalent in the Orang Ulus (classified as other natives in Fig. 6 at 39%), followed by Iban (30%), Malays (19%), Bidayuh (5%), Melanau (4%) in descending order. The Chinese was ranked lowest (2%) among the local ethnic groups contracting cholera. The remaining cases (1%) occurred among foreigners which were mostly Indonesian laborers.

The occupation data available from the cholera patients are summarized in Fig. 7. Although occupation data were not available for 807 (48.3%) of 1,672 cases, the rest of the data and some other observations lead us to agree to the general concept that cholera is a disease of poverty. This is because poverty is mainly responsible for poor hygiene. Infants and children who do not develop enough immunity to cholera at their ages are more susceptible to cholera than the adults. This is particularly true in the poor family where hygienic condition is not good. Two groups out of

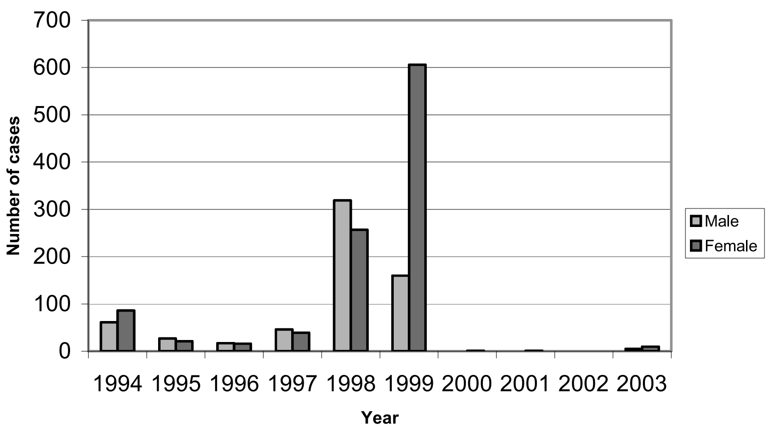

Fig. 5　Incidence of Cholera Cases in Males and Females between 1994 and 2003

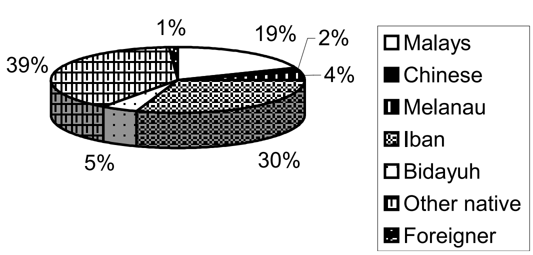

Fig. 6　Incidence of Cholera Cases in Different Ethnic Groups between 1994 and 2003

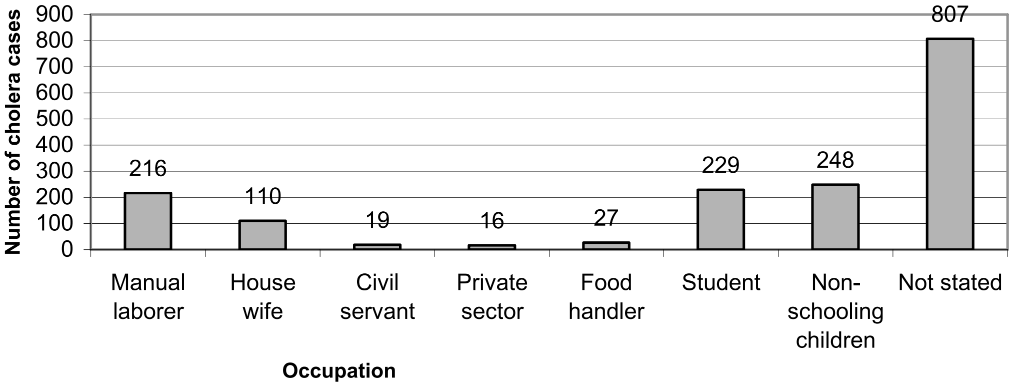

Fig. 7 Incidence of Cholera Cases in Different Occupational Groups between 1994 and 2003

occupation, school children and students from 5 to 17 years-old and pre-school children from 0 to 4 years-old, made up 229 (13.7%) and 248 (14.8%) of the total 1,672 patients, respectively. Most of the infected pre-school children and infants were from poor income families (data not shown). House wives of low income family in rural area consisted of 110 patients (6.58%). These suggest that household transmission often takes place in poor families. A part of cholera cases among school children was those in Lawas where infection was due to poor hygiene in the preparation of food at school where two cases of cholera were found among the cooks at Lawas Secondary School canteen. Of the adult patients, cases among those with low income, manual laborers (216 patients) and food handlers (27 patients), were higher than those among the high income groups, civil servants (19 patients) and white collar workers (16 patients) from the private sector.

Considering the age groups, 7% (108) of the cases were infants; 26% (439) were children between 2 to 12 years; 13% (224) were adolescence, 13 to 18; and 45% (749) were adults between 19 to 59; whereas 9% (144) of the cases occurred in the elderly, aged 60 and above (8 ages unrecorded; Fig. 8). The majority of the patients were adults between 19 and 59. This finding was typical in the food-borne outbreak where adults gathered to attend festive parties or funeral feasts.

The Epidemic Spread in the Southern Zone

Small outbreaks of cholera occurred in Kuching and Samarahan from 6 September to 1 November in 1997 involving 14 cases and 10 carriers in Kuching and 10 cases and 34 carriers in Samarahan. These two small outbreaks were strongly suspected to have been caused by *V. cholerae* O1 brought in by the Indonesian labor workers and domestic maids coming to Sarawak across the border at Tebedu in the Serian district. As evidence for this, on 30 September 1997, the WHO representative

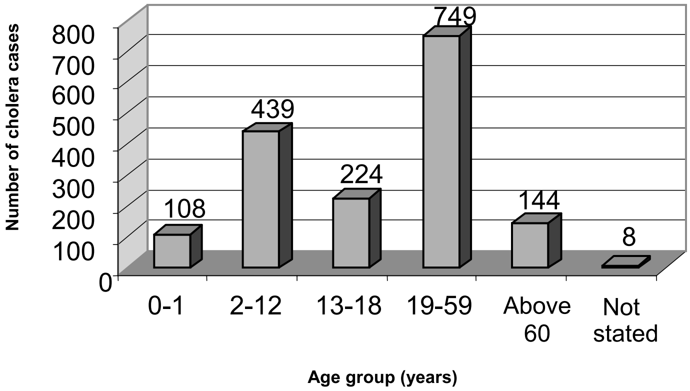

Fig. 8　Number of Cholera Cases in Different Age Groups between 1994 and 2004

for Brunei Darulsallam and Malaysia based in Kuala Lumpur received a message from the WHO South East Regional Office to report many deaths possibly due to cholera in two remote districts in Irian Jaya, Indonesia. These areas have suffered from the long and very severe drought caused by the El Niño and has a thick haze from bushfires. The message was passed to the Ministry of Health (letter dated 9 October 1997 from Dr. Liu Xirong, WHO representative for Brunei Darulsallam and Malaysia based in Kuala Lumpur) who then directed all of the State Health Departments to carry out surveillance activities on Indonesian workers coming into the country particularly those having contact with people from Irian Jaya. Sarawak Health Department, being close to the Indonesian border, received the news from reliable sources earlier. On 28 September 1997, the state health personnel proactively carried out rectal swabs randomly from 10% of the Indonesian workers coming into the state at the Tebedu Checkpoint. Since then, 11 Indonesians were confirmed to be carriers of *V. cholerae* O1 and the last was detected positive on 1 November [Malaysia, Sarawak Health Department 1998]. The final destination of the carriers was given as Serian, Kuching and Miri. The State Health Office alerted all the Divisional Health Offices of the final destination of the Indonesian workers. This provides strong evidence of an epidemiologic link to the small cholera outbreak in the Kuching and Samarahan Division to the occurrence in Indonesia during that same period. It is tempting to speculate that the big cholera outbreak in Irian Jaya immediately before the Kuching-Samarahan outbreak is the source of the latter outbreak. However, direct evidence to support this speculation is lacking. In addition, movement of Indonesian workers to the Kuching-Samarahan area from Irian Jaya is much less frequent than those from other parts of Indonesia. International collaboration to compare the *V. cholerae* strains isolated in these two areas by molecular epidemiological methods would clarify this point.

However, there is no direct evidence that the Indonesian workers were the source of the Miri outbreak that originated from a local native family staying in cholera endemic foci at Kuala Baram in the Miri Division. It is noteworthy there was a large outbreak that was treated at Shin Yang Industrial estate in February 1998 (described below in Table 4). Many Indonesian workers are employed in the Shin Yang Polywood industry in Kuala Baram. It would be interesting to investigate if there was a possible connection between the cholera outbreak in Kuala Baram and flow of the Indonesian workers into the Shin Yang Polywood industry.

The Epidemic Spread in the Northern Zone

The extended epidemic in Miri from 1997 to 1998 was the longest recorded in Sarawak during the recent decade and was thought to be due to the extensive dissemination of *V. cholerae* O1 during the very severe drought season between October 1997 and early April 1998 [*ibid.*]. The problem faced, and short and long term control measures performed during this outbreak are explained below and we believe they will be helpful to other public health authorities to tackle a similar cholera outbreak in Southeast Asia in the future. From our observations and others on the effect of El Niño and cholera, it is of great importance for the epidemiologist in any country to monitor the prediction of future strong El Niño that is available from the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce (through its home page) so that early precautions and public warnings can be initiated by the health authorities to face a possible waterborne disease outbreak in the future.

It Started in Miri Division

The epidemic started when the index case was confirmed by culture of a stool sample from a 36 year-old man admitted to Miri Hospital on 24 November 1997. His mother-in-law was admitted and confirmed positive three days later. The Health Inspector from the Miri Health Department was asked to carry out an investigation. The family members of the index case were interviewed. Rectal swabs were taken and sent to the hospital laboratory for culture. It was determined four other family members of the male patient were asymptomatic carriers. *V. cholerae* O1 biotype El Tor serotype Ogawa was isolated from all family members. The family lives in Kuala Baram (on the Baram estuary). The Health Inspector found the family had consumed samoan, a small seawater prawn that is eaten raw in the form of "*umai*." *Umai* is a local delicacy made from uncooked samoan or chopped fish meat by adding chilies, monosodium glutamate and salt, and sometimes fresh lime juice depending on individual taste. This delicacy is very popular among the locals and served widely in food stalls and restaurants in Miri town during the shrimp season. Raw and cooked food samples were sent to the Miri Hospital Laboratory for investigation. A sample of *samoan* caught from the Baram estuary was confirmed positive for *V. cholerae* and was the same type isolated from the Kuara Baram family on 22 December 1997. By then cholera had spread to Miri town where *samoan* was widely sold at open markets and along the Kuala Baram-Miri road. Cholera was concentrated in two squatter villages at Pujut Corner and Canada Hill in Miri.

The ensuing festive holidays of Christmas and New Years, 1998 promoted rapid mass movement of people from the Kuala Baram Industrial Area and Miri town to other areas within and outside of the Miri Division. For example, the cases detected in the remote villages of Beluru were linked to the movement of people during the Christmas holidays from the squatter area of Pujut corner. The public holidays occurring during the Chinese New Year and Hari Raya further gave rise to an accelerated migration and the increased mobility of people resulted in a further spread of the outbreak. For example, Bintulu Division reported three cholera cases from a family on 14 April 1998 where one of the cases was a worker who came back from Miri. Subsequently, the spread could be linked to poor personal hygiene, poor environmental sanitation with overhanging toilets, and water borne spread due to the contaminated rivers in the affected area. This was compounded by the lack of a safe water supply during the prolonged and severe drought brought about by the unusually severe El Niño. The industrial estates in Kuala Baram, for example, were affected when the shortage of water prompted the industries to get water from barges at Baram River. In addition, the environmental sanitation of the worker’s quarters was unsatisfactory. An outbreak at Rh. Sigi in Niah Subdistrict was linked to the extensive use of the contaminated water from the Niah River.

Furthermore, there is a tradition of giving a feast and prayer service by the natives to mourn the deaths (due to cholera) of their loved ones and apparently caused the surge of cholera cases in the longhouses. For example, a funeral feast and prayer service was held at Rh. Lungan, Beluru in the Marudi District on 27 December 1997 to mourn the death of a 67 year-old woman. Relatives of the deceased from nearby Rh. Biri and Rh. Morgan attended this service and the cholera pathogen spread and gave rise to nine cases and 94 carriers in three longhouses. A large outbreak that occurred after a large community meal served at the funeral was also reported [Gunnlaugsson *et al.* 1998].

Cases were detected from remote villages in Beluru from 20 December 1997. Bekenu was affected after 1 February 1998. Cholera re-emerged in Kuala Baram affecting the industrial area by 4 February. Batu Niah was affected where the outbreak further spread to as far as Suai area by 20 February. Cholera spread to areas along the upper reaches of the Baram River.

The Marudi District was affected as early as 3 December 1997 when cases were reported in Sungei Pedada and Assam Paya villages. The villagers from Assam Paya had bought *samoan* from Kuala Baram and brought it back to the village and this caused the initial outbreak in the Marudi district. Cases flared up three month later in the Marudi district where both Ogawa and Inaba serotypes of *V. cholerae* O1 were isolated. The Inaba serotype was first isolated in Kejaman village in the Marudi district on 21 February 1998. The Inaba serotype was not associated with the initial outbreak in Kuala Baram. However, later in the outbreak, this serotype was also isolated from patients, food and water samples in Kuala Baram and the Miri town area of Pujut squatters, Promin Jaya and Taman Tungku housing areas. This suggests an Inaba serotype spread from Marudi to Miri. The spread of cholera from Kuala Baram to various localities in the Miri Division is shown in Fig. 9 and the breakdown of cases and carriers in the three districts in the Miri Division is shown in Table 2.

The case fatality rate (CFR) in the Miri Division was 1.5% (6/388). The fatality cases caused

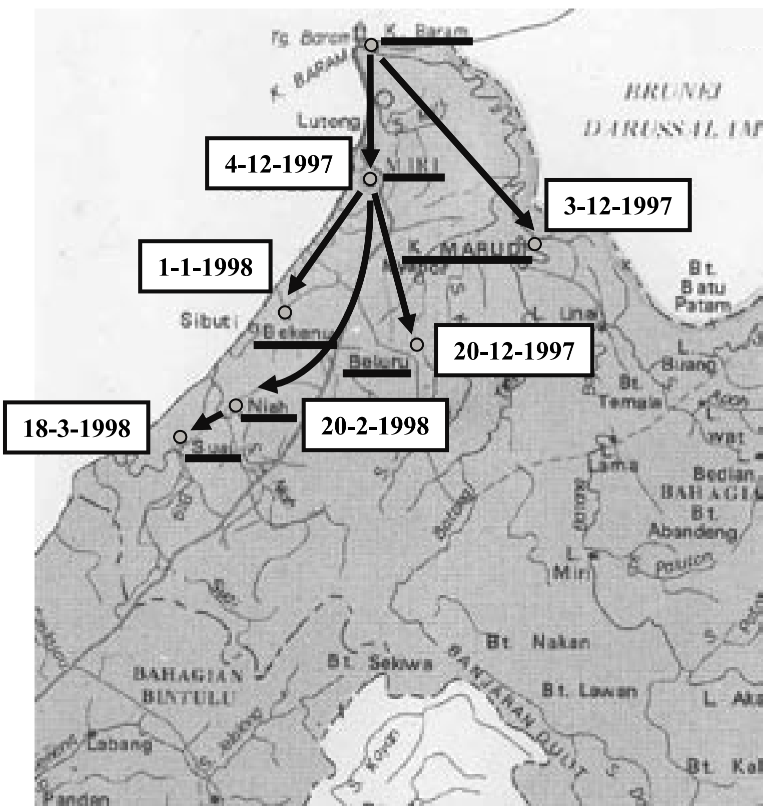

Fig. 9 The Spread of Cholera in Miri Division during the 1997–98 Epidemic
Note: The arrows show the directions of cholera epidemic spread.

by cholera are shown in Table 3. The State Health Department required a laboratory confirmation report to define the deaths as due to cholera. One patient died at home due to persistent diarrhea and vomiting. Two other patients were brought dead to the Marudi Hospital. The deaths were also due to profuse diarrhea. No rectal swab or stool samples were taken from the three deceased for laboratory culture and sensitivity analysis.

Therefore, these three cases were not registered as death caused by cholera even though the deceased came from the epidemic area. Nevertheless, the deaths were not due to poor management of the cases by the medical health personnel but due to refusal of admission by the deceased or being brought to the hospital too late to be resuscitated. Even if the three deaths were included as cholera cases the CFR still remained low. The low CFR is due at least in part to easy access to

Table 2　Distribution of Cholera Cases and Carriers in Each District of the Miri Division

District	Population[a]	Number of Cases	Number of Carriers
Miri District	206,769[b]	262	562
Subis District	[c]	72	259
Marudi District	89,564	51	128
Total	296,333	385	949

[a] Population in year 1998 [Malaysia, Department of Statistic Sarawak 2000].
[b] The population including the Subis district.
[c] The population including Miri and Subis districts is available and is shown above.

Table 3　List of Death Due to Cholera

Sex	Age	Race	Locality	Date				Note
				Onset	Admitted	Confirmed	Died	
Male	61	Iban	Kpg. Pelam, Kuala Baram, Miri District	20-12-97	24-12-97 (Miri Hospital)	26-12-97 (Ogawa)	24-12-97	Brought in dead
Female	67	Iban	Rh. Lungan, Bukit Peninjau, Beluru, Marudi District	20-12-97	Refused admission	29-12-97 (Ogawa)	30-12-97	Died at longhouse
Female	50	Iban	Oil Palm Plantation, Beluru, Marudi District	04-01-98	07-01-98 (Miri Hospital)	06-01-98 (Ogawa)	08-01-98	Brought in critical
Male	63	Malay	Kpg. Sg. Putat, Kuala Baram, Miri District		Not admitted	12-01-98 (Ogawa)	10-01-98	Died at home
Male	5 mths	Iban	Batu Niah Squatters, Subis District (brought to Rh. Biri)	22-02-98		24-02-98	25-02-98	Died at longhouse
Male	78	Iban	Rh. Jali, Sg. Arang, Beluru, Marudi District	04-03-98	06-03-98 (Miri Hospital)	05-03-98	06-03-98	Referred from Marudi Hospital
Death due to profuse diarrhea and vomiting but not classified as cholera cases								
Female	73	Iban	Rh. Mogan, Sg. Ngipa, Beluru, Marudi District		Not admitted		04-02-98	Undiagnosed. Died due D&V
Male	40	Berawan	Sg. Dua, Marudi District		Marudi Hospital		13-02-98	Brought in dead
Male	76	Kayan	Sg. Dua, Marudi District		Marudi Hospital		07-03-98	Brought in dead

health care centers and good medical care service provided by the Sarawak Health Department. The oral rehydration solution (ORS) and intravenous drip were given top priority by the State Health Department under its Emergency Action Plan.

Problems Faced by the Health Authorities and Factors Expanding the Miri Epidemic

1. *Drought*

The prolonged dry weather lasted for six months from November 1997 until April 1998 and was the most severe during the decade. It caused an acute shortage of water. The Northern Zone Water Board had to ration water to limited hours per day in Miri town and other areas that received the treated water except for important government buildings (the hospital) as the water level in its reservoir had run very low. The situation was even more critical in the low-lying rural villages as the rainwater tanks emptied and the gravity fed water pipes had run dry. The villagers then had to depend on river water that was found to be contaminated by *V. cholerae* O1. It became a challenge to practice good hygiene, particularly in the rural villages, in the absence of an adequate water supply.

2. *The Squatter Problem*

Miri is an oil town and is one of the towns in Sarawak with a high growth rate in Malaysia. Job opportunities are numerous in the construction sector, on plantations, and in industry as well as the offshore sector. Many rural people from villages within the Miri Division and other adjacent divisions migrate to Miri town. Most of them are low-income groups and worked as laborers. The relatively high cost of living in the town compared to the villages forced them to stay in the squatter areas. Those who work in the construction sector live in the temporary premises provided. These dwellings had poor sanitations, without properly treated water supplies and were overcrowded. The Pujut and Canada Hill squatter areas were the foci of the Miri town outbreak. Squatters along the Niah River adjacent to the Niah bazaar and the Baram River (not far from the Baram industrial zone) use hanging latrines where the squatters directly defecate into the river. One of the first cholera cases in Niah was a squatter.

3. *Mass Movement of People Moving Out from the Infected Area of Miri during the Holiday Seasons*

Celebration of the festive holidays: Christmas and New Years, Hari Raya, and Chinese New Year provided opportunities for those working in the town to travel back to their villages and longhouses to be with their parents and other family members. There was evidence that asymptomatic carriers from the Miri town area were the source of the cholera outbreak in the affected rural villages and longhouses.

4. *The Social and Cultural Effects*

Close-community life styles are practiced in the longhouses. There are no barriers to mixing with one another. Most longhouses celebrate Christmas and hold open house where food is available to any member of the longhouses. The tradition of visiting or entertaining friends and serving locally brewed wine called *tuak* and food is still very much alive. The foods prepared were contaminated by the *V. cholerae* O1 and this resulted in cholera outbreaks in longhouses just after Christmas particularly in the Beluru and Bekenu areas. This was compounded by the customary practice of organizing a feast and prayer to mourn the death (due to cholera) and was found to expand the cholera outbreak as the number of cases and carriers rose after the feast. This happened in Rh. Lungan in Beluru where a funeral feast was held to mourn the death of a 69 year-old woman who died of cholera. As a consequence, 6 cases and 77 carriers in the longhouses were confirmed positive for cholera.

5. *Confirmed Cases and Carriers were Untraceable*

Based on the epidemic record from the Miri Health Department, stool samples from at least 10 patients who had sought treatment for moderate diarrhea at the Miri Polyclinic were detected positive by the Hospital Miri laboratory a few days later. Unfortunately, the patients could not be found as the addresses given were either improper or not complete particularly for those coming from the squatter area. Similar problems were faced when a mass screening or rectal swab was performed in the affected villages and longhouses. When the confirmed asymptomatic carriers were to be isolated for treatment, the people could not be traced because they are very mobile. In addition, the Health Control Teams were unable to carry out complete contact swabs in longhouses as many occupants were not available when this preventive activity was carried out.

Preventive and Control Measures Carried Out to Fight the Long Epidemic in the Miri Division

1. *Management of Cases and Carriers*

Cases were treated at the nearest hospital, the Miri Divisional Hospital or the Marudi District Hospital. In the rural areas, because of the distance to the hospitals, the cases and carriers were managed at the isolation centers set up during the peak of the outbreak. Only critically ill patients requiring hospitalization were transported to hospital. Isolation centers were set up at Beluru, Bekenu, Marudi, Batu Niah and Shin Yang Industrial estates in Kuala Baram. With the co-operation of the district health officer, the government rest house or the community hall were utilized as the

Table 4 The Number of Cases and Carriers Managed at the Isolation Centers and the Operation Period during the Outbreak Peak

Isolation Center	Date Opened	Date Closed	Cases	Carrier
Beluru	30-12-1997	26-01-1998	57	147
Bekenu	20-02-1998	28-02-1998	5	27
Batu Niah community hall	21-02-1998	10-03-1998	4	70
Shin Yang	20-02-1998	28-02-1998	50	101
Marudi rest house	25-02-1998	06-03-1998	3	92

isolation center because the rural health clinics were too small to accommodate a large number of cases and carriers. The number of cases and carriers managed at each of the isolation centers and their operation period are shown in Table 4. Medical assistants and community nurses managed the isolation centers and provided 24 hour nursing care except for Batu Niah. Because of the long distance between Hospital Miri and Batu Niah, one medical officer was sent to Batu Niah to manage any emergency cases there and around the peripheral area. The isolation centers were of multi-purpose. We used them to isolate infected persons so that they would not contaminate the environment and also to educate the people in personal hygiene, environmental sanitation, and the mode of transmission of the cholera bacterium. The setup of these isolation centers also helped to decongest the hospitals.

2. *Staff Deployment*

As the outbreak spread beyond the Miri District, the medical and health staff including medical officers, medical assistants, nurses, health inspectors and other categories of staff were mobilized and deployed from other divisions in the state not only for control but also for treatment in the affected hospitals and cholera isolation centers.

3. *Mass Chemoprophylaxis*

Antimicrobial agents have been shown to reduce the duration of the disease, to shorten the volume of stool by half and to reduce the excretion of vibrios to the environment. However, the use of antimicrobials as prophylactic measures against the spread of cholera was not recommended. Problems associated with extensive use of antimicrobial prophylaxis cause the potential induction of resistant strains, induction of serious side effects, and a false feeling of complete protection by the users [Seas and Gotuzzo 1996; Sack *et al.* 2004]. All the cholera isolates tested for antibiotics sensitivity at the Miri Hospital Laboratory during the 1997–98 outbreaks were sensitive to

Ampicillin (AP10), Cefuroxime (CXM30), Cefoperazone (CFP75), Ceftazadime (CAZ30), Ceftriazone (CRO30), Gentamicin (C30), Metilmycin (NET30), Ciprofloxacin (CIP30), Chlomphenicol (CM30) and Tetracycline (TE30) but resistant to Ampicillin/Sulbactam (SAM20), Rifampicin (RA5) and Metronidazole (MTS5). In the urban Miri where families lived in individual houses only the contacts who were confirmed to carry the cholera bacterium were given chemoprophylaxis with a doxycycline regimen. The supply of drugs or antibiotics was determined by the policy maker in the Ministry of Health. Doxycycline tablet was supplied by the pharmacy division to treat cholera patient. Antibiotic therapy was stopped immediately once the rectal swab or stool specimen of cholera patients were confirmed negative for three times consecutively. Toward the later part of the outbreak in the rural areas where the carrier rate was high, the Health Department was forced to institute mass chemoprophylaxis to the entire population of the longhouses and villages because the environmental sanitation was poor, the river was contaminated and clean water was absent. During the outbreak a total of 21,172 were given the doxycycline regimen. The use of mass chemoprophylaxis during this outbreak showed the reduction of household transmission and reduced the eruption of the disease in some affected longhouses. Table 5 shows the number of cases and carriers were remarkably

Table 5　Comparison of Number of Cases and Carriers in Affected Longhouses before and after Mass Chemoprophylaxis

Longhouses	Number of Door	Number of Head	Cases	Carriers (Total)
Affected longhouses before mass chemoprophylaxis				
Rh. Lungan, Beluru	39	205	6	77 (83)
Rh. Ngalai, Lambir	30	217	0	15 (15)
Rh. Suyong, Beluru	44	205	0	33 (33)
Rh. Benang, Beluru	56	250	4	15 (19)
Rh. Lawang, Beluru	15	67	7	2 (9)
Rh. Janggat, Kuala Baram	36	218	2	11 (13)
Rh. Belaja, Assam Paya, Marudi	18	96	9	6 (15)
Affected longhouses after mass chemoprophylaxis				
Rh. Menggong, Marudi	13	64	1	0 (1)
Rh. Guntor, Subis	35	214	1	1 (2)
Rh. Biri, Marudi	61	258	0	2 (2)
Rh. Aji, Marudi	57	267	0	1 (1)
Rh. Bada, Subis	24	134	0	1 (1)
Rh. Sidu, Marudi	87	490	1	0 (1)
Rh. Lipa, Marudi	50	287	1	1 (2)

higher in affected longhouses before the use of mass chemoprophylaxis than those after the mass chemoprophylaxis was instituted as a preventive measure.

4. *Intensified Surveillance of Cases of Diarrhea and Vomiting*

During the cholera outbreak period, surveillance was further intensified to include the accident and emergency department of the hospitals, the polyclinic and outpatient departments, and all the rural clinics in the Miri Division. Outpatients with mild diarrhea had a rectal swab taken for laboratory investigation and their complete and accurate addresses were recorded so that they could be traced. Suspected patients were admitted and reported immediately to the operation room set up at the Miri Divisional Health Office for speedy investigation. The control team investigated the patients, visited their residing places, and investigated the contacts by taking rectal swabs. In affected longhouses, mass rectal swabs of all the residents were performed. A total of 20,413 rectal swabs were taken from the contacts during the outbreak period and the positive rate was about 5%.

5. *Interagency Cooperation and Community Participation*

Interagency cooperation and community participation was of paramount importance in handling the drought and to prevent cholera during this outbreak. The Divisional Disaster Action Committee was formed to cooperate with other government agencies. Through interagency cooperation, steps were taken to supply treated water. The Public Works Department transported treated water to the rural villages and other needed places. The Education Department supplied treated water to the rural schools whereas the District Office cooperated in setting up isolation centers in Beluru, Batu Niah and Marudi. Red Cresent volunteers helped the health personnel at the isolation centers. The state government assisted the State Health Department by printing 20,000 educational pamphlets on cholera prevention in addition to pamphlets supplied by the Ministry of Health, and these were distributed to the affected divisions.

6. *Health Education*

Health education was actively performed in all the affected localities by the health teams. The mass media also issued pamphlets about cholera and there were press releases on the prevention of cholera. Another important channel of communication to reach the rural areas was via the local radio stations. Spot messages on the danger of cholera in the various local dialects were done in strategic areas. Health talks on prevention and control of cholera were given to the captive audiences (patients and carriers) at the isolation centers, to groups of private sector executives and community leaders so that they could pass down the message to their workers and communities. More than 20,000 pamphlets were distributed to the local population and 480 health talks were given throughout the outbreak period.

7. *Monitoring Environmental Sanitation*

The activities carried out by the health teams included sanitary surveys of the affected villages, water sampling, and sampling of septic tank effluent at the treatment area in the town. Water samples from the water treatment intake points belonging to the Northern Zone Water Board were monitored weekly. The result of the monitoring activities showed that Miri Hospital and Marudi Hospital were found to have discharged effluents infested with *V. cholerae* O1 into the nearby river. The chlorinator for the sewage system at the Miri Hospital had malfunctioned and the Marudi Hospital did not have a proper effluent treatment plant. The problem was rectified by manually chlorinating the effluent with bags of slaked lime at both hospitals. Disinfection of toilets and chlorination of untreated water supplies were performed in the affected villages. Toilets in the affected areas, where necessary, were built.

8. *Stringent Food Safety Enforcement*

Food samples were taken for Laboratory investigation. Examination of food premises and food handlers were done with the help of the Miri Municipal Council. The local Health Authorities imposed a ban on the sale of "*samoan*" and unhygienic food premises in Miri and Beluru were closed. During the Muslim fasting month, 110 temporary food stalls were prevented from operating until they met the stringent hygiene standards and procedures imposed by the Health Department. These included medical examination screening of all food handlers involved and the specification of types of food that could be sold. Pre-cooked food and cold drinks with ice were not allowed to be sold. During the outbreak period a total of 168 food handlers were rectal swabbed, 69 food samples and 410 water samples (including river water) were used for laboratory examination. None of the food handlers were positive. However, the rate of *V. cholerae* O1 isolation was 3.5% (6/168) in food samples compared to 7.8% (32/410) in water samples (Table 6). Decontamination of infected water sources by chlorination and continued monitoring of the water was done by the health workers until the end of the epidemic.

9. *Water Drilling*

The Ministry of Health brought in two drilling machines. They were used to drill wells for

Table 6 Food and Water Samples Detected Positive for *V. clolerae* O1 by the Hospital Laboratories

Sample	Date Taken	Place Taken	Serotype
Food sample			
1. Shrimp sample	22-12-97	Kuala Baram	Ogawa
2. Shrimp sample (different batch)	22-12-97	Kuala Baram	Ogawa
3. Shrimp sample	07-01-98	Kuala Baram	
4. Cooked vegetable dish	25-02-98	Rh. Biri, Beluru	Ogawa
5. Cooked prawn dish	25-02-98	Kpg. Sealine, Miri coastal area	Ogawa
6. Rice	11-04-98	Promin Jaya, Miri town area	Inaba
Water sample			
1. River water	14-01-98	Sg. Putat Jetty, Sg. Baram	
2. Stored water in jerry can	14-01-98	Kpg. Masjid, K. Baram	
3. Stored river water in drum	18-01-98	Rh. Lungan	
4. River water	31-01-98	Sg. Sibuti, at Kpg. Bulau	
5. River water	18-02-98	Sg. Niah, adjacent Rh. Sigi	
6. River water	26-02-98	Old ferry point, K. Baram	
7. Stored water	27-02-98	Rh. Kalom, Niah	
8. River water	27-02-98	Sg. Teraja, small tributary of Sg. Baram	Inaba
9. River water	27-02-98	Hospital effluent point at Sg. Marudi	Ogawa and Inaba
10. River water	27-02-98	S.R.K. Datuk Sharif effluent point at Sg. Baram	Ogawa
11. River water	27-02-98	Sg. Baram at Long Lama Wharf	Ogawa
12. River water	28-02-98	Sg. Teraja, small tributary of Sg. Baram	Inaba
13. River water	02-03-98	Sg. Baram at Long Lama Wharf	Ogawa
14. River water	02-03-98	S.R.K. Ubong Imang, Lg. Lama effluent point at Sg. Baram	Ogawa
15. River water	02-03-98	New ferry point, Kuala Baram	
16. River water	02-03-98	Old ferry point, Kuala Baram	
17. River water	02-03-98	Ferry point at Sg. Miri	
18. Stored water	02-03-98	Rh. Gendang adjacent Sg. Sibuti	
19. River water	04-03-98	Kuala Sungei Marudi	Ogawa and Inaba
20. River water	05-03-98	S.R.K. Datuk Sharif effluent point at Sg. Baram	Ogawa
21. Stored water	05-03-98	Squatter house, Pujut Corner	
22. Stored water	05-03-98	Squatter house, Pujut Padang Kerbau	
23. River water	05-03-98	Sg. Bilad, small tributary of Sg. Baram	
24. Effluent	10-03-98	Hospital Miri Sewage Treatment plant	
25. Effluent	10-03-98	Hospital Miri perimeter drain connecting to Treatment plant	Positive
26. River water	18-03-98	Sg. Bilad, small tributary of Sg. Baram	Positive
27. River water	18-03-98	Sg. Sebato adjacent Rh. Junid, Suai	Positive
28. River water	20-03-98	Sg. Sebato adjacent Rh. Junid, Suai	Positive
29. Stored water	11-04-98	Promin Jaya Residental housing, Miri	Positive/Inaba
30. Stored water	20-04-98	Pujut Desa	Positive/Inaba
31. Stored water	26-04-98	Pujut Desa	Positive/Inaba
32. River water	09-06-98	Sg. Bakas, villagers bathing and washing point	Positive/Ogawa

Table 7　Localities Where Underground Water Wells Were Dug during the Outbreak Period

Locality	Number of Doors (population)	Existing Water Supply
Rh. Gansol, Suai	23 (117)	RWT-MOH
Rh. Junid, Suai	44 (246)	RWT-MRP
Rh. Kalom, Niah	15 (19)	
Rh. Lungan, Beluru	39 (205)	RWT-MOH
Rh. Biri, Ladang Tiga, Beluru	61 (258)	RWT-MOH
Rh. Assap, Ladang Tiga, Beluru	41 (230)	RWT-MOH
Rh. Barau, Ladang Tiga, Beluru	37 (194)	RWT-MOH

Notes: RWT-MOH: rainwater tank supplied by Ministry of Health
RWT-MRP: rainwater tank supplied under the Minor Rural Project

underground water in remote villages that suffered from a lack of clean water due to the prolonged drought. The first well was successfully dug at Rh. Lungan, a longhouse badly affected by the epidemic. The drilling teams then moved to other identified sites until the end of the outbreak resulting in seven wells successfully dug at seven longhouses (Table 7).

The Epidemic Spread to the Bintulu Division

The first cholera case detected on 14 April 1998 in the Bintulu district that was imported from Miri by a man who worked in Miri and went back to his home in Bintulu. He showed acute watery diarrhea and vomiting at home. Subsequently, two of his family members were confirmed to be infected by the cholera bacterium. This may also provide some evidence that asymptomatic carriers could have traveled out of Miri and shed *V. cholerae* O1 to the nearby division during the long epidemic in Miri. After that, the epidemic steadily swept through the Bintulu Division affecting both Bintulu and Tatau District by 27 April 1998. The affected areas in the Bintulu district were found in residents of the town houses (14 cases), workers in camps in the Kidurong industrial area (13 cases), from oil palm plantation quarter workers (6 cases) and rural kampongs and longhouses residents (32 cases). In Tatau district, the majority of the cases (78 cases) were found in more than 10 longhouses situated along the Tatau River and Tatau Old Bazaar. The remaining 28 cases were concentrated along the Tatau River estuary: one longhouse and two Malay kampongs. The outbreaks in the division ended on 12 June 1998 with a total of 171 cases.

The Epidemic Spread to Limbang Division

Cholera first emerged briefly in Limbang district on 18 April 1998 in one kampong, Kampong Limpasong, located in a coastal area of Limbang. The kampong people were mostly Malay (Kedayan) engaged in small-scale fishing. The cholera outbreak was very small; a brief outbreak causing only five cases ending on 29 April 1998. The numbers of carriers were not determined.

A cholera outbreak reemerged almost one year later on 9 June 1999 in the same coastal locality. Five Malay (Kedayan) kampongs were affected but the outbreak was concentrated mostly in Kampong Limpaku Pinang and resulted in 35 cases including one mortality. Two cases were from Kampong Bangkita and one each respectively from Kampong Meriam, Kampong Penapak and Kampong Belawan. Even though the outbreak lasted only two weeks, the scale was larger this time. It resulted in a total of 40 cholera cases and 48 registered carriers with a CFR of 2.5% (1/40).

By 13 July 1999, cholera spread from the Limbang District to the nearby Lawas District and produced an explosive epidemic of short duration. The nature of this epidemic was different from other outbreaks in the state. The district had a clean record of being free from cholera in the past. The sudden outbreak caught the District Health Department by surprise. The explosive epidemic was caused by the use of contaminated rainwater collected in a big drum that was placed under the rain gutter at the fish market in Lawas town. The collected rainwater was contaminated with *V. cholerae* O1. The water was available to everyone to wash their hands after visiting the fish market. This may have led to a high organic matter concentration in the drum water that may have allowed the cholera bacterium to multiply and persist there. Studies show that *V. cholerae* persists longer in water with high concentrations of organic nutrients [West 1989]. The fishmongers also used the same water for washing their tabletops that caused the contamination of fish sold in the market. Both the rainwater sample and fish samples taken from the market were positive for *V. cholerae* O1. Thus, the collected rain water was confirmed as the main cause of this explosive outbreak in Lawas town and its periphery including the schools. Twenty cases of cholera were from either food handlers or owners of the 19 food outlets in the town. Two cooks from the Lawas Secondary School canteen were also infected. In addition, 23 cases were from Lawas town, 89 were students from 2 secondary schools and 90 were school children from 11 primary schools and 3 kindergartens. The rest of the cases (467 cases) were from the periphery kampong area. Eighty-three percent (572/689) of the cases were female and only 17% (117/689) were male. Most housewives had to do marketing for their family and had patronized the fish market and other infected food outlets in the town. This may be why there was a high infection among females in this epidemic. Although there is no direct evidence, people in Lawas District were probably more susceptible to infection by *V. cholerae* O1 than those in other districts because of lack of previous outbreaks and thus lack of specific immunity.

After the mobilization of the experienced state health personnel who had just handled the arduous outbreak situation in Miri, the Lawas epidemic, even though explosive, was short lived and lasted for only one month due to the rapid and effective control measures imposed.

Discussion

High incidences of cholera were recorded during the extreme climatic conditions, the unusually strong El Niño from 1997 to 1998. This El Niño caused very severe and prolonged drought in Sarawak and led to a widely disseminated *V. cholerae* O1 in contaminated domestic water. This drought period was also responsible for the explosive 1999 outbreak in Lawas District as the spread of the *V. cholerae* O1 was strongly suspected during that time. Most of the cholera cases were recorded in the three year period, during and after a strong El Niño from 1997 to 1999, which constituted 85.3% (1,427 cases) of the cumulative 10 year cases. The epidemic originated from Kuala Baram in Miri in November 1997 and spread widely within the division (Miri, Marudi and Subis District) and beyond the division affecting Bintulu Division (both Bintulu and Tatau District in 1998) and Limbang Division (Limbang District in 1998 and Lawas District in 1999).

The history of El Niño during the last 10 years occurred three times: May 1994–March 1995; June 1997–April 1998; and June 2002–March 2003 [U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration Website 2004]. During each occurrence, the El Niño varied in strength measured by differences in sea surface temperatures (SST) varying from normal SST for the entire Pacific Ocean where the higher the difference the stronger the effect of the El Niño on the world climatic conditions. El Niños tend to be associated with severe drought particularly over the western Asiatic Pacific region and a very wet climate especially over the southern part of Latin America. The 1994–95 and 2002–03 El Niños were milder whereas the 1997–98 El Niño was the strongest on record and developed more rapidly than any El Niño over the past 40 years. [*ibid.*].

The association of El Niño with cholera has been reported [Colwell 1996; Salazar-Lindo *et al.* 1997; Kumate *et al.* 1998]. The rise in the marine water temperature associated with the El Niño during the 1990–95 period promoted an increased development of the marine plankton leading to a simultaneous massive contamination of bivalve shellfish and fish which were eaten by the residents of the cities along the 2,000-kilometer Peruvian coastline. This consumption of contaminated shellfish by the Peruvian coastal populations led to the appearance of cholera in Chancay, Callao and Chimbote, seaports that are more than 400 kilometers away from each other [Kumate *et al.* 1998]. The high incidence of cholera cases in the Southeast Asian countries could be associated with the strong 1997–98 El Niño. An unusually high incidence of *V. cholerae* O1 was observed in Southern Thailand between late December 1997 and March 1998 [Kondo *et al.* 2001]. A cholera outbreak in

Irian Jaya, Indonesia in 1997 led to many deaths (personal communication, Dr. Liu Xirong, WHO representative for Brunei Darulsallam and Malaysia based in Kuala Lumpur). The occurrence of extensive cholera epidemics in Sarawak [Malaysia, Sarawak Health Department 1998] coincided with the strong 1997–98 El Niño (Figs. 1 and 4).

Therefore, based on all of this concurring evidence, the effect of El Niño on the occurrence of cholera epidemics in Sarawak was examined. The spread of cholera epidemics in Sarawak during and after the very severe drought caused by the unusually strong 1997–98 El Niño effect is illustrated in Fig. 1. It would be necessary to analyze in detail the relationship among the climatic data, environmental parameters, and incidence of cholera in various parts of Sarawak and the strength of El Niño in the 1994–2003 period to further support the hypothesis on the El Niño-cholera relationship.

The prolonged epidemic in Miri Division that lasted more than six months from 28 November 1997 to 18 June 1998 was the longest cholera outbreak in Sarawak history from recent decades. The epidemic resulted in 385 cholera cases and 949 asymptomatic carriers. Many other asymptomatic carriers were missed by mass rectal swab as well as mild cases that sought treatment in private clinics and went unrecorded. Most private clinics only provide treatment with antibiotics and oral rehydration salt and ignored the rectal swab and the laboratory diagnostic services provided by the government hospital. The Bintulu epidemic in 1998 originated from an imported case that came from Miri during the drought period while the Limbang epidemic in 1999 was the "carry forward effect" of the 1997–98 El Niño. During that period asymptomatic carriers may have traveled from Miri to the adjacent Bintulu Division and Limbang Division and spread the *V. cholerae* O1.

Therefore, the state Epidemiologist should closely monitor the occurrence of probable strong El Niño using the United States National Oceanic and Atmospheric Administration (NOAA) website which has proven to have accurately predicted upcoming El Niños that cause varying degree of drought in the western pacific region. The surge of the cholera cases in the state usually coincides with the occurrence of drought. By monitoring the possibility of forthcoming El Niño, the state epidemiologist should be able to give early warning to the State Health Department and advise to prepare for possible outbreaks of diarrhea diseases.

Large outbreaks usually occurred in the northern zone (Bintulu, Miri, and Limbang) more so than the central (Kapit, Sarikei, Sibu) and southern zones of Sarawak (Kuching, Samarahan, Sri Aman). The northern zone had 84% (1412/1672) of the total cholera patients whereas the remaining 16% were from the central and southern parts. This should give notice to the Sarawak Health Department that the communities living in the northern part of Sarawak are very susceptible to the *V.*

cholerae O1 infection. It also indicates that the northern environments, particularly along the coastal areas have high numbers of the cholera bacterium and changes in environmental conditions may trigger a cholera outbreak. Identifying high- and low-risk areas and the observation on the possible occurrence of extreme global climatic changes can help in the estimation of resources needed for effective health planning and it may help determine the varying patterns of diseases [Salazar-Lindo *et al.* 1997; Colwell 1996; Ali *et al.* 2002].

In the Kuching and Samarahan Division, the number of cases has been limited even during the extensive outbreaks in 1997 and 1998. Kuching division recorded a relatively low number of cases (82 cases). The Kuching division is the most populated and developed of the nine divisions. Kuching City is the capital of Sarawak and the center of management for the state government. Almost all of its settlement areas receive a treated water supply, have a proper sanitary system, and have a good road transport system as well as good access to good health facilities. Nevertheless, big cities like Kuching have never been free of squatter problems and that always provides for poor hygiene-related diseases like cholera. As a parliamentary constituency directly under the care of Sarawak Chief Minister, Samarahan is a fast developing division with good public amenities and the area is well supplied with treated water by the Public Works Department. This was probably the main reason why cholera remained as a small and manageable outbreak even though it occurred regularly. The coast and downstream of the Samarahan division are the cholera endemic foci.

Kapit Division, which is an inland division and away from the sea, and Sri Aman Division were free of cholera epidemic. The interior parts of Sarawak are undulating hills and are covered by a thick vast forest. There is plenty of mountain spring waters that are not affected by the extreme dry seasons and provide clean swiftly flowing water to the interior inhabitants. This may explain the absence of cholera epidemics in the interior parts of Sri Aman and the Kapit Division. In addition, the plentiful flow of fresh water does not accumulate organic matter and provides an unsuitable environment for *V. cholerae* O1 to persist [Birmingham *et al.* 1997]. However, the absence of cholera along the coastal part of Sri Aman Division with close proximity to the endemic coastal area of Samarahan Division cannot be explained.

The difference between the total numbers of male and female being infected and the result of two-sample t-test statistic, where $\alpha=0.05$ was calculated to be $p=0.566$ showed insignificance. This indicates that physiological differences between male and female do not influence susceptibility of humans to the infection by *V. cholerae* O1 and subsequent development of cholera symptoms.

The Orang Ulus, the Iban and the Malays were the most susceptible to *V. cholerae* O1 infection. The Orang Ulus and the Iban (also called the Sea Dayak) mostly live in longhouses built along the rivers in the low-lying areas. They were infected by cholera bacteria through consumption and usage of contaminated river water for washing and bathing during the dry season. Hughes *et al.* [1982] noted that the use of river water for drinking, cooking, bathing and washing was important in the transmission of *V. cholerae*. The occurrence of cholera epidemics during the drought period; the presence of hanging latrines over the rivers; the utilization of river water as a source of a water supply; and the presence of *V. cholerae* in the river water during epidemics support the hypothesis that the river serves as an important route of cholera transmission particularly in the Miri Division. The social and cultural practices of the close community life style and free sharing of food and drink among all the longhouse dwellers during festive and non-festive seasons give rise to the large number of cholera cases among the Iban and the Orang Ulus.

The Malays mostly live along the coastal areas and river estuaries of Sarawak. They are small-scale fishermen who catch fish and shrimp (prawn) in the shallow area of the sea, and collect cockles and crab at the river estuaries. It was proven that the saline seawater provides a suitable environment for *V. cholerae* O1 to persist particularly in the coastal sea faunas [Islam *et al.* 1994; Guthmann 1995]. Thus, the Malay are prone to infection by *V. cholerae* O1 through consumption of contaminated seafood particularly those eaten uncooked like "*umai*" and "*cencalok.*" *Umai* is a popular local dish made from uncooked but freshly caught *samoan* whereas *cencalok* is a preserved but uncooked *samoan* with salt added to taste and could be kept for long period before consumption.

An analysis of the occupations of the patients showed a high incidence of cholera attack in the low-income laborer and rural housewives (Fig. 7). During the El Niño, the river water in nearby low-lying settlement areas or longhouses became very low and even dried out in some places and the natural flow of river water halted. *V. cholerae* O1 was isolated from numerous rivers in the Miri Division. The widespread outbreak in the interior parts of the Miri Division occurred mostly where the river water was contaminated. In addition, the ecological and poor sanitary conditions during the dry period in the longhouses, squatters, and poor rural communities provide a suitable environment for transmission and rapid dissemination of *V. cholerae* O1. The extensive use of the contaminated river by the longhouse occupants for domestic purposes led to the major outbreak.

Non-school children and students were the major victims of cholera (Fig. 7). The infected non-school children and infants were for the most part the family members of the low-income groups. This suggests that household transmission took place to a considerable degree. The infected students were from schools in Lawas District. They had been infected because of poor hygiene in the preparation of food in the school. This is supported by the confirmation of two cholera cases among the cooks from Lawas Secondary School canteen. Fig. 8 shows that the majority of the cholera patients were from adults of the active aged group of 19 to 59 years old. This finding was typical of food-borne outbreaks where adults have gathered to attend festive parties or funeral feasts.

Various intervention activities and preventive measures carried out by the Health Department and the local authorities during and after the major 1997–99 epidemics effectively prevented further epidemics in the state. There were no cholera outbreaks in year 2000, 2001 and 2002 in the state. The climate during these years may be responsible at least in part for the absence of a cholera case. After three years quiescence, a *V. cholerae* O1 infection took place in cholera-endemic Miri Division in 2003 but it was very well averted by the highly prepared and experienced State Health personnel, thus, limiting cholera to only 15 cases.

Therefore, the early deployment of State Medical and Health personnel to the epidemic areas, the intensified surveillance of diarrhoeal diseases followed by the quarantine and treatment of infected individuals at isolation centers and hospitals were effective ways in managing the cholera epidemics. As importantly, the encouragement of community participation, the interagency cooperation and intensive health education for the poor communities with low education status were also crucial in the management of the epidemic. The management of cholera epidemics would further be strengthen by monitoring of community sanitation, assisting in the construction of proper latrines, providing safe water supplies by drilling underground water wells, and providing uninterrupted gravity fed water by building dams at a higher water intake area. The enforcement of stringent food safety procedures for food handlers would also be a keystone in controlling future outbreaks of cholera and other diarrhea diseases particularly in the rural area of Sarawak. Although mass chemoprophylaxis proved to reduce household transmission and eruption of cholera in the affected longhouses in the Miri Division, it should only be instituted in the critical situations where the rapid spread of cholera is threatening to lives in the affected communities due to the long distance to the nearest diarrhea treatment center.

The Rajah Brooke ruled Sarawak for 100 years (1841–1941). Sarawak, then, became a Crown Colony in 1941 after the Rajah ceded Sarawak to the British Government. Sarawak achieved its independence from the British Government when it became one of the Malaysian states in 1963. The number of cholera cases in Sarawak before the independence was much larger than those in the 1994–2003 periods reported in this study. All rural settlement had no proper water supply, poor refuse disposal and practiced indiscriminate disposal of feces before 1963. The rural people depended on shallow well, river and streams as their water supply. These water sources were susceptible to bacterial contamination during dry month. Proper latrine was lacking and the rural folks commonly took the easy way of squatting under the tree or on the river bank to pass stool. Communication systems, particularly land transport, were poor. The rural people took days and weeks to travel down by rivers or by land (on foot) to the limited health facilities available and vice versa. It was difficult for the health team to reach the rural settlement to institute preventive and control measures in time of disease outbreak. After the independence from the colonial rules the new Malaysian Government, through its New Economic Policy, has drawn up many plans which put much emphasis on the rural socioeconomic development. More than 90% of the rural population during that time was the Malaysian natives which were locally called the Bumiputra. After 1963, much progress had been brought to the rural areas which include safe water supply, provision of toilets, improved sewage and refuge disposal, and much improved education standard. All these factors had contributed to the improved personal hygiene, awareness and knowledge to fight against diseases, thus, successfully scaled down the magnitude of outbreak of communicable disease like cholera in the recent decades. Nevertheless, due to the large land size and vast rainforest area in Sarawak, there are some rural populations which remain isolated from the government development plan.

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