AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C 20523
BIBLIOGRAPHIC INPUT SHEET

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Batch 80

1. SUBJECT CLASSIFICATION

A. PRIMARY
Health

NS00-0000-G744

B. SECONDARY
Tropical diseases—Sri Lanka

2. TITLE AND SUBTITLE
Environmental assessment of malaria control project,Sri Lanka

3. AUTHOR(S)
Gerberg,E.J.; Wilcox,Henry

4. DOCUMENT DATE
1977

5. NUMBER OF PAGES
104p.

6. ARC NUMBER
ARC CE614.532.G362

7. REFERENCE ORGANIZATION NAME AND ADDRESS
IC&R

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

9. ABSTRACT

10. CONTROL NUMBER
PN-AAF-335

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Disease control
Ecology
Environmental factors
Insect control
Insecticides
Malaria
Pesticides
Sri Lanka

13. PROJECT NUMBER

14. CONTRACT NUMBER
AID/Asia-C-1233

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

CE
614.532
G362

PN-AAF-225

Contract
AID/ASIA-C-1233
(ICtR)

DEPARTMENT OF STATE

AGENCY FOR INTERNATIONAL DEVELOPMENT

ENVIRONMENTAL ASSESSMENT

OF

MALARIA CONTROL PROJECT - SRI LANKA

A.I.D.
Reference Center
Room 1656 NS

BY

EUGENE J. GERBERG

AND

HENRY WILLCOX III

AID/asia-C-1233

INSECT CONTROL & RESEARCH, INC.
BALTIMORE MARYLAND 21228

ENVIRONMENTAL ASSESSMENT

OF

MALARIA CONTROL PROJECT - SRI LANKA

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I.0 INTRODUCTION

1.1 Purpose of the Environmental Assessment

The Agency for International Development (AID) has promulgated two new regulations effective June 30, 1976. The AID "Environmental Procedures" (Regulation 16) and the interim regulations on provisions for assistance in the procurement and use of pesticides.

The AID "Environmental Procedures" are intended to assist AID in implementing the requirements of the National Environmental Policy Act of 1969 (NEPA). AID's new policy is to (1) assist in the strengthening of the indigenous capabilities of developing countries to appreciate and evaluate the potential environmental effects of the proposed projects and (2) ensure that any environmental consequence of proposed AID activities are considered in collaboration with the host country, and yet remain consistent with the intent of NEPA.

Based on an Initial Environmental Examination, an Environmental Assessment (EA) was determined to be required. The purpose of the EA is to provide AID and host country decision makers with a comprehensive understanding of the reasonable foreseeable environmental effects, both positive and negative of a proposed action and its reasonable alternatives, carried out with or affecting the host country. The expected benefits of the development objectives can be weighed against any adverse short of long term impacts upon the human environment or any irreversible or irretrievable commitment of resources.

1.2 Purpose of Project

Malaria in Sri Lanka (SL) ranks as the most prevalent major disease affecting the general population. In 1975 there was approximately one half million diagnosed cases of malaria. The purpose of this project is to bring

malaria under control, and to strengthen the institutional capabilities within an integrated nationwide health service system to implement the malaria control program during the attack and maintenance phases. This project has been given the highest priority by the government of Sri Lanka (GSL). The Cabinet of the GSL has approved a full five-year anti-malaria campaign.

AID support of a malaria control program in Sri Lanka is consistent with AIDTO CIRC A-733 dated July 3, 1973, which provides that assistance be provided if a country demonstrates its own interest and concern for malaria control through the provision of an adequate budget and staff to carry out the program. The malaria control project (MCP) is also in accord with the AID new initiatives calling for missions to work with host governments in developing programs to improve the quality of life and the standards of health and well-being of the people, particularly the poor majority.

The project is a large scale 5-year effort to reduce the incidence of malaria in SL to a minimum of one case per 1000 population per year country wide. The program is divided into 3 phases: (1) intensive spraying, (2) selective spraying with surveillance and (3) surveillance with phased integration into the General Health Services. Program components to achieve this result include:

1. Spraying the vector resting places of rural homes including outhouses, with residual insecticide to interrupt malaria transmission.

2. Continuous surveillance of the population at risk to malaria to detect cases of the disease.

3. Treatment of cases detected using anti-malarial drugs.

4. Training and supervision to insure modern effective and safe malaria control techniques are implemented.

5. Research, both basic and applied, to provide epidemiological and entomological knowledge on malaria in SL.

6. Health education to familiarize the general public of the causes, methods of prevention and activities of the malaria control program.

7. Evaluation of program effectiveness through monthly country wide reviews and annual evaluations.

2.0 DESCRIPTION OF COUNTRY

2.1 Location and Size

Sri Lanka is a pear-shaped tropical island in the Indian Ocean located 18 miles off the southeast tip of the Indian mainland. It lies between the northern latitudes 5°55' and 9°50' and the eastern longitudes 79°42' and 81°52'. It is bounded on the west by the Gulf of Mannar and on the east by the Bay of Bengal. It has an area of 25,332 square miles (65,610 km^2). It is 270 miles (432 km) long from Point Pedro, its northernmost tip, to Dondra Head, its southern tip, and 140 miles (224 km) wide from Colombo on the west to Sangamankanda Point on the east coast.

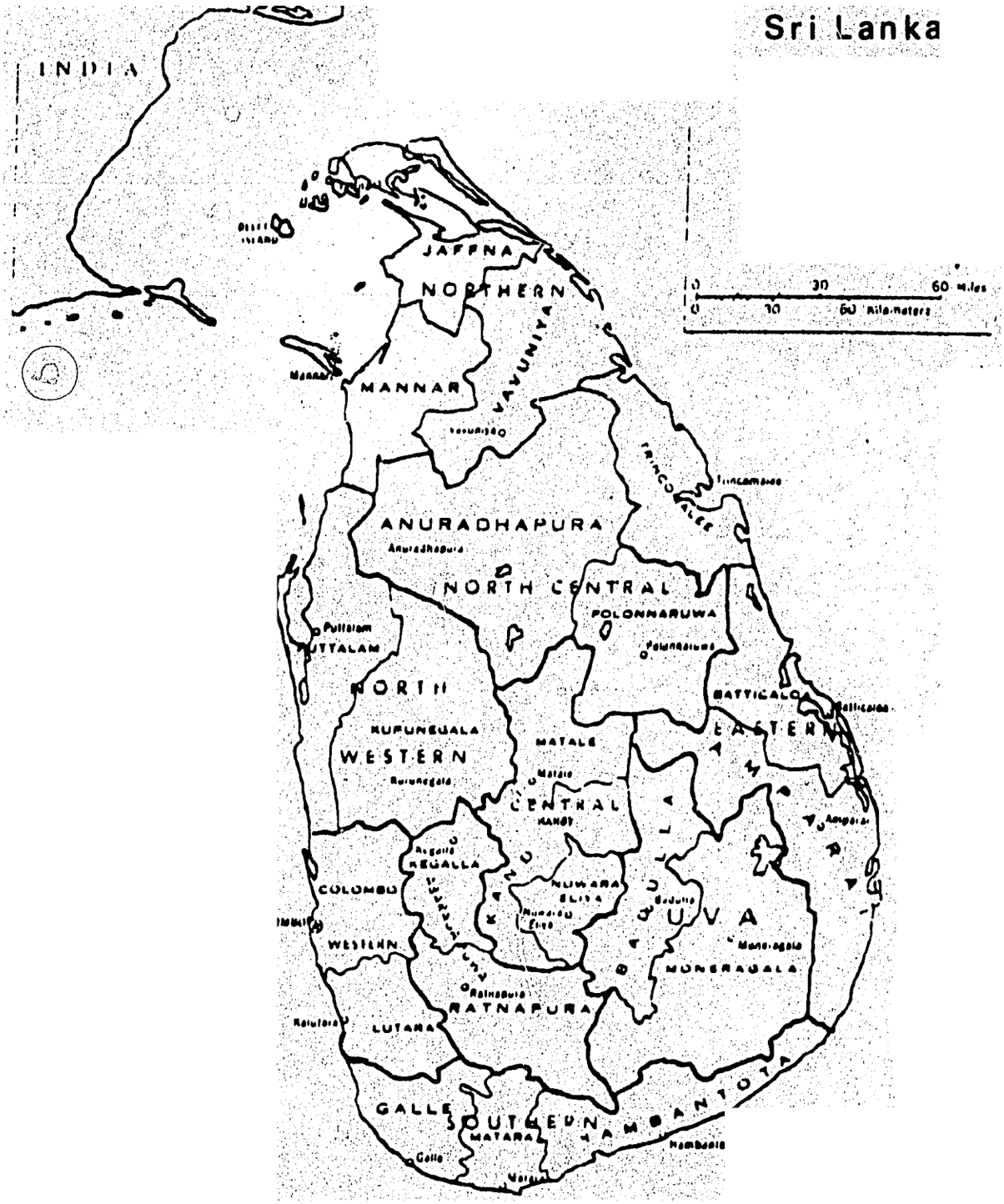
2.2 Physiography

The island has a coastal belt that rises from sea level to 100 feet (30.5 m) above, approximately 25 miles (40 km) across at its widest point. Sandy beaches extend for great distances, indented by coastal lagoons. The soil is sandy and saline. An extensive belt of rolling plains striated with ridges rising from 100 to 500 feet, (30.5-152m) in the south, covers most of the island. The soil is fertile loam, humic and in the north, limestone. An irregular shaped mass of hills occur in the south central portion, with heights reaching over 6000 feet (1829 m). The highest elevation is at Pidurutalagala (8292 ft.-2528 m).

The rivers rise in the high mountains of the central southwestern hill country and flow over the plateau to the plains. Some are streams that dry

up in the dry season. Rivers are more numerous in the southern and southwestern parts. In the northern, eastern and northeastern plains, long, dry spells may cause the majority of the rivers and streams to be reduced to a trickle for the most part of the year. There are 16 principal rivers, the Mahaweli Ganga (206 mi., 330 km) being the longest.

Though there are few natural lakes, there are 12,000 bodies of water ranging from tiny ponds to man-made lakes, several miles wide. Some of these large bodies of water are used as reservoirs or tanks.


Sri Lanka
INDIA
JAFFNA
NORTHERN
VAVUNIYA
MANNAR
TRINCOMALEE
ANURADHAPURA
NORTH CENTRAL
POLONNARUWA
PUTTALAM
NORTH
WESTERN
KURUNEGALA
MATALE
CENTRAL
KANDY
BATTICALOA
EASTERN
COLOMBO
WESTERN
KEGALLA
NUWARA ELIYA
UVA
MONERAGALA
RATNAPURA
LUTARA
GALLE
SOUTHERN
MATARA
HAMBANTOTA
0 30 60 Miles
0 30 60 Kilometers

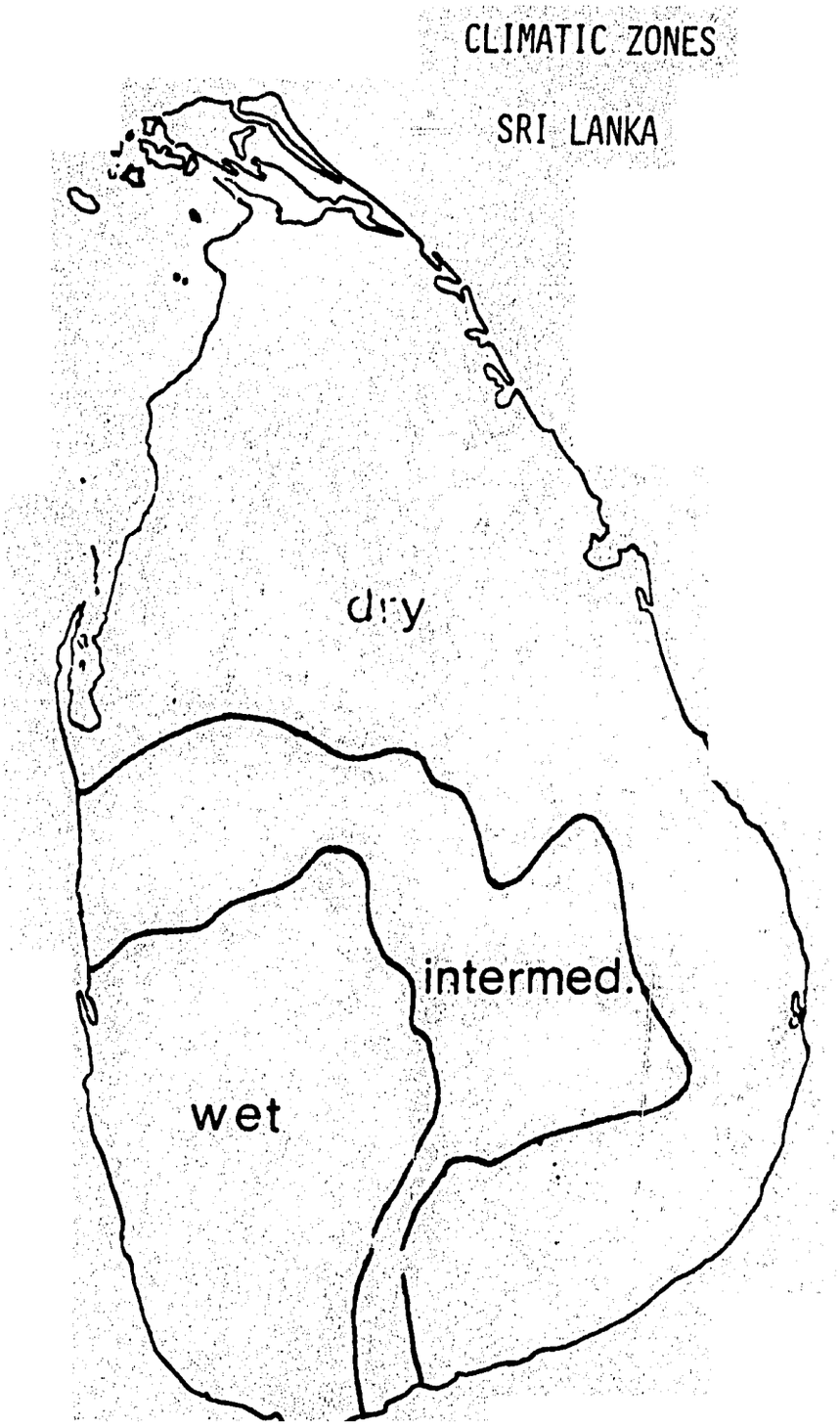
2.3 Climate

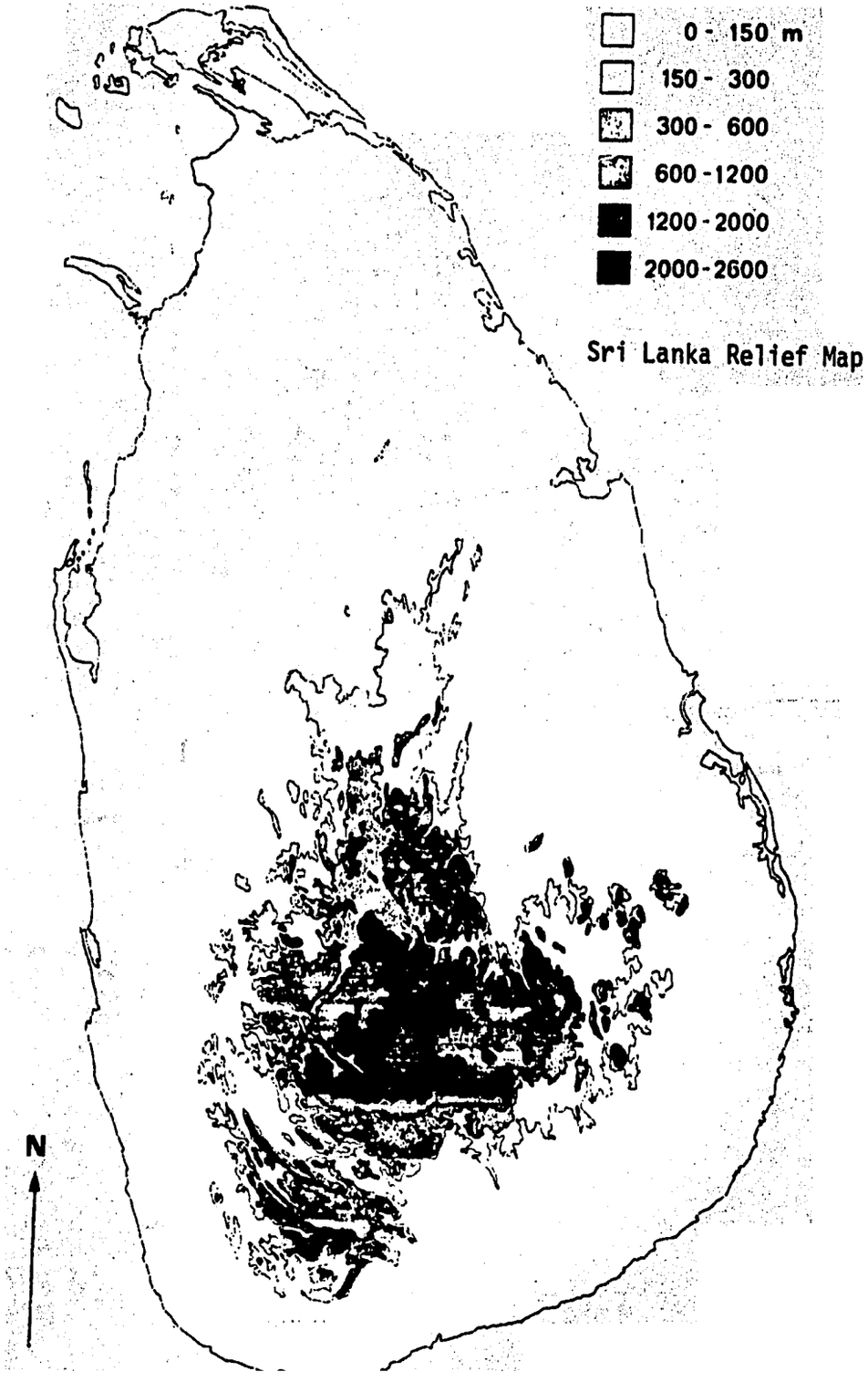
Since Sri Lanka is a relatively small island near the equator, the surrounding ocean tends to stabilize the temperature and relative humidity. Variations are small in any one place throughout the year, however considerable variation exists between the lowlands (Colombo, sea level, 80.6° F. annual average) and the mountainous areas (Nuwara Eliya, 6199 ft., 1890 m, 60.0° F. annual average).

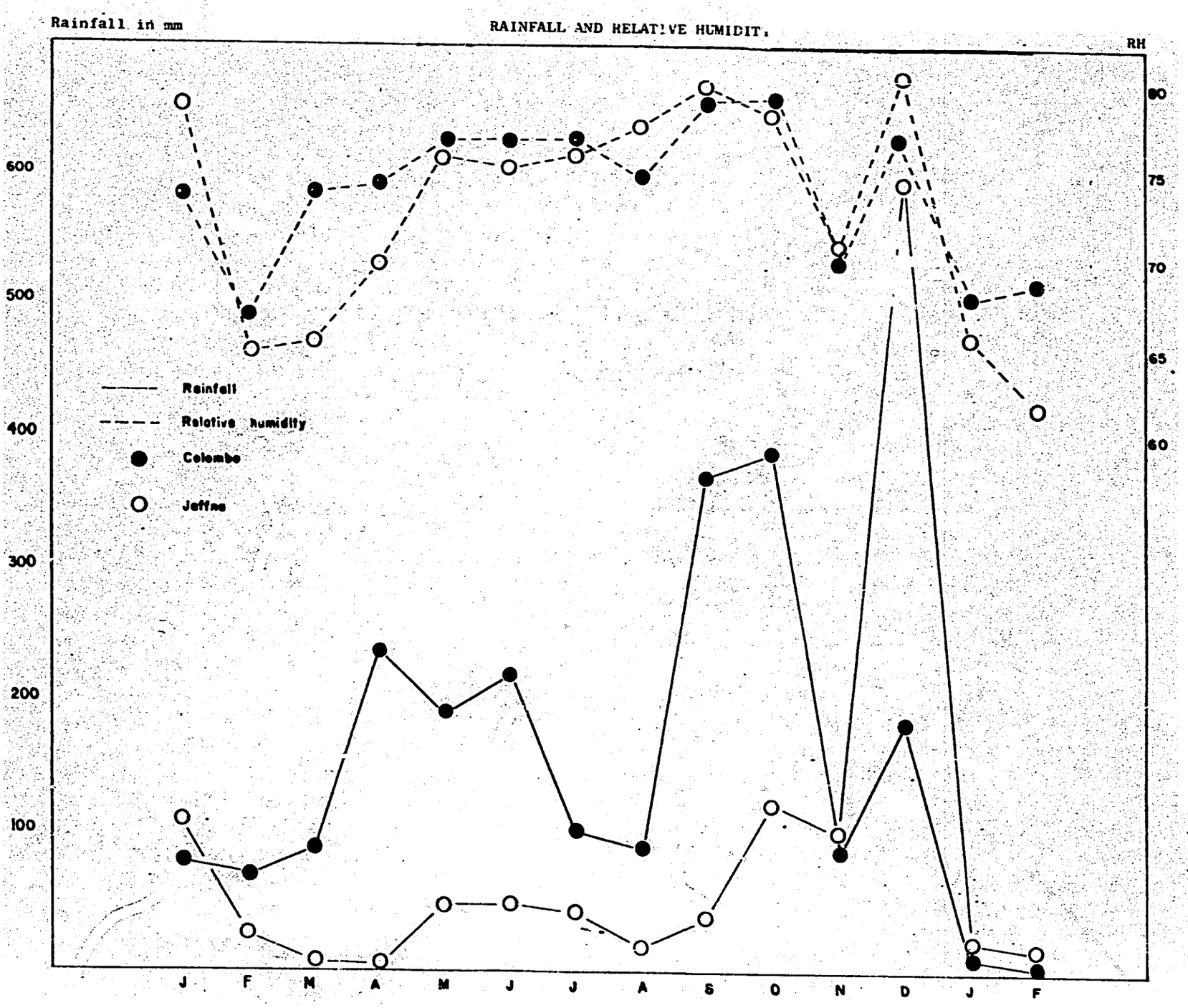
The island's relative humidity is generally high, ranging from 61% to 90%. Seasonal variations occur but are not great. Humidity typically increases at night as the temperature decreases.

Rainfall is of three main types - monsoonal, convectional and depressional. There are two monsoon seasons and two intermonsoon periods. The southwest monsoons (Maha) occur from May to September, bringing 15-25 inches (35-63.5 cm) of rain to the southwest coastal region, moving inland to the hill country and dropping 35 inches (89 cm). The northwest and southeast may remain dry. In August rainfall activity shifts to the northern and eastern plains, bringing 2-5 inches (5-13 cm) of rain. The intermonsoon period, October, produces convectional rains, usually in the afternoon. Islandwide, this is the rainiest period of the year. The northeast (Yala) monsoon starts in November and drops 15-20 inches (35-51 cm) on the northern and eastern slopes of the hill country. It is a weaker and drier monsoon than the southwest monsoon. By February the rains have dwindled to 2-5 inches (5-13 cm) per month over the eastern half of the island. March through April, the second intermonsoon period, may bring some rainfall because of depressions, but generally the quantity is less than the first intermonsoon period.

The intensity and distribution of rainfall has created three basic climatic zones - dry, intermediate and wet. These zones correspond very closely with the different levels of endemicity of malaria. The low rain-


CLIMATIC ZONES
SRI LANKA
dry
intermed.
wet


0 - 150 m
150 - 300
300 - 600
600 - 1200
1200 - 2000
2000 - 2600
Sri Lanka Relief Map
N


Rainfall in mm
RAINFALL AND RELATIVE HUMIDITY
RH
600
500
400
300
200
100
80
75
70
65
60
Rainfall
Relative humidity
Colombo
Jaffna
J
F
M
A
M
J
J
A
S
O
N
D
J
F

HO/VBC/72.395

fall of the southwest monsoon that may occur in the dry zone, intermediate zone and fringe areas of the wet zone can result in pool formation in the streams and rivers. As the main mosquito vector of malaria (Anopheles culicifacies Giles) favors drought pools, this may produce a vector population explosion resulting in periodic epidemics of malaria.

2.4 Vegetation

A large part of SL, particularly in the southern and western coastal regions, is covered by dense vegetation with vast tea estates in the high lands and rubber and coconuts in the midlands and lowlands. These tree crops have replaced much of the virgin evergreen forests of SL.

SL can be divided into 6 generalized ecosystems:

1. The Dry zone Manilkara ecosystem covers the northwestern and southeastern lowland where annual rainfall ranges between 600 and 1200 mm The vegetation is characterized by medium-sized semideciduous trees like the Ceylon ironwood Manilkara hexandra Roxb., Dub. and the Satinwood Chloroxylon swietenia D.C. over a layer of spinous bush, and dense creepers. Much of the ecosystem is now changed, because of exploitation of the wood and cultivation or grazing. In many areas there is a secondary spinous dense scrub vegetation or a dry grassland, kept open by fire. In Mannar island and surrounding areas the sandy soil has, besides Manilkara and Bauhinia, a sparse tree vegetation of Acacia planifrons W. & A.

2. The Dry zone Chloroxylon ecosystem covers much of the remaining lowland and parts of the upland. It may be doubted whether there are any large remains of primary forest in this area. Usually the secondary character is evident. In its old stages the forest is dense, dominated by a number of tall deciduous or semi-deciduous trees, e.g. the Satinwood Chloroxylon swietenia D.C., the Trincomalee wood Berrya cordifolia Burret, the Ceylon oak Schleichera oleosa Lour., Oken, and the evergreen Ebony

Diospyros ebenum Koenig. Initially, exploitation means removal of the tall deciduous trees, often followed by shifting cultivation. The next widespread stage is a dense shrub, less spinous and less dry than in the Manilkara ecosystem. As in the latter there are patches of grassland with scattered trees, dry savanna, kept open by fire.

3. The Intermediate zone ecosystem occupies peripheral parts of the wet zone lowland and wet upland to about 900 m above sea level. Much of the area was cultivated in comparatively recent time and is now occupied by coconut plantations or food crops. Most remaining forests are degraded or secondary. Clearing the forests in this area of high rainfall resulted in degeneration and erosion of the soil. In the secondary forest the humid and evergreen character is therefore less clear. In its climax stage the ecosystem is based on a tall forest (upper stratum at about 30 m) composed of numerous trees, many of which are evergreen, e.g. Canarium zeylanicum BL., Dipterocarpus zeylanicus Thw., Filicium decipiens Thw., Artocarpus nobilis Thw. and Euphoria longana Lamk. The secondary forest is more transitional characterized by several of the species of the Dry zone Chloroxylon ecosystem. As a result of human interference certain areas are occupied by savanna, with scattered trees resistant to fire.

4. The Lowland wet evergreen forest ecosystem originally covered the southwestern part of SL to about 900 m above sea level. In this area the perpetual rainfall exceeds 2000 mm and the mean temperature of the two coldest months is 20° C. The virgin forests were composed of numerous evergreen tree species, some reaching heights of 40-45 m. There are very few remains of this, the foremost forest type of SL. The dominating trees are Dipterocarpus spp., Doona spp., Vatica spp., Hopea spp., Shorea spp., and Mesua ferrea L. Exploitation and cultivation of this area of rain forest has degraded the soil. On exposed ground the humic layer was soon destroyed, the nutrient cycle broken and upwards movement of water during hot and dry days produced a lateritic cementation of layers near the surface. Uncultivated, deforested areas on mountain slopes are in places covered by fernland,

mainly Gleichenia linearis Cl., or savanna.

5. The Sub-montane wet evergreen forest ecosystem occupies the area between about 900 m and 1500 m altitude in the wet zone. Although less productive than the Lowland wet evergreen forest, this ecosystem, transitional between systems 4 and 6, is composed of numerous tall species of trees, some of which are economically important, e.g. Doona spp., Calophyllum spp., and Wormia triquetra Rottb. Epiphytes are common. Deforestation has advanced far: grassland, "dry patanas", or "talawa", a type of savanna, and more recently plantations of tea, have occupied much of the area covered by the sub-montane wet evergreen forest.

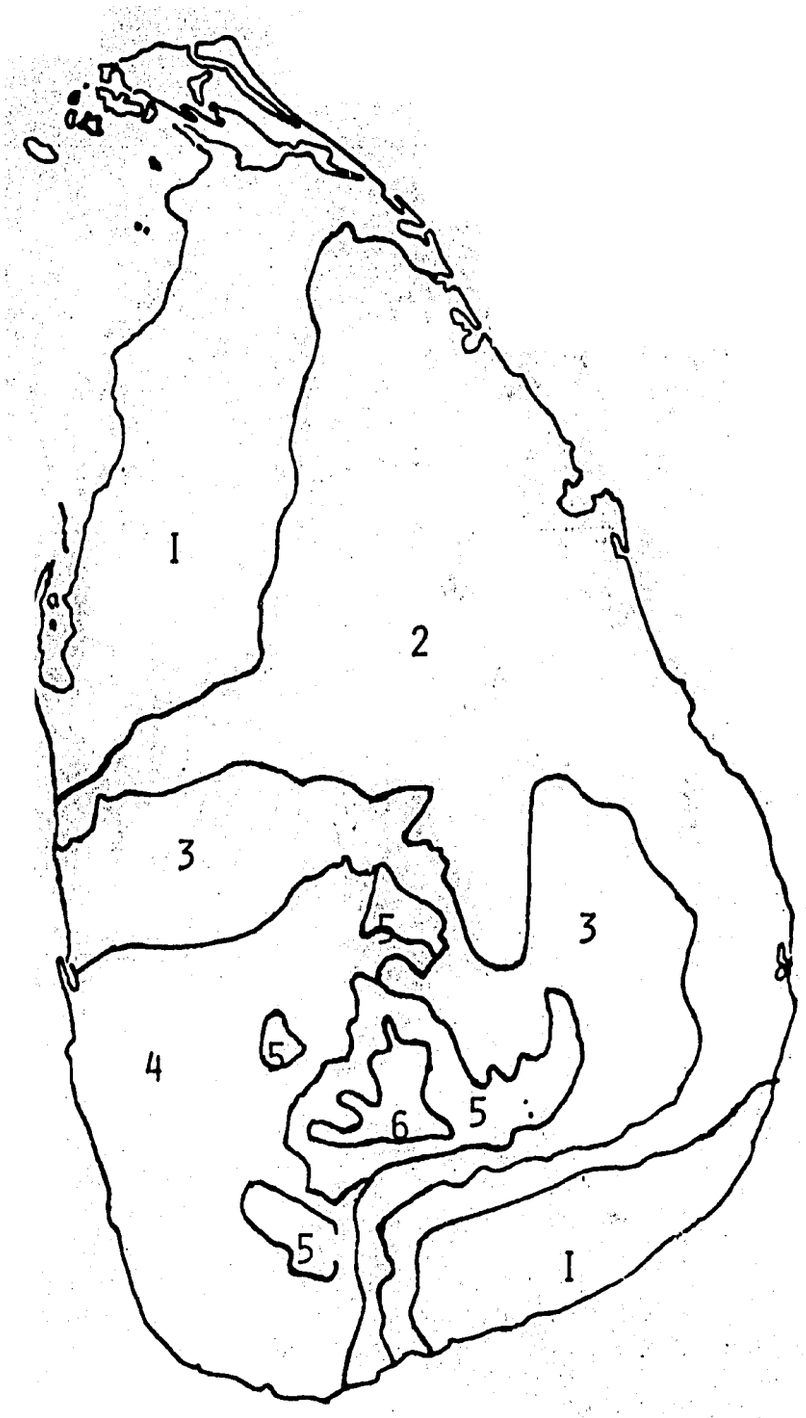
6. The Montane wet forest ecosystem covers the high altitude areas in Ceylon, above about 1500 m. The humidity and rainfall are high and the temperature of the coldest months comparatively low. The low evergree forest grows and regenerates slowly. Characteristic elements are e.g. Syzygium spp., Gordonia spp., Michelia nilagirica Zenk., and Rhododendron arboreum Sm. The trees usually bear mosses and lichens. Deforestation ha resulted in the wet patanas, a grassland, at places with much Pteridium aquilinum L., Kuhn and scattered specimens of Rhododendron arboreum, adorned with Usnea.

2.5 Animal Life

Sri Lanka has been very progressive in its attempts to preserve and protect its wildlife. In 1938, an ordinance was passed to "provide for the protection of the fauna and flora of Ceylon". Since then amendments have been added in 1964 and 1970. The ordinance restricts disturbing the fauna and flora in the areas set aside as Natural Reserves. In the Strict Natural Reserve, no one may enter, except by permit to conduct scientific research. The ordinance also prohibits or restricts the hunting of many species of birds and animals. Nearly 10 per cent of the total land area has been set aside for National Parks, Sanctuaries and Forest Reserves.

SRI LANKA

GENERALIZED ECOSYSTEMS



1. THE DRY ZONE MANILKARA ECOSYSTEM
2. THE DRY ZONE CHLOROXYLON ECOSYSTEM
3. THE INTERMEDIATE ZONE ECOSYSTEM
4. THE LOWLAND WET EVERGREEN FOREST ECOSYSTEM
5. THE SUB-MONTANE WET EVERGREEN FOREST ECOSYSTEM
6. THE MONTANE WET FOREST ECOSYSTEM

Elephant, wild buffalo, deer, sambhur, bear, leopard and crocodile are found in the parks. Approximately 400 species of birds have been recorded from Sri Lanka.

A few endangered species (Federal Register, October 27, 1976) occur in Sri Lanka. These are listed below:

Asian elephant	Elephas maximus
Langur	Presbytis entillus
Langur, purple faced	Presbytis senex
Crocodile, Ceylon mugger	Crocodylus palustris kimula
Bengal Monitor	Varanus bengalensis
Indian Python	Python molurus molurus

It is not anticipated that the anti-malaria campaign will have any direct impact on any of the endangered species.

2.6 Socio/economic Conditions

2.6.1 Population and Population Growth

SL had an estimated mid-year population of 14 million people in 1976 of which 10.9 million (78%) were rural and 3.1 million (22%) were urban. The average household size is 5 individuals. Eighty per cent of the population live in malarious zones. The annual growth rate was estimated to be 1.7% in 1976, down from 2.8% in 1963. The government has been concerned for many years about the social and economic strain that a high growth rate places on society. To this end, they entered into an agreement with Sweden in 1958 to receive assistance in a family planning program. This program has been successful in decreasing the birth rate from 36.6/1000 in 1960 to 27.3 in 1974. The death rate has declined from a level of 27.2/1000 at the turn of the century to 8.0/1000 in 1975. A highly successful public health program, especially with regard to the prevention and control of malaria has dramatically curbed the death rate. The most dramatic im-

provement occurred in the mid 1940's with the use of DDT to prevent and control malaria. This was especially significant among infants.

Although the population is healthier, as evidenced by life expectancy increases - 32 years in 1922; 43 years in 1946; 66 years in 1975; the drop in the death rate has resulted in a much more densely settled population - 178/sq.mi. in 1922, 263/sq.mi. in 1946 and 540/sq.mi. in 1975. The strain of increasing population density manifests itself in many ways, among which are overcrowded classrooms, higher unemployment, insufficient hospital space and more governmental spending on welfare activities.

The Sinhalese are the largest ethnic and linguistic community constituting 72% of the population. The Sinhalese community is divided into 2 groups based upon geographical origin and cultural distinctions. The low country Sinhalese (62%) live primarily in the western and southern coastal areas, while the Kandyan Sinhalese (38%) occupy the highlands of the south-central region.

The largest and longest established minority community are the Tamils, constituting about 20% of the population. The group called Sri Lankan Tamils, constitute slightly less than half of the Tamil population, are descendants of the early Tamil kingdoms of Ceylon. They are concentrated in the eastern and northern coastal areas of SL. The Indian Tamils are descendants of Tamils imported from Southern India by the British colonists to labor in the vast tea plantations and estates located in the Kandyan region.

The Moors, descendants from early Arab traders, constitute approximately 7% of the population. The balance of the population consists of Malays, Burghers and aboriginal Veddahs.

2.6.2 Mortality and Morbidity

A combination of increased health care facilities and the control of

malaria have greatly influenced the rapid decline in the crude death rate and infant mortality. Over the last thirty years both rates have decreased to 1/3 of the original rate. The increasing popularity of maternity hospital use has given SL one of the lowest infant mortality and maternal death rates in south-east Asia. Diseases of the heart, circulatory and nervous systems, cancer, parasitic diseases such as hookworm, tuberculosis influenza, pneumonia, anemia, gasteroenteritis, childbirth and accidents caused most of the deaths from 1965 to 1975 (in order of prevalence).

Though the malaria mortality is now low, due to widespread rural health centers, the morbidity is of epidemic levels. There were between 1/2 to 1 million cases of malaria in 1976. In the 1935 malaria epidemic over 100,000 lives were lost.

2.6.3 General Health and Welfare

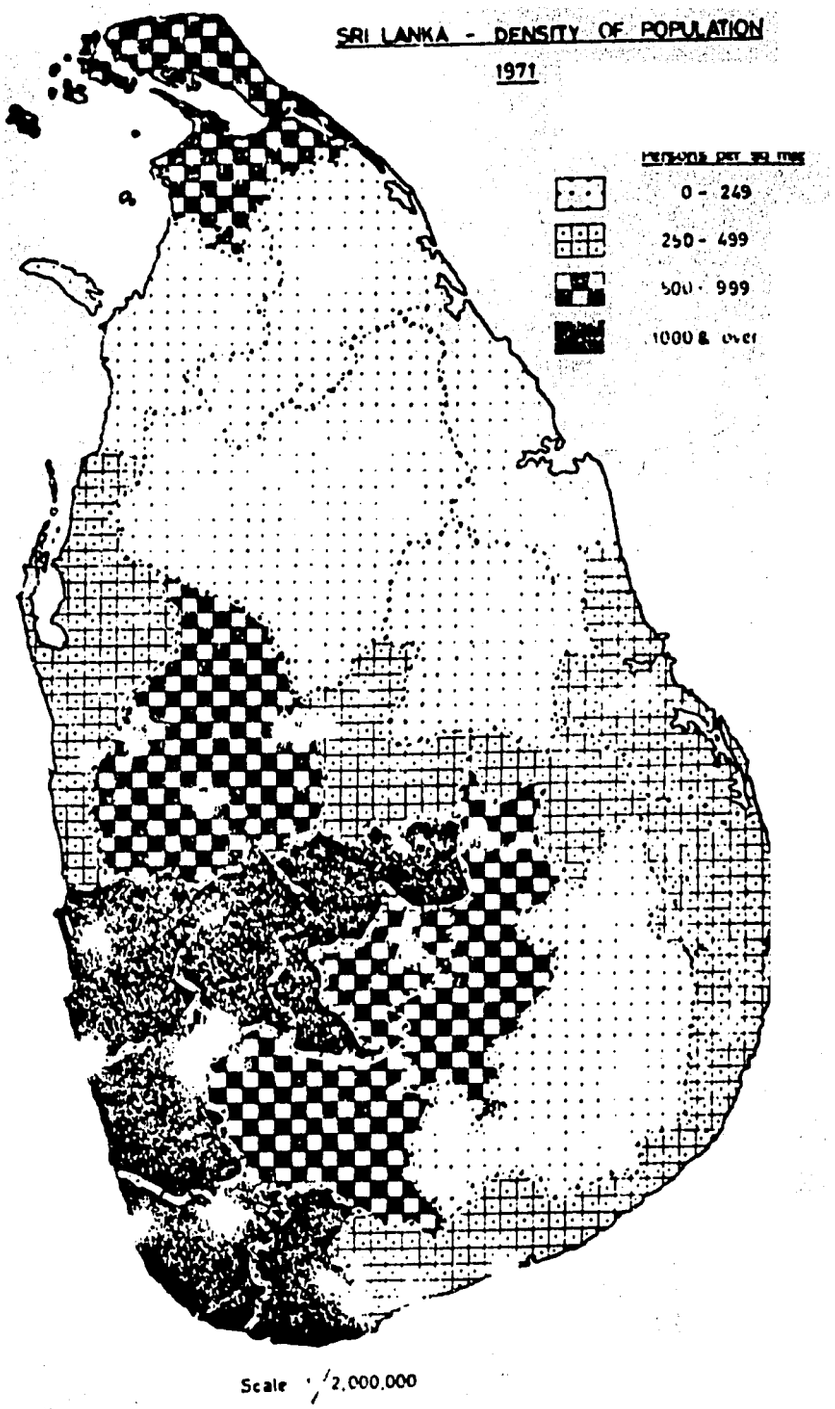
SL has 750 medical institutions, which include Teaching, Provincial, District and Cottage hospitals, Central Dispensaries, and Maternity Homes. The quantity of medical service available in SL is much higher than the average for South Asia, and quality of the service is considered high.

The country is divided into 104 health areas, each of which is under the charge of a Medical Officer of Health (MOH). A team of Public Health Inspectors (Sanitarians) and one or more Public Health Nurses assist the MOH. There are approximately 2,000 Western and 10,000 traditional Ayurvedic private medical practitioners dispersed throughout the country. In 1974, it was estimated that there were 951 people per medical practitioner The average citizen of SL has a medical practitioner of either the Western or Ayurvedic type within 0.8 miles from his home, and a Western type medical practitioner within 2.2. miles.

The Director of Health Services administers both curative and preventative health services including all the specialized campaigns such as the Anti-Malaria Campaign.

Population Growth of Sri Lanka (1901 - 1970)

Year	Population	Annual % increase	Density per sq. mile	Birth rate	Death rate	Infant mortality per thousand	Maternal mortality per thousand	Life expectation of birth (years)
1901	3 566 000	1.9	141	-	-	-	-	-
1911	4 '06 000	1.5	162	-	-	-	-	-
1921	4 499 000	1.0	178	38.9	-	-	-	31.7
1931	5 307 000	1.7	210	37.8	22.1	-	-	37.2
1946	6 657 000	1.6	263	37.4	20.3	101 (1946-50)	9.3 (1946-50)	45.7
1953	8 098 000	3.1	320	32.8	10.7	75 (1951-55)	5.0 (1951-55)	58.1
1963	10 582 000	2.9	423	34.4	8.5	55.8	2.4	63.5
1969	12 240 000 (est.)	2.5	500	30.4	8.3	47.7 (1967)	1.8 (1968)	-
1970	12 514 000 (est.)	2.1		29.4	8.0	50.2 (1968)		


SRI LANKA - DENSITY OF POPULATION
1971
0 - 249
250 - 499
500 - 999
1000 & over
Scale 1/2,000,000

Outpatient care is provided at special departments in the hospitals, clinics and dispensaries. Government provided medical attention is available to everyone, resulting in crowded waiting rooms and long lines of patients.

There were 894 rural health centers in 1962, which provided curative, preventive and educational health services. They are dispersed throughout the country and are connected by an ambulance service. Maternal and child care are their main concern.

2.6.4 Agriculture and Industry

The agricultural sector (including forestry and live-stock) accounts for about 40% of the gross national product, over 50% of the labor force and 95% of SL's foreign exchange earnings. Rice, the staple food of most of the poulation, is the core of the subsistence sector of the economy. Rice production in SL is primarily a small land holding, hand operation. Approximately 85% of all the paddy holdings contain less than 2 acres. In 1975, there were 1,254,417 acres harvested. There are two seasons for planting crops; the Maha (July-November sowing and harvesting 5-6 months later) and Yala (February-June sowing and harvesting 4 months later). The average yield per acre varies from year to year but is approximately 46 bushels. The GSL subsidizes the cost of certified seed, and maintains a Guaranteed Price Scheme for paddy, under which it stands ready to purchase all the farmers rice at a rate that will normally provide him with an adequate profit.

Tea is SL's largest export crop, and SL is the second largest producer of tea in the free world. Tea is the source of nearly 48% of SL's foreign revenue. Most tea is grown on large estates, as a large capital investment, and a large labor force is required. Tea requires at least one worker per acre. Approximately 600,000 acres were under tea cultivation (1974).

Vital Statistics (Rates per Thousand) 1946—74				Malaria Morbidity and Mortality Rates			
				MORBIDITY		MORTALITY	
Year	*Birth Rate*	*Crude Death Rate*	*Infant Mortality Rate*	*No. of Cases*	*Rate per Thousand*	*No. of Deaths*	*Rate per Million*
1946	38.4	20.3	141	2,768,385	403	12,587	1,873
1947	39.4	14.3	101	1,459,880	207	4,562	661
1948	40.6	13.2	92	775,276	107	3,349	471
1949	39.9	12.6	87	727,769	97	2,403	328
1950	39.7	12.4	82	610,781	79	1,903	252
1951	39.8	12.7	82	448,100	56	1,599	206
1952	38.8	11.8	78	269,024	33	1,049	132
1953	38.7	10.7	71	91,990	11	722	89
1954	35.7	10.2	72	29,650	3.47	447	53
1955	37.3	10.8	71	11,191	1.25	268	31
1956	36.[illegible]	9.8	67	7,906	0.79	144	16
1957	36.5	10.1	68	10,442	1.12	8	0.8
1958	35.8	9.7	64	1,037	0.1	1	0.1
1959	36.9	9.1	58	1,596	0.15	—	—
1960	36.6	8.6	57	422	0.04	—	—
1961	35.8	8.0	52	110	0.01	—	—
1962	35.5	8.5	52.8	31	0.0031	—	—
1963	34.4	8.6	55.8	17	0.0016	1	0.096
1964	33.2	8.8	56.9	150	0.0137	1	0.091
1965	33.1	8.2	53.2	308	0.0273	1	0.089
1966	32.3	8.3	54.2	499	0.0434	—	—
1967	31.6	7.5	47.7	3,466	0.29	1	0.084
1968	32.0	7.9	50.3	440,644	36.39	64	5.28
1969	30.4	8.1	52.7	537,705	43.36	49	4.03
1970	29.2	7.5	47.5	468,202	37.9	12	1.0
1971	30.1	7.7	43.1	145,368	11.48	7	0.58
1972	29.7	8.0	45.1	132,604	10.2	4	0.31
1973	27.8	7.7	46.2	227,713	17.11	2	0.15
1974	27.3	8.9	48.5	315,448	23.15	2	0.14

Rubber is the second most important export crop, and SL is the fourth largest natural rubber producer. Rubber is grown on plantations mainly in the wet zone at lower altitudes. Approximately 565,000 acres were under rubber cultivation (1974).

Coconuts are the third most important export crop. Many of the coconut plantations are less than 10 acres in size. Much of the approximately one million acres of coconut plantings are in the coastal areas.

Other crops raised for export or domestic use include cinnamon, cocoa, cardamon, citronella oil, cloves, coffee, nutmeg, pepper, chilies, onions, potatoes, pulses, corn, sugar, tropical fruits and other vegetables.

About 5 million acres are used for agricultural purposes, with 70% of the cultivated land located in the wet zone. About one half of the total cultivated area is used for tree crops, tea, rubber and coconuts. In the decade ending in 1973, agricultural output increased at an annual rate of 2.3%, approximately less than or equal to the population growth rate. Production in subsequent years has been adversely affected by drought conditions and by the increase in the incidence of malaria.

The most important industries are those concerned with the processing of the main agricultural export products - tea, rubber and coconuts. Most of the larger investment intensive industries are in the public sector, while the private sector is involved in smaller light and intermediate consumer industries. The GSL has been encouraging cottage industries.

Mining is carried out in both the public and private sectors. SL is one of the world's leading producers of amorphous graphite (plumbago). There are rich deposits of ilmenite, rutile and zircon. Gemming or gem mining is carried on both legally and illicitly. SL produces rubies, topaz, sapphires, cat's eye, alexanderite, amethyst, tourmaline, garnet, moonstone, etc.

2.6.5 Gross National Product

Since 1970, the annual increase in GNP has averaged 2.5%, somewhat higher than the population growth rate 1.7%. The real GNP (1975) was $3.1 billion. The per capita GNP (1975 was $225). The slow pace of economic development is mainly due to inadequate investments in the productive sectors. The value of industrial production was $850,000,000 (27% of GNP). Except for food grains, prices of major imports, fertilizers and petroleum products have risen sharply while price increases for the main exports, tea, coconuts and rubber, have been relatively moderat Due to recent changes in the market, tea prices have been rising. SL now faces a severe foreign exchange shortage.

2.6.6 Employment

Due to poor production performance, the employment situation has deteriorated and about 20% of the labor force is unemployed and another 15% are underemployed. The average per capita GNP is low (US$225 in 1975), however, this is an increase of 9.7% from the last year. The cost of living index in 1975 rose 6.7% well below the 12.3% increase in 1974. The easing of inflationary pressures followed the downward trend in prices of food. Average earnings per day of an agricultural worker in 1973 was Rs 3.82; in a trade other than agriculture, Rs 10.76; and all trades, Rs 4.37. In 1975 there were 4 million employed.

2.6.7 Social Structure

Sri Lanka, though a relatively small island has a respectable degree of social heterogeneity. The present estimated population is 14 million people, with an average household size of 5.

The two most important structural features of Sri Lankan society have traditionally been caste and kinship. Although not officially

recognized by the government, caste is still an integral part of Sri Lankan society, especially in regard to marriage. Caste may be defined as an endogamous network of interrelated families which occupies a fixed social position within a strict hierarchy of the specifically defined family networks. As in India, the Sri Lankan Tamil's caste system is related to ritual purity in a religious sense, with lower castes being impure and polluting. Traditionally, castes were representative of trade professions, although, today caste trades and modern occupations do not necessarily correspond. The determination of caste and the nature of the caste hierarchy varies amongst the ethnic groups and also geographically within the groups. For instance, the Sinhalese recognize at least 24 castes, however, differences in intensity occur between the highland Kandyan and lowland Colombo sub-groups. The Kandyan Sinhalese are the more conservative group. Most Sinhalese belong to higher castes, with the agriculturalist or Goyigama caste being the most prominent. For example, about 3/4 of the low country Sinhalese belong to high castes.

The caste system of the Tamils, especially the Jaffna Sri Lankan Tamils, remain quite dominant. Over 18 different castes are recognized by the Tamils with the most prominent again being the cultivators or Vellalas. Vellalas still maintain a superordinant position in Jaffna society.

Caste is most important today in matters regarding marriage, household matters and ritual observances. Also linked to the caste system are social identity and interaction patterns, especially in rural areas. If people come from far away areas and their heritage is unknown, they are confirmed in a relevant caste position within the local community, before they can interact with others. Intimate visits between neighbors are made only within the same caste, particularly if meals or presence in kitchen areas is involved. Meals represent many symbolic features and are therefore subject to ritual pollution from someone in a lower caste. These caste influences on house visitations and presence in cooking areas has a direct relevance on the malaria program. Fever case detection and household spraying fre-

quently involves the necessity of lower caste caseworkers and spraymen in food production areas with the consequence of rejection of the anti-malaria campaign. To solve this problem, the AMC has been able in most cases to employ local people usually of the caste, as spraymen, or work with the public health inspectors, who are usually of a higher caste, to gain community support and cooperation to meet the AMC objectives.

A similar problem exists in the Moslem communities where the purdah or seclusion of women is practiced. Women are left at home during the day while the men work in the fields or away from home. Spraymen have been allowed to continue work only through the cooperation of local religious leaders or by using a public health mid-wife (who is a respected health worker) as a chaperone.

The extent of the spread of malaria control is directly related to the social acceptance of household spraying and drug treatment. Household spraying in particular represents an inconvenience at the very least because it requires the removal of all furniture from the home and leaves an unpleasant odor that may last for a few days. All cases of rejection have received special attention from AMC personnel. By using diplomacy, teaching, peer pressure and special "mop up" crews, most problems are readily overcome.

In the more remote jungle areas, a significant number of people engage in illegal lumbering and gem mining. Because of the illegal nature of these activities, the people are suspicious of outsiders, especially government workers. These people have been hesitant to cooperate with outsiders, but with their concern for health, especially malaria, since they are in one of the most endemic areas, they have been for the most part responsive to AMC efforts. AMC personnel have gained the trust of these people through respecting their sanctity and by not becoming police informers.

SL has five major religions present with Animism being the oldest.

There are few, if any full-time practicing Animists on the island, however, the old beliefs still permeate the daily lives of almost all the people, particularly in reference to causes of illness.

Of the four formally recognized religions present, 64% of the population are adherents of Theravada Buddhism and it seems to be gaining increased influence. Strongest amongst the Tamils and composing 20% of the people's religious following is Hinduism. Buddhism and Hinduism are interrelated in SL with Buddha representing spiritual purity and a leader of the path of enlightment rather than a god to be venerated. Many of the duties of both religions have close correlations.

Christians represent 9% of the people with the remaining 7% Muhammadans.

The complexities of the various religions are important as they basically predicate the beliefs held about health and cause and cure of illness. Three types of medical practitioners are present in SL with curiously no evidence of conflict or competition: Western trained physicians, Ayurvedic doctors, and "charmers".

Charmers diagnose the supernatural cause of illness by using magical talents and supernatural assistance. Once diagnosed, treatment is given to neutralize these supernatural influences in the form of ritual prescription of appeasement up to and including exorcism if demon possession is diagnosed.

Ayurvedic medicine concerns itself with the detection of imbalances of bodily forces with subsequent prescriptions of herbal pharmaceuticals. Some 70-80% of the population consult an Ayurvedic medical practitioner when sickness occurs.

Western medical specialists, health centers, and hospitals through the efforts of the central government are present throughout the island. Health services and drugs are provided to the people free of charge with visitation strongly encouraged.

Interestingly, Ayurvedic practitioners and charmers are fully aware of the Western medical system and will refer the patient to that system when the case is out of their speciality. Much of the population rely on all three systems in the case of illness, just to make sure.

Malaria is generally accepted as being caused by a mosquito bite, with a trip made to a health center, hospital or dispensary to obtain the proper pills when the well known symptoms of malaria occur.

2.6.8 Education and Literacy Rate

Free compulsory schooling for children aged 5-14, free university education and compulsory religious education have been well established for many years in SL. Over 85% of the 5-14 year olds attended school in 1971 with a large percentage going on to higher education in either the arts and sciences, teacher training or vocation-technical training.

For the last 200 years there have been 2 main forms of primary and secondary schools - private and public. The private missionary schools that were established primarily to teach Christianity were self-supporting institutions under the responsibility of the clergy. The traditional village schools, open to all village children, provided instruction in the local language, reading, writing, arts, and crafts. Eventually, a conflict arose between the two systems due to a small educated elite that secured the best employment and a large group of partially educated underemployed.

Since the institution of free public schooling in 1946 and 1947, a program of 7 years of elementary and 5 years of secondary education has evolved. Secondary education is structured into two phases - the first 3 years are devoted to general education and provides a logical termination of formal education for those students who do not wish to continue on to college or vocational school. The last two years are utilized for college entrance subjects.

SL has a very high literacy rate of about 80%; much higher than other countries of South Asia. This has been due to a widespread demand for education and the easy access to free public schools. In 1974, there were 9,625 elementary and secondary schools employing 100,910 teachers with 2,534,071 pupils. This created a 25.11 pupil/teacher ratio, excellent even by Western standards with a government education expenditure of Rs. 549.437 million.

At the university level, the University of Sri Lanka has 6 campuses spread throughout the island and a Law College. In 1974, these consisted of 132 departments, 1536 instructors and 12,667 students for a student-instructor ratio of 8.3:1.

In 1973, there were 28 Teacher Colleges with a total enrollment of 9,283 students, an increase of 13% over the preceding year. In addition, there were 12 technical and vocational institutions with an enrollment of 7375 students.

The developmental needs of the country are of increasing influence to the direction and curricula at all levels of education. There is still a severe shortage of scientists and middle-level technicians needed for the country's development. Research is confounded by the unavailability and inadaquacy of modern laboratories, equipment and facilities. Foreign travel for any purpose is impossible without foreign funded travel and tuition scholarships, due to the government's program of combating the balance of trade deficit.

2.6.9 Government and Legislation

SL became a free independent and sovereign Republic within the British Commonwealth in 1972, with a parlimentary form of government. The National State Assembly of SL is a unicameral elected body of 157 representatives of the people and under the new constitution exercises the legislative, executive and judicial power of the people.

The general direction and control of the government is vested in a Cabinet of Ministers who are responsible collectively to the National State Assembly. The election of members to the Assembly is free and by secret ballot. Every citizen of age 18 or older is qualified to be an elector at elections to the Assembly. The island has a record of peaceful and orderly elections for a considerable period with very keen interest as evidenced by an 80% or greater voter turnout.

The Prime Minister nominates the President, heads of the Cabinet and has executive authority over the Government. He or she is appointed by the President, from the membership in the National State Assembly as the most likely to command confidence of the National State Assembly.

Legislation under the Mosquito-Borne Diseases (Preventive) Regulations published under the Quarantine and Prevention of Diseases Ordinance (Chapter 173) provides for entry into premises for spraying, the taking of blood smears and treating persons suffering from or believed to be suffering from malaria and for notifying the proper authorities of the MOH of malaria cases within 24 hours by the medical practitioner.

In cases of persistent refusals to spraying, notice of prosecution is served on the chief occupant that his house must be sprayed before the next visit of the spray team. This notice usually has the desired effect, and the occupant subsequently allows his house to be sprayed when the spray team visits it.

3.0 MALARIA CONTROL IN SRI LANKA

3.1 Historical Review and Epidemiology

Malaria has always been prevalent in SL. Anopheles culicifacies is considered to be the only established malaria vector in SL. There have been ancient recorded instances of intermittent fever accompanied by chills

and rigors, which have ravaged the country. The ancient seats of civilizations like Anuradhapura and Polonnaruwa have been destroyed more by the scourge of malaria than by the periodic Tamil invasions from South India. Some believe that the Tamil invasions may have so disorganized the elaborate system of irrigation and agriculture created by the Sinhalese that extensive Anopheline breeding occurred. In 1638, a Dutch map of the island showed great areas, particularly the North-Central Province, depopulated by 'fever sickness'.

Modern knowledge of malaria in SL is based on a 1927 monumental report by H. F. Carter. SL is subjected to periodic epidemics of malaria at 3-5 year intervals. Epidemics have occurred in 1906, 1911, 1914, 1919, 1923, 1928-29, 1934-35, 1939, 1940, 1943, 1945-46, 1968-72 (primarily vivax), 1972-? (vivax and falciparum). Malaria in SL is "river malaria", that is it occurs mainly along the environs of the major rivers and their tributaries, and it is "drought malaria", that is that epidemics occur when there is little rainfall and the volume of water in the rivers is so reduced that the rivers are broken up into a series of relict pools. The failure of the South West monsoon causes epidemics in the South Western and Central foothills. The North East monsoonal rains (October-March) increases transmission in the Dry Zone-hyperendemic area. Malaria still affects most of the people in SL. At present three-fifths of the country is malarious with six epidemic zones in the country, based on the intensity of malaria transmission:

1. Jaffna Peninsula (hypo-endemic)
2. Northern Dry Belt (hyper-endemic)
3. Eastern Foothills (hyper-endemic)
4. Eastern Coastal Belt (hyper-endemic)
5. Intermediate (meso-endemic)
6. Wet Zone (hypo-endemic)

The three climatic zones, based on the rainfall received from the South Western monsoon, can also be categorized into epidemic areas. The Dry Zone which receives less than 20 inches of rain is hyper-endemic. The Intermediate Zone which receives 20-40 inches of rain is meso-endemic. The border of the Wet Zone which receives over 40 inches of rain is hypo-endemic, with the major portion of the Wet Zone being non-malarious. Malaria occurs in the wet zone only when the climatic conditions approximate the dry zone.

Malaria control in SL can be categorized as follows:

The pre-DDT era before 1946.

The DDT era which commenced in 1946.

The Malaria Eradication program from 1958 to 1964 (withdrawal of spraying in April 1964). Malaria was successfully controlled in SL using residual insecticides and anti-malarials. In 1962-63 the malariometric indices were at the lowest level, but 1964 saw the first setback. By 1968 the epidemic was in full swing.

The emergency program commencing at the end of 1968, consisting of residual DDT spraying on a 4 monthly cycle; and radical treatment of all clinical and suspected cases of malaria.

DDT resistance noted in 1969.

The 1972 epidemic as a result of DDT resistance, climatic factors and specifically drought conditions.

The 1975 revised program of limited spraying (due to limited financial resources) of malathion at $2g/m^2$ on a 3 monthly cycle.

The clinical cases of malaria in SL have reached a stage where they

adversely affect the economic development of the country. In 1972 there were 363,645 reported cases of clinical malaria, in 1973 there were 412,149 clinical malaria cases and in 1974 there were 708,601 clinical cases of malaria.

3.2 Vector Biology and Ecology

Anopheles culicifacies Giles, is the only proven malaria vector in SL. It breeds in clean, stagnant or slow moving water, in sand or rock pools, beds of streams, irrigation channels, rain-water collections, rice fields, tanks and hoof prints. The female prefers sunlit or lightly shaded water for oviposition. The larvae develop in 11-15 days at 32°-37°C. The pupal stage lasts approximately 24 hours. The adult flight range is approximately 0.8 km. Carter found the catching rate was much less in houses removed from the larval breeding sites than those near them. A 97% reduction was noted in houses 600-900 m removed. Most movement of adults occur at dusk and dawn. Longevity of the adult is related to temperature and humidity. The range for maximum longevity (7-21 days) is 25-30°C and 60-80% RH.

It is essentially a dry zone species, widely prevalent in jungle-covered plains and in villages. It is rarely found above 2,500 ft. (762 m) elevation. It invades the intermediate zone from the dry zone only during times of drought, when breeding conditions are most favorable, and is rare in the wet zone, which accounts for the relative freedom of this area from malaria. This species breeds well in jungles where it feeds upon wild animals (zoophilic). In the dry zone, it feeds upon domestic animals as well as humans. The vector enters houses in the evening, and is especially active from dusk to 9 P.M. The mosquito commonly rests in dwellings, particularly on walls and ceilings after taking a blood meal.

Though this species feeds on man, it is still partially zoophilic. If mechanization of agriculture increases, with a resultant decrease in the domestic animal population, the vector may shift its attention more to

man and become increasingly anthropophilic. This change in feeding pattern might increase its vectorial capacity.

There are 20 species of Anopheles reported from Sri Lanka. Aside from A. culicifacies, the only proven vector, there are 8 species that are considered vectors outside of SL - A. maculatus, aconitus, annularis, barbirostris, hyrcanus var. nigerrimus, leucosphyrus, tessellatus, and varuna. As far as can be determined they have not been incriminated as vectors in SL.

3.3 Proposed Malaria Control Program

3.3.1 Plan of Operation

The Government of the Republic of Sri Lanka (GSL) and the World Health Organization (WHO) have entered into mutual agreement concerning the implementation of a malaria control program in SL covering the period of 1977-81.

The following is an abstract of this program which will also have financial as well as commodity and/or technical inputs from United States AID, the United Kingdom, Japan, Netherlands and France.

Malaria has been endemic to SL for many years and as such has been the major health problem of the country. The first formal program to combat the disease was initiated in 1946 using DDT. This program was successful in reducing malaria morbidity from 44,300 per 100,000 population average 1937-45 to 5 per 100,000 in 1960 and mortality from 1835 per million to 0.2 per million population. In 1958, the (GSL) created the Malaria Eradication Program. As a result of their efforts on this program, the incidence of malaria as late as 1967 was 0.3 cases per 1,000 Annual Parasite Incidence (API). However, the relief was short-lived and two years later the rate jumped to 43.4 API, primarily due to inadequate financial and administrative support once malaria ceased to be an emergency health problem. GSL embarked on another program and by 1972 had reduced the incidence to 10.2

API. However, by this time the vector was developing resistance to DDT, the traditional insecticide used in controlling malaria, and the incidence, due to favorable environmental conditions (mainly droughts), again increased.

The country is divided into 104 Health (Administrative) Areas. The degree of malaria incidence by health areas in 1975 is given as follows:

API below	0.1%	6	Health	Areas
	0.1-0.9	10	"	"
	1-9	40	"	"
	10-49	28	"	"
	50-99	5	"	"
	100-199	13	"	"
	200+over	2	"	"

Some of the non-malarious areas have shown a relatively high incidence due to the great majority of cases being imported from the highly malarious areas. The mortality ascribed to malaria has been very low due to the many convenient and closely located health centers. The recorded deaths due to malaria from 1967 are given in the following table:

1967	1	1970	12	1973	2
1968	64	1971	7	1974	2
1969	49	1972	4	1975	5

The positive case detection rates as depicted on the following table presents the recent historical growth and seriousness of the present malaria situation in SL. These statistics represent only detected and recorded cases with every reason to believe that this is only 40-50% of the actual total

Malaria Case Rates in Sri Lanka for the Period 1967-1975

Year	Total No. of Recorded Malaria Cases	P.v.	P.f.	Mixed	API
1967	3,466	3,026	191	1	.3
1968	440,644	439,618	951	67	40.5
1969	537,705	534,214	2,995	492	48.8
1970	488,202	466,587	1,358	252	40.6
1971	145,368	141,458	3,711	199	12.1
1972	132,604	129,109	3,495	228	11.0
1973	227,713	218,139	9,486	196	17.3
1974	315,448	289,241	26,207	1,027	23.2
1975	400,777	336,918	63,859	1,782	29.0

P.v. - *Plasmodium vivax*; P.f. - *Plasmodium faciparum*
API - Annual Parasite Incidence - 1973/1975 taken from March 1976 Situation Analysis

3.3.2 Objectives of the Work Plan

The GSL, with assistance from WHO and bilateral agencies, has the following objectives in connection with this plan of intensive malaria control program:

1) the drastic reduction of the incidence of malaria,
2) the elimination of indigenous *P. falciparum* infections; and
3) the ultimate eradication of malaria from the country.

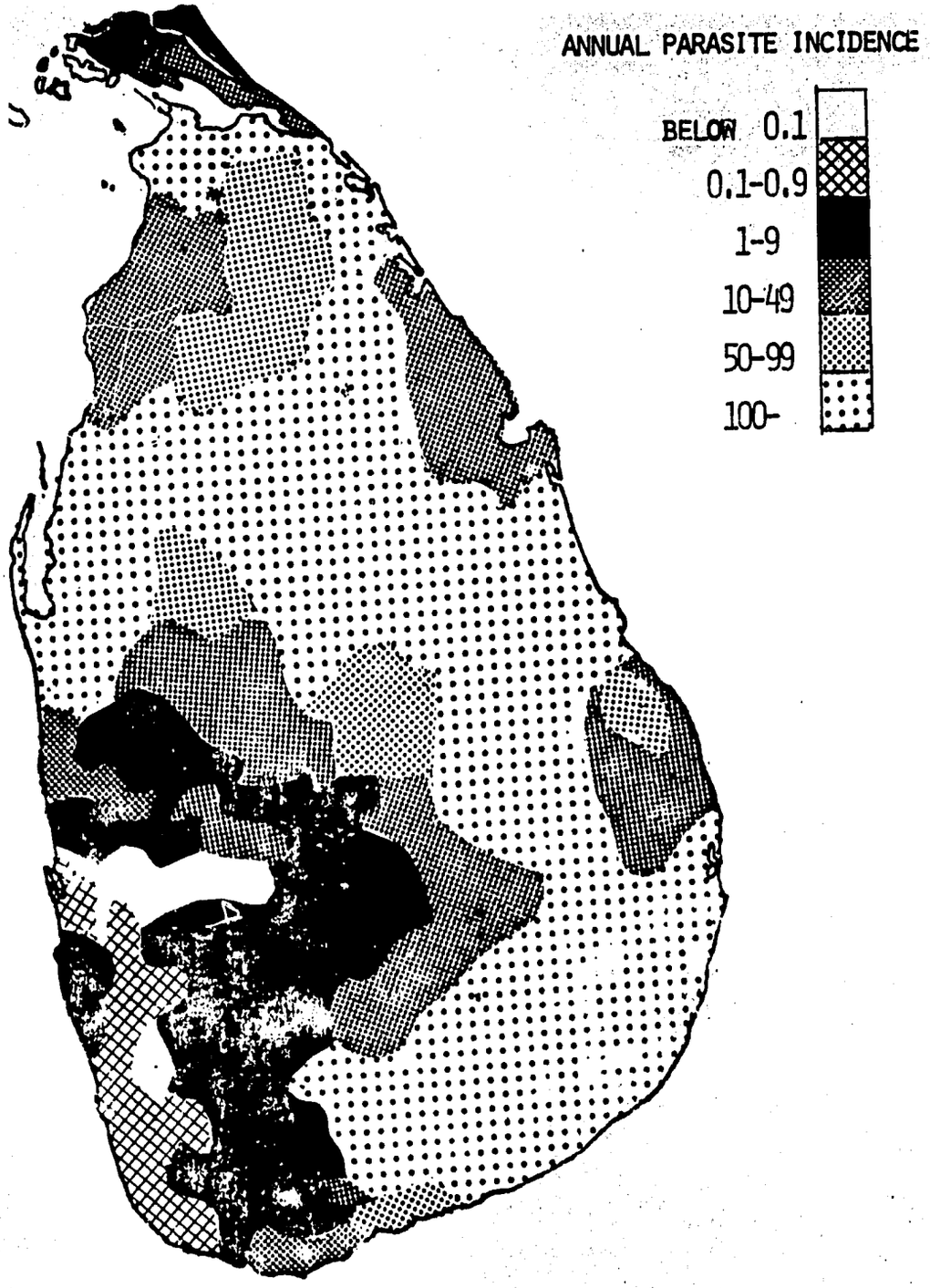
3.3.3 Methods of Action

Using the insecticide malathion, a full scale attack will be implemented

SRI LANKA

1975

INTENISTY OF MALARIA



in the malarious areas against A. culicifacies to bring about the lowest possible level of transmission.

The surveillance operations that follow will minimize the reservoir of infective cases and the vigilance machinery developed will keep a strict watch of the status achieved. Definite steps will be taken at this stage to integrate the vigilance machinery set up with the general health service in order to achieve the final objective of eradication.

Geographical reconnaissance will be conducted, consisting of taking a census of all houses and other structures, population, numbering of houses, preparation of individual house cards affixed inside houses, preparation of general maps, village maps, and itineraries for spraying, surveillance and supervision. Completed geographical reconnaissance will be up-dated continuously throughout the program.

Residual house spraying will be conducted against the vector utilizing 50% malathion wettable powder at a dosage of $2gm/m^2$. This will be formulated in the field as a 5% suspension in water by mixing 770 gms (2 lbs.) in 7.75 liters (2 gal.) of water. The spray will be applied at the rate of 4 liters/ $100m^2$. All human and animal dwellings and outhouses, all temporary structures found in development projects, land settlements, "Chena" cultivation, forest camps, geming sites and other temporary dwellings in the malarious zones will be treated. The surfaces to be spryaed include surfaces of walls, roof, all eaves, roofed verandahs, latrines, under surfaces of furniture and behind picture frames, and all surfaces of temporary fixtures in the household outhouses.

The residual spraying will be carried out regularly for four years. In the first two years, the areas which are highly malarious containing population of 4 million with 923,000 houses will be sprayed once every 3 months, 4 rounds per year (Perennial Spraying). In the subsequent two years, the spray area and the number of cycles will be reduced (Seasonal Spraying).

With the withdrawal of regular spraying, focal and mopping-up spraying will be carried out to eliminate the persistent foci. Focal spraying will also be carried out in areas of unstable malaria, whenever necessary, where regular spraying is not carried out, as a preventative measure.

3.3.4 Larval Control

Larval control is not contemplated and will be carried out only as a supplementary measure, by the use of suitable larvicides in urban areas with limited breeding places and population concentrations of a high malariogenic potential. Downstream weekly intermittant flushing of the potential breeding places will be used wherever found useful and feasible.

3.3.5 Drug Administration

A five day course of medical treatment with amodiaquine/chloroquine and primaquine according to recommended dosage, will be given to all clinical and suspected cases of malaria during the intensive spraying period. Presumptive treatment with recommended dosages of amodiaquine (or chloroquine) and pyrimethamine will be given for all fever cases.

Mass drug administration with recommended dosages of camaquine and pyrimethamine will be carried out as an emergency measure to eliminate residual and new active foci at the late stage, and during the early stage in areas requiring supplementary measures.

Weekly prophylactic drug protection with the accepted dosage of amodiaquine or chloroquine is made available to temporary visitors from non-malarious areas into high malaria risk areas and also to those engaged in development projects in malarious areas.

3.3.6 Case Detection

During the first two years of the program passive case detection will

be the main activity in both the spray and non-spray areas and will be carried out by all medical institutions in the country. When the case load becomes low, active case detection will be gradually established and will be carried out by Field Assistants (ACD Agents) who will visit all houses in the area under their charge, in cycles of one month.

3.3.7 Epidemiological Investigations

Epidemiological investigations will be brought into operation when the case load decreases to manageable levels. They will consist of case investigations, mass blood survey and entomological investigations and depending on the epidemiological situation will be followed by remedial measures including focal spraying and mass drug administration.

3.3.8 Assessment

Parasitological and entomological data will be mainly used to assess the impact of the attack measure. In addition, periodic checks of the fever and malaria attendance in all medical institutions and the constant monitoring of the deaths due to malaria and the effect of malaria morbidity and mortality on the vital statistical parameters will be used to assess the impact of the program.

All parasitological and entomological assessments will be carried out in indicator areas, selected on the basis of the incidence of malaria, population movement and the availability and location of medical institutions. These indicator areas will be representative of the epidemiological zones. The interpretation of results will be in conjunction with the data obtained from all health areas.

3.3.9 Entomological Assessment

Entomological assessment will include observations of the susceptibility status of the vector to malathion, its indoor and outdoor biting rates,

parous rates, resting densities within houses during daytime, the 24 hour survival rate of vector mosquitoes from outlet traps in sprayed houses and the activity and persistence of insecticide residues on various surfaces of treated premises.

The methodology for obtaining the necessary data for this assessment will include susceptibility tests, all night indoor and outdoor human bait collections, dissections and examination of ovaries and salivary glands, space spray collections, outlet window trap collections and bio-assay tests. Entomological assessments will be carried out at fixed observation stations in the indicator areas fortnightly and in other health areas at monthly intervals.

3.3.10 Field Research

Field research within the malaria program will be carried out to meet the needs for changes and problems which may arise. Such research will include:

(a) regular monitoring of the susceptibility status of the vector to malathion and periodic checks to determine any changes in its resistant status to DDT. The response of the vector to fenitrothion and propoxur will also be checked at intervals.

(b) continuation of periodic field trials to monitor the susceptibility of parasites to anti-malaria drugs, particularly that of P. falciparum to 4-aminoquinoline.

(c) trials to determine the efficiency of different regimes and dosages of drug treatment.

(d) biological control measures including the use of larvivorous fish.

(e) cytogenetic and other studies on the vector in relation to its bionomics.

(f) Ultra Low Volume (ULV) spraying of malathion to study the feasibility of its use in the program.

3.3.11 Laboratory Services

WHO recommended methods will be followed in the examination of blood slides for malaria parasites and will be carried out at the seven Regional laboratories and the Central laboratory. The surveillance agencies will be informed of the results promptly. Initially, the Regional Medical Offices will be notified of the P. falciparum cases for investigation and remedial measures and later all cases when the case load is lowered.

The cross checking laboratory will examine a random selection of ten percent of all negative slides and ten percent of P. vivax positive slides and all P. falciparum positive slides from all examined blood slides at every laboratory each day to cross check the work of each microscopist daily. However, a routine cross check of all positive blood films and ten percent negative films will be made when the case load comes down.

3.3.12 Training

Regular training and refresher courses for various categories of personnel engaged in the program will be organized by the National Malaria Eradication Training Center of the Anti-Malaria Campaign (AMC) and will be carried out at Central and Regional levels.

The AMC will also conduct orientation courses in malaria for other Health Department personnel, government servants and community volunteers. Lectures, seminars, etc. also will be conducted for professional organizations. The AMC staff will be encouraged for specialization in Public Health

and Malariology together with study tours on various aspects of malaria control through WHO and bilateral assistance.

3.3.13 Health Education

Health education of the community will be carried out by all program personnel during field activities. A more organized program will also be carried out by the health educators at Central and Divisional levels in collaboration with the Health Education Section of the Ministry of Health (MOH) and the AMC. The utilization of the mass media for securing community participation and maintaining public awareness of the importance of the malaria program will continue.

3.3.14 Plan of Action

Program Phasing

The program is scheduled from 1977-1981. The main activities will be residual house spraying and surveillance and in general will be based upon the operations of the attack phase of the eradication program.

Operationally, the country will be divided into two areas. The greater part of the dry zone and the intermediate zone including a population of 3.8 million and the rest of the country having a population of 10.2 million (1977).

Perennial home spraying will be carried out in the high malarious areas for two years, 4 rounds annually at 3 monthly intervals. In the next two years some areas will be brought under seasonal spraying while other areas remain under perennial spraying, the spacing and withdrawal of spray operations being progressive and determined by the transmission potential. With the reduction in spraying, surveillance will be strengthened. A total of 53 health areas will come under insecticidal coverage, of which 25 will be sprayed completely and the remaining 28 partially.

In areas of unstable malaria and the non-malarious areas, where there will be no regular spray coverage, the malaria situation will be constantly monitored for focal spraying whenever necessary.

Withdrawal of spray operations in most parts of the country is expected by the end of the fourth year. During the fifth year localized spray activities will continue in areas of persistent transmission while intensified surveillance will continue on the rest of the areas.

The assessment of the achievements of the program will be made by an independent team at this stage. However, an annual assessment will be carried out by a team composed of nationals, WHO, and bilateral agencies. While after the first two years the Government and WHO with the assistance of the bilateral agencies will arrange for a special evaluation team to assess the work accomplished and make recommendations covering future operations.

Criteria for Reduction of Cycles and Withdrawal of Spraying

The changing of spray operations from perennial to seasonal will be determined at the end of the second year of the program by a comprehensive analysis of the epidemiological and operational aspects.

Withdrawal of spraying will be based on the following criteria:

(a) The minimum blood examination rate during the last year of spraying being 10% and the maximum annual parasite incidence not exceeding 0.5 per thousand population per health area.

(b) A full scale surveillance machinery being in operation for at least one year in the original high malarious area.

(c) Taking into account beside (a) and (b) above, the malaria receptivity and vulnerability of the area.

The normal operational unit for phasing and assessment of operations will be a Health Area. However, in Health Areas under partial coverage, the above criteria will be applied on the defined population under spraying. At the beginning of each operational year a detailed plan of action for the year will be prepared.

3.3.15 Details of Activities to be Carried Out

Geographical Reconnaissance

The up-dating of the geographical reconnaissance in areas under insecticidal coverage will be continued by the squad chief throughout the program while the ACD Agents also will note any changes. With the reduction in the case load, this will be done by the surveillance agents. Additionally, the spray teams and the surveillance agents will record the entry of immigrants or temporary residents.

Spraying Operations

A total of 53 Health Areas including a population of 3.8 million (1977) will be undertaken for residual house spraying.

Perennial spraying will be made to cover the three monthly periods March to May, June to August, September to November, and December to February; while the seasonal spraying will be during March-May and October-December. Permanent employees of the program will carry out perennial spraying while seasonal spraying will be staffed by permanent and seasonal laborers engaged locally.

Three spraymen and a porter supervised by a squad chief will form a

spraying unit. A mobile unit, provided with a vehicle and a driver will consist of six spraymen under the supervision of two squad chiefs, one of whom will be in charge of the unit. A mobile unit may also consist of six spraymen, one squad chief and a driver-overseer, who will be in charge of the vehicle as well as the unit. The mobile units will operate in remote areas. On an average, eight to ten houses will be sprayed by each sprayman per day.

Each spraying supervisor will supervise four to five spraying units being directed in all his activities by the Public Health Inspectors attached to the Sub Regional Offices, and by the Officers of the Regional Offices and Headquarters. The spraying activities will also be supervised by the Public Health Inspector's Vigilance Units.

3.3.16 Safety

A practical and complete safety program already instituted by the Anti-Malaria Campaign over the past two years has proven to be effective.

All spraymen have been issued protective clothing, hand gloves, masks, and hats. Regular supplies of adequate amounts of soap is made available and frequent washing is encouraged. Strict instructions have been given not to smoke, eat, or drink during worktime without a thorough wash. The baseline data on cholinesterase level on representative samples has already been established. However, it is the expressed view of the Anti-Malaria Campaign to re-examine all operational personnel involved with malathion handling.

3.3.17 Assessment

The impact of malathion will be evaluated throughout the program by intensive parasitological and entomological assessment in five indicator

health areas. In the health areas under spray coverage, parasitological data will form the main tool of assessment supplemented by entomological observations.

Monthly observations of parasite incidence from passive and active case detection, species prevalence, age groups and blood examination rates will form the parasitological assessment.

Entomological assessment will be carried out by the entomological teams under the direction of the Entomologists. An entomological team will consist of one Entomological Assistant, one Field Assistant, four Insect Collectors and will be provided with a vehicle and a driver. Two entomological teams will be stationed at each of the five indicator health areas as their base and be responsible to observe eight to ten health areas including the indicator health area.

One entomological team operating from the Headquarters in Colombo will monitor the unstable malarious areas in the Western Zone while the unstable malarious areas inland will be monitored by a second team attached to the Kandy Regional Office. Both these teams will assist the work in other areas whenever necessary.

3.3.18 Epidemiological Investigations

The Public Health Inspector Vigilance Unit together with the Officers of Sub-Regional and Regional Medical Officers will be responsible for this activity which will be carried out when the case load decreases to manageable levels. This includes interviews with patients, mass blood surveys and entomological investigations. The assistance of the entomological teams also will be obtained for case investigations as and when necessary.

3.3.19 Remedial Measures

Remedial measures to eliminate foci of infection will include radical

treatment of cases and presumptive treatment to immediate neighbors, monthly follow up of blood filming for a minimum of one year, focal spraying when necessary, mass drug administration depending on the receptivity and vulnerability of the area and the intensity of transmission of the focus.

3.3.20 Laboratory Services

A total of 217 microscopists at the seven Regional Laboratories and the Central Laboratory in Colombo will examine about 1.5 to 2 million blood films annually. A Medical Laboratory Technician or a Supervising Microscopist will be attached to each regional laboratory. The storage and issuance of chemicals and equipment to the laboratories and cleaning and supply of glass slides to the surveillance agents will be carried out by the Central Laboratory. The mass viewing of slides will be carried out at the cross checking laboratory as described under Section 3.3.11.

3.3.21 Participation and Integration with the General Health Service

This will be developed in two stages during spray operations and after operations have been withdrawn. The implementation during the spraying period will be under the strict administrative and technical control of the Superintendent, AMC. However, even during the intensive spraying perio a very important role will be played by the General Health Services in the control of malaria by way of blood filming and treatment of clinical and suspected cases. The Regional Medical Officers will furnish the Medical Officers of Health with relevant data and will brief the Superintendents of Health Services regularly of the progress of the program. The Superintendent, AMC is responsible for the entire program. He will brief the Deputy Director (Public Health Services) and the Director of Health Services on the status of malaria and the progress of the program at the Malaria Committee Meetings and also furnish information for the Inter-Ministerial Committee. The Health Education Unit of the Ministry of Health will also participate in carrying out health education in consultation with the Superintendent, AMC.

After the withdrawal of spray operations during the fifth year the spraymen will be absorbed into the General Health Services to perform various duties according to their capabilities while a small number will be retained for focal spraying. The Field Assistants who were in charge of spraying teams will be deployed as surveillance agents.

Case detection and treatment activities, focal spraying and other remedial measures during the first few years after withdrawal of spraying will be carried out within the same administrative set up and under the strict control of the Superintendent of the Campaign. However, more responsibility on epidemiology, case detection, health education, etc. will be handed over to the Medical Officer of Health and the Superintendent of Health Services.

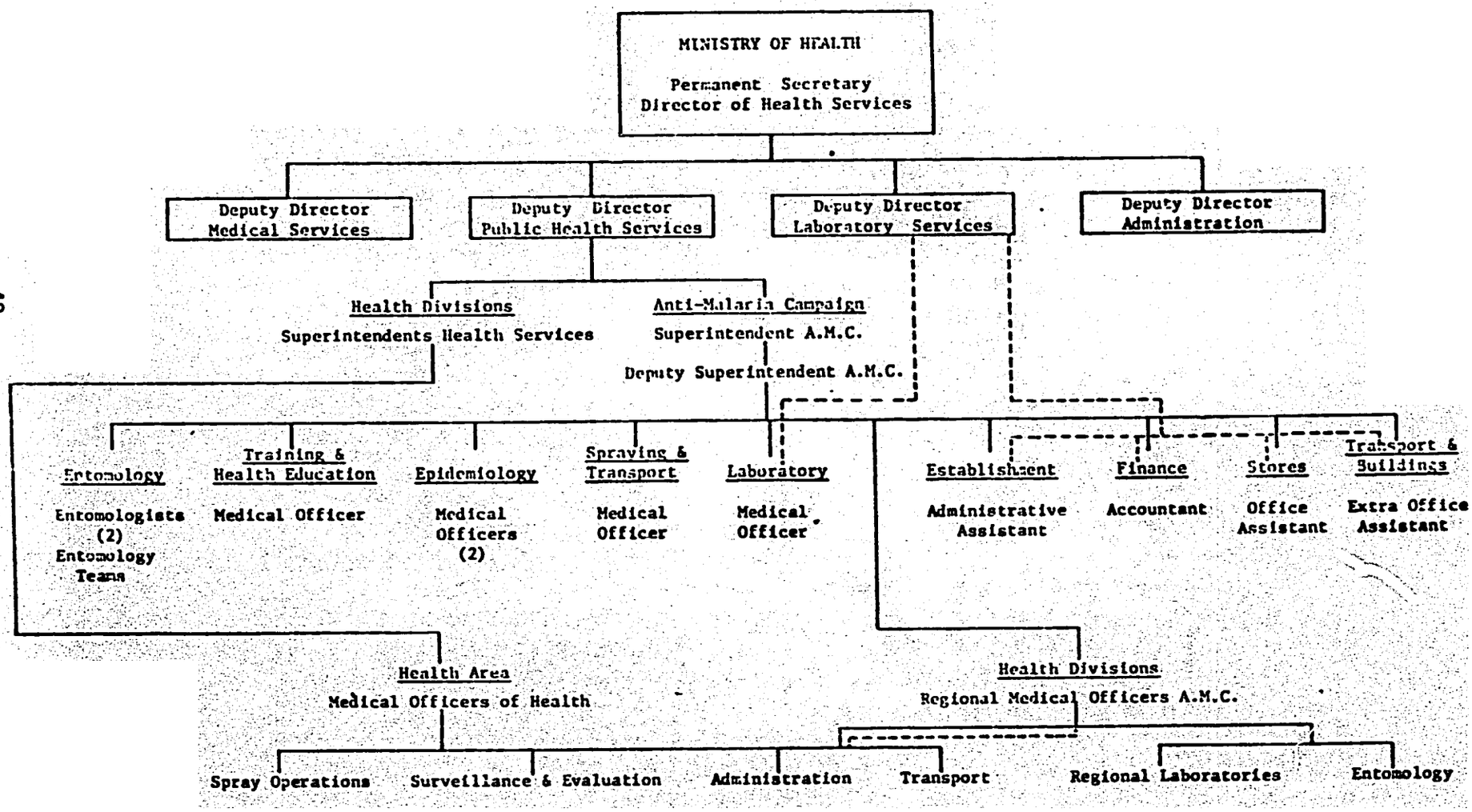
As successive health areas become free of malaria the surveillance agents will be absorbed into the proposed cadre of polyvalent health workers after suitable training. They, along with the other Public Health Inspectors will carry out vigilance activities under the direction of the Medical Officer of Health. The work of the Medical Officer of Health, will be supervised by the Superintendent of Health Services with the technical guidance of the Superintendent, AMC.

3.3.22 Administration and Assignment of Responsibility

With the technical advice and assistance of WHO and other bilateral agencies as provided in the Plan of Operation, the project will be conducted under the responsibility of the GSL.

Subject to such detailed arrangements as may be agreed between the parties for the accounting for and control of funds, supplies, and equipment provided by international and other agencies, the GSL shall assume the full administration, technical and operational direction of the projec

ANTI-MALARIA CAMPAIGN
ORGANIZATION CHART



In the operation of the project, the senior malariologist provided by WHO shall act as the chief technical advisor to the GSL. Under the direction of the senior malariologist, other advisors provided by WHO shall act as advisors on the project in their respective specialities. If agreed upon by the GSL and the bilateral agencies, any other advisor will work in collaboration with the WHO and National personnel.

In carrying out all the functions, activities, rights and duties of WHO as provided for in this Plan of Operation, the WHO shall be represented by its Regional Office for South East Asia. Any personnel appointed to the project by the WHO shall be responsible to the WHO and act under its supervision and direction, through the Regional Office. The WHO, through its Regional Office shall deal with the Ministry of Health, GSL in all matters concerning technical assistance to be provided under this Plan Operation.

3.4 Cost/Benefit

The cost SL has to bear due to the endemic incidence of malaria in the country both with and without a malaria control project is difficult to assess. As with any medical entomological problem, the loss of life and human suffering due to the disease, although probably the most significant factor, cannot be addressed due to the impossibility of assigning a monetary value. Authorities on the economics of disease and health agree that a value estimation of the benefits of health care programs and control of a disease can only be approximated and always are less than reality.

SL is committed to the control of malaria. This is a major economic commitment both for the GSL and the cooperating countries that are providing grants and loans. From 1975-1976, the GSL has doubled the AMC budget within the total health program.

An economic analysis has been made to appraise the malaria control

project in terms of whether the program is worthwhile from an economic standpoint. AID loans totaling U.S. $12.0 million over the next five years are proposed. On the basis of the economic analysis conducted by Mr. Ruiz de Gamboa in 1977, the project is suitable for AID loans to the GSL totaling U.S. $12.0 million.

Malaria has always been a major health problem in SL and the disease is highly endemic in the dry zone which constitutes about three fifths of the country and contains over 65 percent of its population. An increase from the previous year of over 200 percent of malaria cases detected and treated in 1975 seems to indicate that without the constraints imposed by the project, the annual parasite incidence (API) will reach an average of 425 per thousand (comparable to that which existed from 1931 to 1947). The project will prevent 28.9 million malaria cases and enable the economy to save U.S. $40.0 million equivalent from 1977 to 1981.

Project economic costs are estimated at U.S. $20.0 million equivalent, excluding duties on import items (which are transfer payments), and estimated at a shadow exchange rate of U.S. $1.00 = Rs 20.

The project will produce substantial direct and indirect benefits. This analysis has quantified only those expenditures and losses avoided that can be valued in money terms. The avoided expenditures and losses during the five year project are as follows: U.S. $27.5 million equivalent in medical treatment; U.S. $4.3 million equivalent in malaria drugs; U.S. $7.7 million equivalent in loss of earnings; and U.S. $0.6 million equivalent in the value of food imports (rice) required to satisfy excess caloric intake. Current estimates indicate that the economic rate of return on alternative investments lies somewhere between 8 percent and 22 percent; in this analysis it is estimated at 15 percent.

The project was subjected to three of the most commonly used primary tests of value. The benefit-cost ratio is 1.8 indicating that the project is acceptable in terms of generating benefits in the excess of cost (i.e., for every $1 spent on malaria control the project will yield $1.80 in benefits). The net present worth is U.S. $11.2 million when discounted with an opportunity cost of capital of 15 percent (i.e., $11.2 million in benefits will be generated over the useful life of the project after all economic costs are covered, including the opportunity cost of capital). Finally, the internal rate of return to the project is well over 50 percent which compares very favorable to the average 15 percent rate of return accruing to alternative investments.

4.0 PESTICIDE USE

4.1 Data on Proposed Insecticide

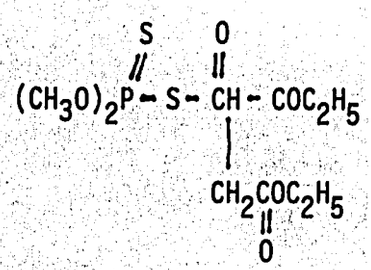
4.1.1 Names and Structure

Common Names: malathion, mercaptothion (S. Africa), Carbofos (USSR), maldison (Australia)

Trade Names: Cythion, Emmatos, Fyfanon, Karbofos, Kop-Thion, Kypfos, Malamar, Malaspray, Malathion, Malatol, Zithiol

Chemical Names: O,O-Dimethyl-S-(1,2-dicarbethoxyethyl) phosphoro dithioate or (S-1,2-Di(ethoxy carbonyl)ethyl dimethyl phosphorothiolothionate

Structural Formula:



Empirical Formula: $C_{10}H_{19}O_6PS_2$

Molecular Weight: 330.4

4.1.2 Physical and Chemical Properties

Physical State: Clear, colorless, yellow, amber or brown liquid

Specific Gravity: 1.2315 at 25°C

Solubility In:

- water: at 20°C-120 ppm; at 25°C-145 ppm; at 30°C-300 ppm

- organic solvents: Completely soluble in most alcohols, esters, and ketones, aromatic and chlorinated hydrocarbons; poorly soluble in aliphatic hydrocarbons

- lipids, fats: Moderately soluble

Melting point: 2.85°C

Boiling point: 156 - 157° at 0.7 mm Hg

Vapor pressure: 4×10^{-5} mm Hg at 30°C

Flammability: Flash point (open cup) greater than 120°C

Stability: Decomposes under alkaline conditions at high temperatures and at pH below 5. Relatively stable to light and under mildly acidic conditions.

Analytical Methods: CIPAC Handbook 1
AOAC Handbook of Methods

4.1.3 Toxicology

Malathion, since its introduction in 1949, has been used worldwide. Like other organophosphate insecticides, it exhibits its toxicity by depression of cholinesterase. However, it is far less toxic to mammals when compared with other cholinesterase inhibitors and is relatively non-persistent. It is a safe general purpose insecticide suited for the control of

mosquitoes and flies and of sucking and chewing insects on fruits and vegetables. Owing to its low mammalian toxicity and high insecticidal activity, malathion is used on a large scale by the WHO for the eradication of Anopheles mosquitoes. The acute oral LD_{50} to rats is 1,375 mg/kg. Rats fed with 1000 ppm of technical malathion for 92 weeks showed normal growth.

The largest dose of malathion that has been reported as nonfatal to humans is 200 mg/kg of body weight. The threshold of incipient toxicity to humans appears to be 24 mg of malathion with estimated acceptable daily intake of 0.02 mg/kg body weight.

The scientific data on the residues and fate of malathion show that it is rapidly degraded in soil and natural waters.

There have been a number of studies of the exposure hazard of spray operations in orchards, field crops and to people living in communities where malathion was used for mosquito abatement. It appears that malathion does not represent any hazard to humans in these operations. Exposure under spray conditions would have to be multiplied by 120,000 - 500,000 to approach the LD_{50} of experimental animals for dermal and respiratory exposure as reported by one investigator. In another study, the calculated exposure in spray operations was less than 0.01% of the toxic dose. Conclusions have been made from the work of a number of investigators that the concentration of malathion in working areas ranges from 0.01 to 0.6 mg/m^3 and in communities 0.1×10^{-6} mg/m^3. When these values are compared to the threshold limit values set by the Amer. Conf. of Gov't. and Industrial Hygienists of 10 mg/m^3, it is obvious that the exposure hazard is very low.

It appears that under field conditions, malathion residues are unlikely to migrate to any significant extent through ecosystems by environmental transport mechanisms. Malathion after over 20 years of use for a variety of pest control conditions, has produced no apparent adverse effects on the environment.

Acute Toxicity

The exact numerical value for the LD_{50} of any substance may be influenced by more than a dozen variables among which are the species, strain, sex, and age of the experimental animal; the nature of the vehicle, if any, in which the toxicant is dissolved or suspended; the presence of other substances such as emulsifying agents or diluents in the formulation, the period of observation over which mortalities are counted; and the season of the year in which the experiment is performed. For this reason, it is unrealistic to express an LD_{50} value to a high degree of precision and in making comparisons of results from different laboratories, it is essential to know something of the conditions under which the figures were obtained.

As the manufacturing experience of malathion has evolved, the degree of purity of the product has increased. Initial production of the technical material was 60-65%, while all of the U.S. produced malathion technical now offered for sale has a guaranteed minimum purity of 95%. It has been demonstrated that an increase in the grade of purity is associated with a decrease in the acute oral toxicity.

Acute Mammalian Studies

Oral - The LD_{50} for the rat was 1000-1845 mg/kg, the mouse 720-3321, guinea pigs 570-815, cats 7500, rabbits 900, sheep 150, cattle 200-560 and calves (dairy) 80. It is presently unknown why a selective toxicity seems to exist to sheep, cattle, and calves.

Routes other than oral

Species	Routes of Entry	Measurement	Value Male	Value Female
Rat	Intraperitoneal	LD_{50} (mg/kg)	750	1,000
	Intravenous	LD_{50} (mg/kg)	50	50
	Subcutaneous	LD_{50} (mg/kg)	1,000	--
	Dermal	LD_{50} (mg/kg)	4,444	4,444
	Inhalation	LC_{50} 8 hr (mg/liter)	60	60
Mice	Intraperitoneal	LD_{50} (mg/kg)	420 to 815	
	Inhalation	LC_{50} 8 hr (mg/cu m)	15	
Guinea Pigs	Intraperitoneal	LD_{50} (mg/kg)	500	
	Dermal, 24-hr exposure	LD_{50} (mg/kg)	12,300	
	Inhalation, 5 ppm 4 weeks		No Effect	
Dogs	Intraperitoneal	LD_{50} (mg/kg)	1.51 ml/kg*	
	Intravenous	LD_{50} (mg/kg)	430 to 600	
	Inhalation, 5 ppm 4 weeks		Blood cholinesterase activity reduced	
Rabbits	Dermal	LD_{50} (mg/kg)	2,400 to 6,150	
	Eye	Slight transient irritation		

WHO toxicity classification: slightly hazardous (50% WP).

* Of a 95% malathion solution

Subacute Mammalian Studies

Several dogs and cats sprayed with 2.5 and 5.0% malathion produced no effect on the dogs as judged by maintenance of appetite and weight, absence of any gross signs of toxicity, and maintenance of normal plasma and red blood cell cholinesterase activity.

Similarly, cats were not affected by the six successive weekly applications of the 2.5% spray.

Cats receiving the 5 percent spray at both the 15 second and 30 second time of discharge, showed no effect insofar as appetite, body weight, and gross appearance were concerned. However, there was a gradual depression of red blood cell cholinesterase to between 60 to 70 percent of normal for the former group, and 50 to 60 percent of normal for the latter group. There were no overt signs of excessive cholinergic stimulation in any case, and activity of red cell cholinesterase returned to normal levels within a 3-week period following the final exposure.

No restraint was imposed on the animals of either species to prevent oral intake following spraying. It seems very probable, therefore, that ingestion of malathion occasioned by licking of the fur was a factor in bringing about cholinesterase depression in the cats at the higher levels of application. The dogs had very little, if any, tendency to preen themselves.

The results indicate a satisfactory margin of safety for malathion applied dermally as a low pressure spray in dosages that would be adequately effective for control of insect parasites on dogs and cats.

Toxicity to Man - The earliest field survey was conducted by an American Cyanamid Company technician in apple orchards in the vicinity of Wenatchee, Washington, during spray operations in May and June 1952.

Plasma and red cell cholinesterase determinations were made on hand and speed sprayer operators while malathion spraying was in progress.

A total of 12 men were examined. All but a single man observed no personal preventive measures to avoid exposure. The spray formulation used by 11 men was 50 percent emulsion and an average of 1 pint of this was used in 100 gallons of water. One sprayer used one gallon in 150 gallons of water. One man used 11 pounds of 25 percent wettable powder per 600 gallons of water. Exposure times were 8 to 9 hours per day for 2 to 9 days immediately prior to testing 8 men. The other 4 had exposure times varying between 6 hours per day for 13 days and 6 hours per day for 2 days.

In no instance was any evidence of cholinesterase inhibition observed

Malathion has been ingested by human subjects at the rate of 16 mg/day for 47 days without any significant depression of plasma and erythrocyte cholinesterase activity. However, when malathion was ingested for 56 days at 25 mg/day, the blood cholinesterase was decreased 25%. The threshold of incipient toxicity (the maximum amount of the drug being tested that can be ingested daily for a prolonged period of time without depressing the pretest level of plasma or erythrocyte cholinesterase activity more than 10%) appears to be 25 mg for malathion.

Malathion inhibits acetyl cholinesterase, causing the accumulation of acetylcholine at various synapses. This results in initial stimulation and later inhibition of synaptic transmission. The onset of symptoms is always less than 24 hrs after exposure.

Allowable Daily Intake (FAO/WHO): 0.02 mg/kg.

Teratogenicity

In 1968 it was reported that an injection of 900 mg/kg of malathion

into pregnant rats 11 days after insemination did not produce any abnormalities in the fetuses.

When 62 mg of malathion was injected into hen eggs, the hatchability was reduced by 60% and anomalies occurred in the embryos. A 1 mg malathion injection into hen eggs did not produce embryonic malformations, but the hatchability was reduced by 25%. Changes in bone ossification were brought about by a 0.1 ml injection of 2% malathion solution (2 mg malathion) in chick embryos.

When oysters were exposed to 10 ppm malathion, there was a 42% reduction in egg development, a 3% survival of larvae, and a 41% difference in length of larval development.

Field Exposures to Aerosols and Sprays - In 1954, the California State Department of Public Health with the assistance of the U.S. Department of Agriculture conducted a study to evaluate the effectiveness and health hazards of the outdoor use of malathion aerosols for the control of *Culex tarsalis* mosquitoes. Spray clouds were produced by Husman and Beskil generators. Subjects of the experiment stood in the spray pattern at various distances from the generators. Exposures took place several times daily over a period of 2 weeks. Careful estimates were made of the amount of malathion to which the subjects and the generator operators were exposed by skin contact and by inhalation. The men were carefully observed throughout the study. Observations included repeated physical examinations and determination of blood cholinesterase levels. No toxic effect from malathion was found. The conclusions drawn were, "...malathion... can be used safely in aerosol form against adult mosquitoes in populated areas".

A tabulation from Rutgers University shows the following figures from various literary sources:

Insecticide	Acute oral LD_{50} to rats (mg/kg of body weight)	Probable amount of undiluted chemical needed to be eaten to cause death of 150 pound person
DDT	250	3 to 9 teaspoonfuls
Malathion	1,500	12 to 48 teaspoonfuls

It was assumed that humans would be affected in the same manner as test animals. However, these values are subject to considerable variatior with the species, age, and sex of the test animal and with the carrier in which the toxicant is administered.

In Florida in 1956, 8,000,000 acres of land were sprayed from a B-17 aircraft to control the Mediterranean fruit fly. The malathion used was a bait spray of about 5 percent concentration. In this completely successful program, urban and rural areas alike received a total of about 5 million pounds of technical malathion without any adverse effects upon the human population.

Three groups of four male human subjects were exposed to each of three different atmospheric concentrations of malathion in aerosol form. Identical 1-hour exposures were repeated twice a day, 7 days a week, for 6 consecutive weeks. Each man, therefore, had 84 exposures for 42 consecutive days. All exposures were more severe than one would expect to occur in unsupervised domestic use of malathion aerosols. Both the results of the cholinesterase activity determinations and careful observation of the subjects failed to reveal any significant effect of exposure to malathion.

In 1958 during a 4-1/2 month period, three men wearing only coveralls

sprayed the holds of 34 ships containing grain. Again blood cholinesterase levels remained perfectly normal.

Malathion's dermal toxicity is remarkably low, and its use does not present any significant toxicological problems. The above conclusion was confirmed by Hayes et al., who reported that there was no decrease in blood cholinesterase following dermal application of 1, 5, or 10% malathion dust applied five times weekly for 8 to 16 weeks.

In several studies investigating the exposure hazard to spray operators using malathion for mosquito abatement, it appears that malathion did not present a hazard to persons who were exposed. The calculated exposure in spray operations was less than 0.01% of the toxic dose.

No data were found concerning chronic exposure to malathion. In view of the long widespread use of malathion, the absence of case reports of chronic toxicity implies that such effects occur very rarely, if at all.

It appears that malathion is not hazardous to human health unless ingested in large quantities.

Fatalities - Deaths directly or indirectly attributable to malathion have been extremely rare. Throughout the entire world, reports of fatalities reaching this country since malathion was introduced commercially in 1953 total fewer than twelve. In every instance poisoning was due to ingestion of concentrated material.

During the 1976 malaria control program in Pakistan, 5 accidental deaths of spray persons were believed to be related to malathion intoxication. A thorough investigation by WHO/USAID/Government of Pakistan teams have determined that in all cases improper safety precautions were being practiced. Workers and supervisors, used to the handling and safety of DDT, did not regard malathion as a dangerous material requiring specific

handling procedures. Poor work practices, including mixing of the pesticide by hand, not washing pesticide contaminated clothing, eating pesticide contaminated food and failure of adequate skin cover during spraying, were common occurrences.

Broken malathion containers with pesticide spillage were found in virtually all storage rooms. Frequently, inadequate storage facilities in villages resulted in the pesticide being stored in homes. Exposure to villagers occurred during the spraying of houses, since some residents remained inside their homes while spraying was taking place. In essence malathion was not being regarded or respected as a poison. In addition it was found that certain supplies of malathion were old from storage and 2 brands of malathion contained contaminants which rendered them excessively toxic.

This epidemic represents the first report of significant illness among workers exposed to malathion. Numerous studies of pesticide plant employees, agricultural workers, and spray persons in malaria programs have not observed significant toxicity following malathion exposure.

In summary, the death of 5 people due to improper safety procedures in handling, storage and use was a tragic avoidable event if certain standard safety precautions had been taken. On the other side of the coin, taking into account the dramatic drop in P. falciparum malaria shown to have occurred by the use of malathion in 1976, one can conservatively estimate that more than 100,000 Pakastani lives were saved solely by malathion.

Nonfatal Accidents - Considering the enormous quantities of malathion that have been used since 1953, the number of alleged cases of poisoning that have been reported in the United States have been remarkably few. If from the list one eliminates cases in which (1) exposure to malathion was either not definitely established or of a degree not likely to be injurious

to health, and (2) clinical manifestations were not consistent with a diagnosis of phosphate ester poisoning and the diagnosis was not confirmed by cholinesterase tests, the number of cases remaining is less than a dozen. Only one of these arose out of the use of malathion for the purpose for which it is intended, namely; as a pesticidal chemical. In this instance gross disregard for even the most elementary safety precautions led to massive, prolonged, and repeated exposures by ingestion, by skin absorption, and by inhalation of particulate matter. All of the other cases resulted from the ingestion, either accidentally or with suicidal intent, of concentrated material.

4.1.4 Environmental Significance

A 20-acre tract in Ohio where malathion was applied at 2 pounds per acre was sampled for small animals. Animals recovered (for residue analysis) were mice, chipmunks, opossums, weasels, flying squirrels and shrews. With the exception of mice and chipmunks, there was no reduction in the mammal population. Larger mammals such as raccoons and opossums showed only minor effects. Big game animals should not be affected. All mammal populations tested recovered to 85 percent of normal after 2 weeks. The tests were terminated 1 year after the spray application. Some residues of malathion were found, but were minute or practically non-existent. It was found that in 12 to 24 hours after application, 60 to 80 percent of the insecticide had been excreted by the mammals.

Birds - The LD_{50} for young mallards was 1,485 mg/kg to malathion when the birds were fed the stated dosage orally in capsules. The LC_{50} for mallards was greater than 5,000 ppm; for pheasants, 2,500 to 4,500 ppm; for bobwhites, 3,300 to 3,700 ppm; and for coturnix, 2,200 to 2,300 ppm of malathion in diets of 2-week old birds when fed treated feed for 5 days followed by clean feed for 3 days.

Malathion in acetone injected into hen eggs at 25 ppm, 100 ppm, 200 ppm, 300 ppm, 400 ppm, and 500 ppm killed 15, 13, 38, 29, 58 and 94 percent of the embryos. This toxicant also caused teratogenic effects, especially when combined with ethion in a 3 to 1 ratio.

When chickens were fed malathion at a dosage of 100 mg/kg, the chickens developed leg weakness. Mode of action was unknown.

Malathion applied at 12.8 ounces per acre for western spruce budworm control in Idaho apparently had no affect on pheasants that were caged within the spray area. No dead or distressed animals were reported in the treatment areas.

During a spray program where malathion was applied at 2 pounds per acre, many types of birds were nesting in test plots. Eggs in the nests hatched and developed to adults. Young broods also developed with no apparent adverse effects. A brood of young ruffed grouse was observed before spraying in the spray plot, and it was still in the area at the end of the year.

Most species of wildlife exposed to malathion applications at dosage rates required for insect control apparently tolerate the insecticide rather well. Effects on wildlife outside of target areas appear to be minimal. Mice and quail exposed to ground applications of ULV malathion at one and 10 times the recommended rate (1.5 and 15.0 fluid oz/min) did not exhibit any poisoning symptoms. Caged quail exposed to malathion spray (12 to 16 fluid oz/acre) in the field and fed on sprayed feed showed small differences in growth rates compared to untreated birds.

The subacute oral toxicity of malathion to avian species is as follows:

Species	5-Day LC_{50} (ppm)
Bobwhite quail	3,497
Japanese quail	2,128
Mallard duck	5,000
Ring-necked pheasant	4,320

Fish - No adverse effect is expected to occur to fish populations from the indoor spraying programs.

The toxicity of malathion to 3 species of fish, as measured by the 48-hour EC_{50}, was as follows: channel catfish at 8,900 ppb, 24° C.; bluegill at 86 ppb, 24° C.; and rainbow trout at 79 ppb, 13° C.

Fish in the streams in a malathion treated (2 lb/acre) watershed area were unaffected by the treatment.

An investigation of the persistence of malathion in fish revealed that about 50 percent of the chemical was lost in less than 1 day.

Reptiles and Amphibians - Reptiles and amphibians in a malathion treated (2 lb.acre) watershed area were unaffected by the treatnent,

Aquatic Insects - Small immature stages of some insects are affected by malathion spray. Bottom samples of living aquatic insects taken before and after spraying apparently were near the same level.

Soil and Soil Organisms - Malathion degrades rapidly in soils, (in 2 days), primarily through microbial action. However, chemical hydrolysis is significant at higher pH or at higher content of soil organic matter. Several soil organisms are shown to degrade malathion. Major degradation products of malathion were thiolate and phosphate and phosphorothioic acid. Sewage lagoon microorganisms readily degraded malathion.

Malathion degradation in soils is directly related to adsorption. In aqueous soil-free systems inoculated with a soil extract, after a lag of about 7 days, rapid malathion loss was found to occur. In sterile and nonsterile soil systems, malathion degradation was rapid, 50 to 90% in 24 hrs, with no lag phase. Thus, chemical hydrolysis apparently accounts for

malathion loss in soils. In acid systems (pH 2) little hydrolysis occurs; it is slow at pH 9 (50% in 20 days), but rapid at pH 11 99% in 1 day). At pH 9; hydrolysis was via diethyl thiomalate with thiomalic acid and O,O-dimethyl phosphorothioate as the final products. Malathion degradation in soils follows first-order kinetics and is directly related to the extent of adsorption. Rates vary among soils even at constant adsorption.

Water - Malathion residues in water are degraded rather rapidly. In practically all experiments, residues of malathion in water degraded more rapidly than those of other pesticides studied under the same experimental conditions.

4.1.5 Efficacy

Malathion has been successfully used for many years in public health programs for mosquito abatement throughout the world. As malaria vectors become increasingly resistant to the chlorinated hydrocarbon insecticides such as DDT, dieldrin and BHC, an intensive search was conducted on many potential organo phosphate insecticides in various screening programs. Studies conducted by mosquito laboratories throughout the malaria endemic parts of the globe as early as 1956 found malathion at 2 g/m^2 to be an acceptable substitute providing effective control for 16 weeks on wood, thatch, mud, plaster and whitewashed surfaces. Malathion is one of the WHO approved insecticides for worldwide use in malaria control programs.

4.2 Data on Alternative Insecticide (Fenitrothion)

4.2.1 Names and Structure

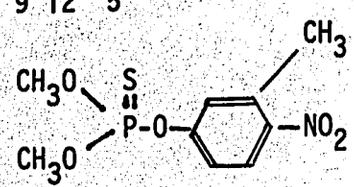
Common Name: Fenitrothion

Trade Names: Accothion, Agrothion, Bay 41831, Cytel, Folithion, M & P, Novathion, Nuvanol, S 5660, Sumithion

Chemical Name: (O,O-Dimethyl O-(4-nitro-m-tolyl) phosphorothioate

Empirical Formula: $C_9H_{12}NO_5PS$

Structural Formula:



4.2.2 Physical and Chemical Properties

Physical State: yellow-brown liquid

Molecular Weight: 277.2

Specific Gravity: 1.3227 at 25°C

Solubility In:

- water: very low, approximately 20 ppm @ 25°C
- organic solvents: slightly soluble in aliphatic hydrocartons, miscible in benzene, xylene, acetone, ethanol, cyclohexanol

- lipids, fats: miscible in vegetable oils

Boiling Point: 118°C @ 0.05 mm/Hg; 140-145°C @ 0.1 mm/Hg (decomposed)

Vapor Pressure: 5.4×10^{-5} mm/Hg @ 20°C

Stability: Hydrolyzes in alkaline conditions. Reasonably stable in neutral to acid conditions.

Analytical Methods: colorimetric; polarographic, GLC & TLC

4.2.3 Toxicology

Fenitrothion is a broad-spectrum insecticide used throughout the world for the control of agricultural, forest and public health pests. Fenitrothion was first reported in 1956 by Drabek and Pelikan. They noted that this compound was remarkably less toxic to mammals than other organophosphate insecticides such as parathion, which also inhibits cholinesterase. This compound was subsequently introduced as an experimental insecticide in 1959 by Sumitomo Chemical Co. and Farbenfabriken Bayer - AG.

It has gone through the seven stages of screening by WHO and is one of the compounds recommended by WHO for residual spraying in malaria control programs. Data collected on a longitudinal basis indicated that sustained spraying protection would reduce malaria prevalence levels to an asymptotic limit of 6.9% under the assumption that the inoculation and recovery rate will remain stable. Toxicological data showed the insecticide is safe to use when recommended precautions are observed.

Acute Toxicity studies - Fenitrothion inhibits cholinasterase activity in most animals. Oral $LD_{50's}$ by single administration of Fenitrothion were determined to be 250-330 mg/kg (330 mg/kg, 95% confidence limit) in

male rats and 834-1270 mg/kg (1030 mg/kg, 95% confidence limit) in male mice. Acute dermal LD_{50}'s were found to be 890 mg/kg for male rats and 2800 for male mice.

Chronic Toxicity studies - Fenitrothion, 97.1% pure, was used in a two year chronic oral toxicity study using purebred beagle dogs. At dietary levels of 30,100 and 200 ppm, the results indicate no significant differences in overall weight (total and gained), food consumption, behavioral reactions, adverse pathology and hematology between the control and the test groups. Results of similar tests on cattle, sheep and swine produced no permanent effects either. A reproductive study on rats (26 wks) using Fenitrothion showed no noticeable effects upon gestation or fetal survival with any level of Fenitrothion feeding.

Teratogenicity - Results of a study conducted by the Industrial Bio-Test Laboratories Inc., indicated that daily oral doses of technical Sumithion administered to pregnant albino New Zealand rabbits produced no observable adverse effects on either parents or fetuses. Technical Sumithion was administered to the test animals at daily rates of 0.3 mg/kg and 1.0 mg/kg of body weight for 13 days during early gestation. A positive control group of pregnant rabbits was given daily oral dosages of Thalidomide (37.5 mg/kg/day) and the results obtained demonstrated the susceptibility of this strain to teratogenic agents. No effects in body weight gain were noted which could be attributed to Sumithion. No deaths or unusual reactions were noted among females. Fetal mortality was not affected by treatment with Sumithion nor were any external abnormalities observed among the fetuses obtained from those treated with the material.

In another study, no adverse effects on gestation or survival were noted in rats when fed 10, 30 and 100 ppm of Sumithion. This was a three generation reproduction study.

Mutagenicity - In a study by Sumitomo Chemical Company, Ltd., a

tryptophen aurotrophic strain of Echerichia coli K 12 and Coliphage lambda were used to detect possible mutagenic effects of Sumithion. No evidences of reversion were observed which suggests that Sumithion has no mutagenic effects on these microbial systems.

Tumorigenicity - Two long term feeding studies on rats were conducted by Tokyo Dental College. The tests involved the daily feedings of 400, 200, 100 and 25 ppm (1st study: 1965-1967) and 25, 10 and 5 ppm (2nd study: 1968-1970) of Sumithion over a two-year period. There were no signs of tumorigenicity of Sumithion based on the histopathological examinations of surviving animals.

4.2.4 Environmental Significance

Man and Large Mammals

Tests using cows, steers and sheep treated daily with Sumithion at doses of 100 mg/kg in feed, depressed cholinesterase activity in the blood plasma, but this returned to normal 30 days after treatment ceased.

Small Mammals

No effect was observed in small mammals in Northern Maine where the forest had been treated twice with Sumithion at the rate of 0.125 lb/acre.

Birds

Accothion applied at a rate of 0.25 lb/acre applied twice did not produce bird mortality, but many birds were sick. At 0.125 lb/acre applied twice, little or no effect was observed on any birds. Ducks fed concentrations of 25 ppm for periods of 5 - 9 weeks showed no reaction nor did they show any effects after being confined in ponds that were treated six times at bi-weekly intervals with 0.4 lb/acre of Sumithion.

Fish

No significant mortality occurred to salmon parr in New Brunswick streams sprayed with Sumithion at a rate of 0.5 lb/acre.

Soil and Soil Organisms

Treatment of forest soils with massive doses of fenitrothion at the rate of approximately 100 lbs/acre did not alter population numbers or respiration of the soil microflora. Twelve months after exposure, fenitrothion had nearly disappeared from the potted soil sample.

Water

The stability of fenitrothion in aqueous solutions of various pH levels in laboratory beakers was stable at pH levels from 4 to 9. In water pulluted with bacteria, particularly Bacillus subtilis, insecticidal activity of fenitrothion diminished rapidly within a three day period.

4.2.5 Efficacy

Fenitrothion, an organophosphorus insecticide, has been evaluated for residual spraying in anti-malaria programs in large-scale field trials. These projects have involved entomological, parasitological and toxicological evaluations of the insecticide applied in hyper/holoendemic malarious areas. All houses and animal shelters were sprayed at a target dosage of 2 g/m^2 at three month intervals for a total of eight consecutive spray rounds in two years. The spraying in Kisumu, Kenya produced a marked and rapid decrease both in malaria incidence and prevalence. Other studies have shown a potential of long range control at 1 g/m^2. Fenitrothion has successfully passed the stage VII (final stage) in the WHO testing and evaluating scheme for malaria control insecticides and is presently on their list of recommended chemicals.

5.0 ENVIRONMENTAL IMPACT

5.1 Anticipated Favorable Impact of Proposed Program

5.1.1 Effect on Man

The obvious effect of a successful anti-malaria campaign is the reduction or eradication of malaria. Though malaria ranks as the highest major disease in SL, actual mortality due to malaria is low. This is undoubtedly due to the high level of rural medical care. Though mortality is low, morbidity based on reported cases of malaria has reached epidemic proportions. In 1975, there were 400,777 cases reported. As many cases are unreported, it has been estimated that there existed over 1 million cases. The favorable impact on man would be the reduction of malaria and improvement of health.

The effect on education, with its future implication is rather significant. Thirty percent of the total population is of school age (6-17 yrs). On the assumption that an attack of malaria would lead to 5 days incapacitation, the following table indicates the possible loss of school days:

	No. of malaria cases cases (detected & undetected) age 6-17 years	No. of school days lost
1972	114,093	570,465
1973	138,458	692,290
1974	237,573	1,187,865
1975	431,802	1,709,010

Thus the anticipated favorable impact on people would be a reductio in loss of school days due to malaria attack

The favorable impact on earning capacity is discussed under 5.1.4.

An ancillary favorable impact on people as a result of the spraying program would be the reduction of household mosquitoes, Culex fatigans, capable of transmitting filariasis, and Aedes aegypti capable of transmitting dengue fever. Filariasis or elephantiasis occurs in scattered foci in many parts of the island. The endemic area, however, is along the western coastline from Negombo to Matara, in the "non-malarious zone".

The Second Asian Malaria Conference (WHO Tchn.Rep.Ser. 1956) lists some benefits attributed to successful malaria control projects, aside from elimination of losses due to malaria illness, deaths and endemicity. They are as follows:

(a) Lower infant and general mortality rates

(b) Reduced absenteeism among schoolchildren, public servants and workers in general

(c) Reduced incidence of certain insect-borne diseases

(d) Increased and more uniform use of land

(e) Increased tourism

(f) Increased public understanding of, and cooperation in, public health and welfare programs.

5.1.2 Effect on Natural Environment

The anticipated impact on the natural environment is negligible. House spraying is a contained activity and there is essentially no interaction between the domestic environment and the natural environment.

5.1.3 Effect on Social Environment

The rural areas will be the major recipients of a beneficial impact on the social environment. Malaria is most prevalent in rural areas and often keeps the people from actively participating in agricultural productivity. Many areas would be completely unproductive due to the malaria health hazard were it not for the AMC. Therefore, one social consequence of a successful malaria control program would be a contribution toward a popular dispersion and increased migration into formerly inhospitable areas.

Based solely on health as a measure of benefit, the people living in small communities, in rural malarious areas will be most directly affected favorably by the malaria control project. It is in these areas in which the project plans to concentrate its efforts. Even some of the smallest farms in the remote "chena" cultivation areas are presently incorporated into the malaria control program. Extension of malaria control services is planned to reach all those in malarious rural areas regardless of ethnic, or caste basis will be minimal and if present, be largely due to local rejection of anti-malarial services. Cases of rejection, even now, receive special attention from members of the AMC and should not pose a significant long term problem in areas of high malaria incidence.*

5.1.4 Effect on Economic Environment

The favorable impact on the economic environment can be readily calculated, when one considers that the loss of earning capacity due to malaria was as high as 25 million rupees in 1975. Forty percent of the population is between the ages of 15 to 60 years, which are considered to be the years of gainful employment of an individual. If the daily average earning capacity of an individual is taken as 10 rupees, and that 5 days are lost due to a malaria attack, the economic loss to the country due to malaria can be seen on the following chart:

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* Personal communication from Dr. W. H. Jansen ASIA/TR "Malaria control project paper entitled Social Analysis".

Estimated Economic Loss Due to Malaria

	No. cases (detected & undetected) of malaria 16-60 yrs. of age	No. of work days lost	Loss of earnings rupees
1972	152,102	760,620	7,606,20(
1973	184,610	923,050	9,130,50(
1974	316,762	1,583,810	15,838,10(
1975	508,823	2,544,115	25,441,150

A successful malaria program would reduce or eliminate the following losses due to malaria:

Losses because of physical incapacity; because of time spent nursing others; decreased efficiency while chronically ill or convalescent resulting in a lower output of labor, smaller or fewer crops; lack of energy to plan effectively or obtain a better job; cost of medical care; cost of spiritual care. Loss is based on the value of a life lost; expenses of a funeral. Losses due to malaria endemicity resulted in lower rentals; depreciated real estate; forced sales; moving from endemic areas.

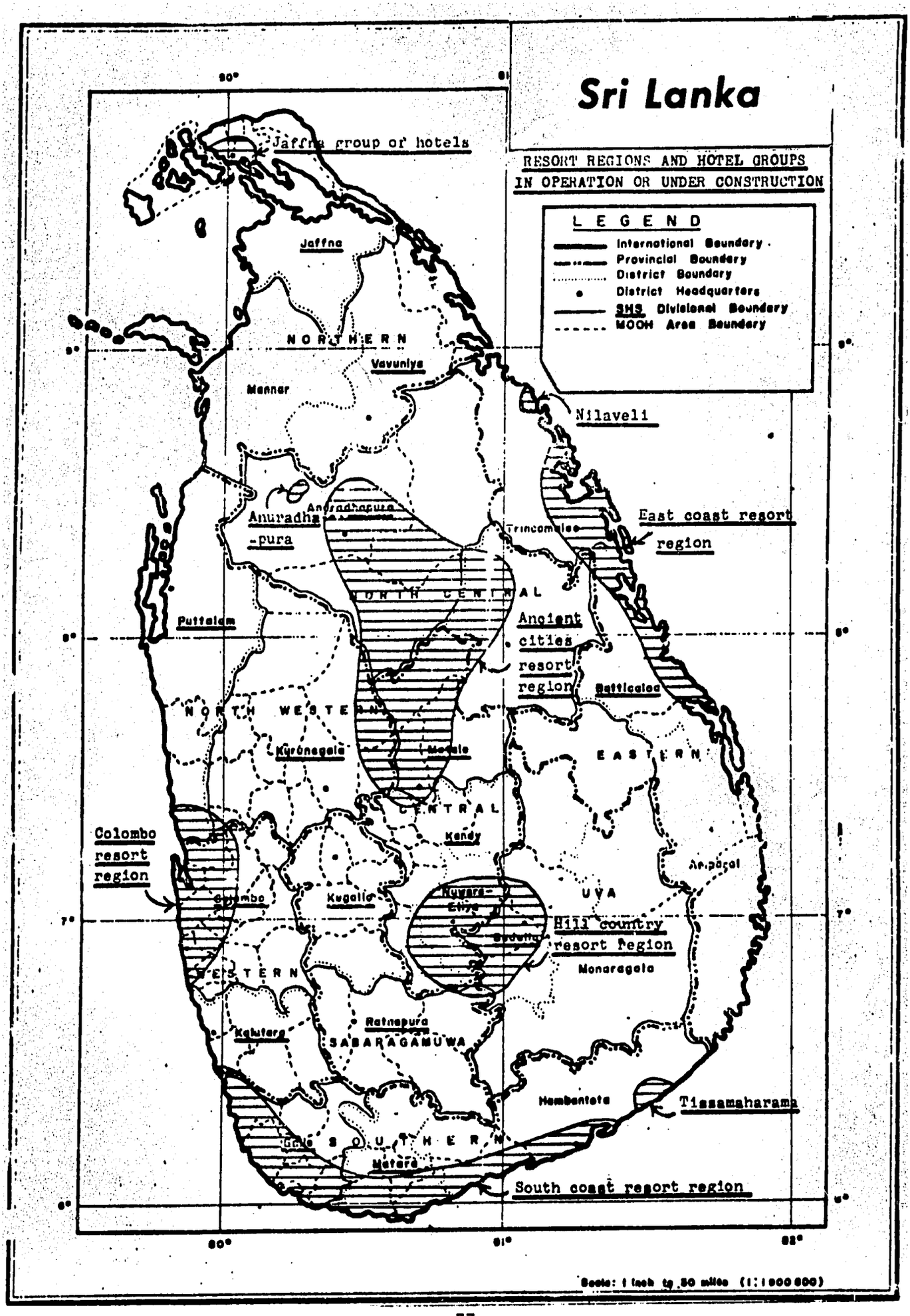
The anticipated favorable impact would be increased economic productivity, to the extent of over 2.5 million days of labor.

As 3/5 of the country's food producing land is in the malarious areas, malaria control will have a decided impact, increasing food production, particularly rice. WHO reports state that the rice crop was increased by 50% because of malaria control. The economic benefits of malaria control depend not only on the relative incidence of the disease in the working population but also on what segments of this population are freed from the burden of sickness. Malaria's greatest impact is upon the low income segment of the labor force. The agricultural worker, whether laboring in his "chena" or in

the rice paddy, is particularly exposed to the bites of malaria-carrying mosquitoes.

A quite often overlooked aspect of the favorable impact of malaria control is the benefit to tourism. Tourism is today one of the world's largest industries, and a growing industry in SL with great potential. The relationship between the eradication of malaria and the upsurge of tourism has been noted in a number of countries, i.e. Sardinia, Tunisia, etc. The growth of the tourist industry in SL is an important part of the GSL planning. The natural beauty and variety of landscapes, unspoiled beaches, historical ruins, art treasures, and wildlife combine to make SL a very attractive place to visit. However, adverse publicity regarding the resurgence of malaria is believed to have been partly responsible for the projected number of tourists not being realized.

The GSL is concentrating on developing 5 major regions for resorts and hotels (in Colombo, in the South Coast, in the hill country, in ancient cities and on the East Coast). Only the Colombo region, the hill country and the western portion of the South Coast are in the non-malarious or hypoendemic areas. All the others are in the endemic or hyperendemic area. As more and more tourists will travel outside Colombo, the possibility of an increase in malaria infection in a proportion to the number of tourists is real. If the tourist acquires P. falciparum or the "malignant tertian" type and it is undiagnosed or poorly treated, it may lead to a fatality. As tourists are notoriously fickle the prevalence of malaria can seriously influence tourism in SL. The removal of the malaria health hazard can increase tourism, which in turn creates new employment, opportunities for the economy, promotes the sale of indigenous crafts and increases the earning of the catering trades. The malaria program by indirectly increasing tourism will have a definite favorable impact on the economic environment, and balance of trade.


Sri Lanka
RESORT REGIONS AND HOTEL GROUPS
IN OPERATION OR UNDER CONSTRUCTION
LEGEND
International Boundary
Provincial Boundary
District Boundary
District Headquarters
SHS Divisional Boundary
MOOH Area Boundary
Jaffna group of hotels
Jaffna
NORTHERN
Vavuniya
Mannar
Nilaveli
Anuradha
-pura
Anuradhapura
Trincomalee
East coast resort
region
NORTH CENTRAL
Puttalam
Ancient
cities
resort
region
Batticaloa
NORTH WESTERN
Kurunegala
Matale
EASTERN
CENTRAL
Colombo
resort
region
Kandy
Amparai
Colombo
Kegalle
Nuwara-
Eliya
UVA
Hill country
resort region
Badulla
WESTERN
Monaragala
Ratnapura
Kalutara
SABARAGAMUWA
Hambantota
Tissamaharama
Galle
SOUTHERN
Matara
South coast resort region
80°
81°
82°
Scale: 1 inch to 50 miles (1:1 000 000)

5.1.5 Effect on Air Quality

It is not anticipated that there will be any effect on the air quality.

5.1.6 Effect on Water Quality

It is not anticipated that there will be any effect on the water quality.

5.1.7 Effect on Land Use

Malaria control has great impact on Land Settlement and Development Projects, however, some of the impact may be considered beneficial and some of the impact could be considered unfavorable. Land settlement and development is necessary for the economic well being of the country, and anything that will promote this growth is a positive step forward, resulting in a favorable impact. SL has resettled over 1 million persons on land previously uninhabitable because of malaria. As these projects are being established in malarious jungle areas, and the people settling in these projects are usually with little immunity, they are therefore a high risk group to malaria. The AMC will undoubtedly have a major effect on the success of a number of projects, such as the Mahaweli Ganga Project. In this light, malaria control has a favorable impact on land development projects.

5.2 Anticipated Unfavorable Impact of Proposed Program

5.2.1 Effect on Man

Most of the anticipated unfavorable impacts of the malaria program on man, are potential rather than actual. There is a potentially hazardous impact on spraymen, transport workers, and storekeepers (warehousemen) from the use of the pesticide, malathion. Malathion is one of the least

toxic to humans of the organo-phosphate insecticides, but like all pesticides, must be used properly and with care. Malathion, under certain conditions, breaks down into iso-malathion, a rather toxic (LD_{50} 89 mg/kg) chemical. If the product contains a comparatively high concentration of iso-malathion, a sprayman with poor work habits may develop pesticide intoxication. Malathion when properly used is not normally considered a potential health hazard. The calculated exposure in spray operations is less than 0.01% of the toxic dose.

Indoor house spraying causes a disturbance of routine household activities, and in the case of caste or ethnic infringement may become a social/cultural problem, as well as an operational problem. Another unfavorable impact on man is the somewhat offensive odor of malathion. The possibility of contamination of the air in the house exists, but is considered somewhat remote since reoccupation is delayed for 2 hours. In tests conducted with human subjects, 16 males were exposed 84 times in 42 consecutive days to concentrations of aerosols ranging from 0.15 mg to 2.4 g of actual malathion/1000 cu.ft. with no significant effect on the subjects' health. However, it is possible that asthmatic persons may develop symptomatic problems, if exposed to the spray particles.

Discoloration and staining of sprayed surfaces can be a problem in urban situations.

Carelessness of indoor spray operations could lead to contamination of food, water and feed products. A potential problem may exist here, though it is reported that malathion is not hazardous to human health unless ingested in large quantities. The acceptable daily intake (ADI) for malathion is 0.02 mg/kg.

A theoretical adverse effect of a successful anti-malaria program, could be the changing of vectorial capacity of now non-vector Anophelines to become vector species. Giglioli (1963) points out that environmental

changes resulting from more efficient agricultural practices such as reducing the number of domestic animals, could cause an Anopheline species, potentially capable of malaria transmission, but presently not showing any vector capacity to alter its feeding habits and thereby become a vector. His example is Anopheles aquasalis in British Guiana.

Determination of favorable or unfavorable impacts on man can be compared to Newton's First Law. For every favorable or unfavorable action there is an equal and opposite reaction. Thus a successful anti-malaria program, increases productivity (favorable) resulting in increase land use and abuse (unfavorable) decreasing mortality and morbidity (favorable) resulting in increasing population (unfavorable) and possible shortages of food (unfavorable).

5.2.2 Effect on Natural Environment

Indoor house spraying of malathion at 2 g/m^2 results in a residue on walls and portions of the ceiling. It is difficult to envisage any adverse effect on the natural environment from this operation. Some non-target organisms that may inhabit the household may be affected. Spraying operations here resulted in mortalities among bedbugs, cockroaches, houseflies, other household insects and possibly geckos. Any of the malathion spray that is deposited on the floor (dirt) should break down within a week. There is not expec ' to be any transportation of malathion to the outside.

A potential for adverse effects on the natural environment exists in the transport and storage of malathion. If accidental breakage of bags occur, or some type of spill, it is possible that malathion could be released into the environment. As malathion is well tolerated by most species of wildlife (birds and mammals) the adverse effect should be minimal with proper cleanup and decontamination precautions taken.

However, if the release should occur near water, the potential for damage to endemic fish populations exists, as malathion is toxic to most species of fish and fish food organisms.

5.2.3 Effect on Social Environment

Perhaps the major anticipated unfavorable impact of the proposed program, would be in the social milieu. All other things being equal, the infant mortality and crude death rates decrease as the efficacy of the malaria control program increases. Thus in SL the average malaria morbidity from 1937 to 1945 was 44,300/100,000 and an average crude death rate for that period was 2,150/100,000. The anti-malaria spray program using DDT began in 1946. By 1960, the average malaria morbidity was down to an average of 5/100,000 and the crude death rate was 860/100,000. According to the official publication "The Population of Sri Lanka", the spraying of DDT, which commenced in 1946, was mainly responsible for the dramatic decline in malaria morbidity, malaria mortality and overall mortality. For the next 20 years the rates continued to decrease, until 1964 when the spray program was interrupted. In 1968, malaria started again to reach epidemic proportions and has continued its upward trend to its present 1/2-1 million cases. In theory, if the proposed AMC is successful, the morbidity and death rates would go down and the population growth would increase, resulting in a population explosion, with all its secondary problems. However, the theory does not seem to function when other external forces are brought into action. The successes of family planning and population planning, would be expected to negate population increases due to malaria control. If this did not occur the unfavorable impact would be an increase in population with the resultant social problems.

5.2.4 Effect on Economic Environment

The main adverse effect on the economic environment is the drain on GSL funds. The overall expenditure for the five-year program is estimated

at U.S. $52,512,000 of which GSL's share would be U.S. $26,810,000. The use of these funds by AMC deprives the GSL from using these funds elsewhere.

A large amount of manpower will be diverted to the AMC, which might be used elsewhere. The impact on the economic environment of the use of this labor force could be argued either as favorable or unfavorable. Perhaps a more significant unfavorable impact on the labor situation, is the expected decrease in loss of manhours due to malaria. Thus an expected increase in labor supply, added to the present unemployment situation, could very well exacerbate the unemployment problem.

As the use of malathion and fenitrothion for pest control (other than by the AMC) will be withdrawn in 1977 by Governmental Order, a substitute pesticide must be found for use in control of agricultural pests. Substitute pesticides will undoubtedly be more costly and perhaps less efficacious than the two OP compounds, and thus will cause an unfavorable impact on the economic environment, as well as other aspects of the environment.

5.2.5 Effect on Air Quality

It is expected that the proposed program will have a negligible, unfavorable impact on air quality. The Radio Isotope Center in Colombo expects to be able to monitor the air quality, but at present there has been no data collected on air quality in SL. The AMC method of operation consisting of indoor house spraying at the rate of 2 g(a.i.)/m^2 of malathion wettable powder, is not expected to have any adverse effect on the air quality of the outdoor environment. The effect indoors would be temporary and negligible as long as standard safety precautions are taken as planned.

As the spraying equipment is hand operated, no source of air pollution by gasoline engines is forseen. The transport of men and materials is not

expected to significantly increase the air pollution over and above the normal usage of transport.

5.2.6 Effect on Water Quality

As the focus of the AMC operations will be on indoor spraying, it is rather inconceivable to expect any impact, favorable or unfavorable on water quality. If any larvacidal operations are undertaken, then there definitely could be an anticipated unfavorable impact on water quality. At present the recommendations are that no larvaciding will be undertaken with the possible exception of certain limited urban areas, where the population density warrants the expenditure of funds and labor. The area that might be treated (if at all) would be minuscule compared to the overall program. The unfavorable impact implications, however, would be the toxicity to fish, and some non-target aquatic invertebrates. There would be no expectations for a build-up in the food chain. Though water that collects in pools in the dried up river beds may be used for drinking water by man and animals, it is highly unlikely that sufficient malathion would accumulate to create a hazard. In addition the use of these pools by man and animals is not common in urban areas.

5.2.7 Effect on Land Use

The anticipated unfavorable impact of the proposed program on land use would be primarily in the expansion of settlers and settlements into areas that previously were too hazardous to farm due to the malarious conditions. The "chena" farming, a type of slash and burn farming is expected to be expanded with some disruption of the natural environment at a rate faster than normal.

5.3 Summary of Favorable and Adverse Effects

The most favorable impact of the anti-malaria program is the improvement in health conditions; increase in attendance at educational and

governmental institutions and agencies; increased productivity, both agricultural and industrial. Tourism would receive a favorable impact with the resultant increase in foreign exchange. The major favorable impact on land use would be the expansion of land settlement and agricultural development.

The anticipated unfavorable impacts are minor, more potential tha actual. The use of pesticides (malathion) involving operational personnel, presents a potential hazard. However, there have been no cases of accidental deaths, sickness or contamination due to malathion spraying of houses reported for SL. AMC is fully cognizant of safety requirements, and attempts to enforce them. The unfavorable impact on the social environment is theoretical. Instead of the expected increase in population growth as a result of an effective malaria program, the population growth has remained somewhat stable. This is probably due to the effective family planning program and the low malaria mortality rate. There is an adverse effect on the economic environment in that AMC diverts large sums of manpower and money away from other projects. As an effective anti-malaria program will result in expansion of land use of previously uninhabitable lands, which in turn will undoubtedly have an adverse effect on the natural environment, this may be considered a possible adverse effect.

It is expected that there will be little or no effect, adverse or favorable on air quality and water quality.

In conclusion the anti-malaria program should not have any significant effect on the environment, except improvement of health conditions. It obviously does not degrade the quality of the human environment or curtail the range of beneficial uses of the human environment and its resources. It has no effect on any natural or cultural heritage.

6.0 RELATIONSHIP BETWEEN SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE OF LONG-TERM PRODUCTIVITY

The short-term health benefit or immediate control of malaria will produce many probable long-term effects on man and the environment, however, only three deserve primary consideration regarding long-term negative benefits. The immediate disease control versus human population increases; immediate control of malaria versus development of vector resistance; and when disease control enables settlement in regions freed of disease that then encroaches on wildlife habitats.

One of the normally accepted impacts of a health benefit program is an increase in the population by saving lives. This will probably not occur in SL because its existing health care facilities and family planning programs have prevented the high rates of mortality that are associated with malaria epidemics and population growth. Instead the proposed program will address the problem of malaria morbidity and prevent the existing population from being ill with the disease. The increase in the general health and well being of the population should decrease the level of minor illnesses. Efficiency of the government, industry, and agriculture will increase as less sick days are taken. Absenteeism will decrease among students and teachers promoting a better level of education. The number of malaria patients entering health care facilities will decrease with a subsequent increase in bed space and efficiency of operation. The public awareness of health education and benefits will increase as mass media publicity, training programs and seminars are conducted.

Immediate control of malaria will open up for development and agriculture areas of the island previously uninhabitable due to the prevalence of disease. This inevitably encroaches on the wildlife habitats in many areas. One million people have migrated into these new open "areas" since the old epidemic was curtailed.

The attempt of the GSL to control and eventually eradicate malaria could cause the development of disease vector resistance to malathion and fenitrothion with the consequence of having to resort to a more toxic insecticide later in the program. However, the intensive research and surveillance programs contained within the plan of action will probably prevent this occurrence and, in any case, provide sufficient advance warning so that proper remedial measures may be instituted.

Immediate control of the present malaria vector with concomitant increases in the mechanization of agricultural practices due to the potential of having larger farming areas could lead to the decrease in number of domestic work animals. This could potentially lead to the increased vectorial capacity of presently non-vectorial species resulting in zoophilic vectors becoming anthropophilic vectors as happened in British Guiana.

In summary, although the potential exists for development of disease vector resistance, population growth and wildlife encroachment, the probability is small. The benefits of the anti-malaria program far outweigh the potential long-term negative effects.

7.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF NATURAL, CULTURAL AND OTHER RESOURCES

It is not foreseen that the operation of the anti-malaria campaign and the concurrent application of malathion at the intended rates will cause any irreversible or irretrievable impact on the environment. As the objective of the spray program is to apply a residual insecticide to the interior walls of houses, the only non-target organisms that may be affected are flies, bedbugs, roaches and geckos.

The human resources committed irreversibly are manpower, money and equipment. If these were not used for the anti-malaria campaign,

probably some, but not all, would be available for other alternative programs.

No endangered species of wildlife will be affected by this project. The anti-malaria project will cause no loss or destruction of historic sites or recreation areas. On the contrary, they will be less hazardous to visit, as far as health is concerned.

8.0 ALTERNATE METHODS

8.1 Mechanical Control

An attempt was made to determine the effect of "flushing" on the larval breeding of Anopheles culicifacies the only incriminated vector of malaria in SL. This mosquito breeds in non-polluted, stagnant or slow moving water and is known to breed in a variety of breeding places. Prolific breeding of the species occurs in sand and rock pools in the beds or rivers and streams. Such conditions occur during drought periods and lead to increased vector densities.

In 1976, prolonged drought conditions led to pool formation along the Mahaweli Ganga at Polgolla, with a resultant increase of A. culicifacies. The Polgolla complex is capable of diverting 2000 cubic feet of water per second into the Dhun Oya known in its lower reaches as Sudu Ganga.

An experiment was conducted to determine if periodic flushing of the breeding places would be a simple solution to larval control. Two trials were conducted in coordination with the authorities of the Mahaweli Development Board to check the quantity of the water and the frequency of discharge for an effective flushing out of the breeding place. The quantity of the water utilized was the amount available for release during periods of low inflow. Baseline data on larval breeding was obtained at 9 locations downstream. Water was released at the rate of 1000 cusecs

for 6 hours or a total of 21.6 million cubic feet of water. Post flushing larval sampling was conducted and revealed that for 6-1/2 to 7 miles downstream there was a flushing action, though a few isolated pools at higher elevations were unaffected.

A second trial was conducted, the water being released at 2000 cusecs for 3 hours. Post flushing samples revealed flushing occurred for approximately 9 miles downstream. It was concluded that the release of 2000 cusecs of water for 3 hours at weekly intervals would significantly reduce the Anopheline and Culiune breeding in the Mahaweli Ganga for 9 - 9-1/2 miles below the Polgolla Dam.*

8.2 Biological Control

8.2.1 Larvivorous Fish

Screening of indigenous larvivorous fish was conducted in 1976 by Prof. H. S. Costa, Professor of Zoology at the University of Sri Lanka, Kelaniya. The following fish have been cleared in the laboratory as larvivorous:

Aplocheilus dayi
Aplocheilus blochii
Aplocheilus werneri
Rasbora daniconius

Though laboratory tests have indicated that these fish are larvivorous, additional data must be acquired before they could be used as a biological control measure. Information must be acquired on the effect of temperature, salinity, pH, water movements, isolation and pollution on the various species of fish.

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* Personal communication. A Report on Anti Larval Operations by Flushing Mahaweli Ganga at the Polgolla Diversion Scheme by Mervyn B. Wickramasinghe.

The introduction of exotic fish has not been attempted for the following reasons:

1. Exotic fish tend to succeed in a non-disturbed environment where the natural biota has been altered, and in effect new niches are created
2. Predators may have been left behind
3. Interspecific competition of the original ecosystem has been removed
4. Tendency of larvivorous fish to become dominant species in new communities

However, the new environment may not suit the introduced species even when it has good eurytropic capacities. Research is being continued by AMC.

8.2.2 Nematodes

The use of an entomogenous nematode worm Reesimermis nielseni has been proposed for the control of Anopheles. An experimental release of preparasitic juveniles in Louisiana resulted in an average rate of parasitism of 55% for anopheline larvae. The practical feasibility of anopheline control in SL using this nematode has not been demonstrated.

8.2.3 Other Biological Agents

Other parasites such as fungi, bacteria, viruses and other predators have been used experimentally but at present have not been proven practical or feasible.

8.3 No Action

The last alternative to the proposed anti-malaria program is no

action. This alternative could prove to be disasterous to the people and the GSL.

The general health and well being of the people would deteriorate. The malaria induced mortality and morbidity rates would accelerate, with a resulting break-down of health care facilities due to overloading. The efficiency of the government would greatly decrease due to the increase in sick leave. The finances of the government would be taxed due to the extra cost of the public health care system.

Agricultural production and expansion would backslide, increasing the food import needs of the country, adversely affecting the balance of trade. Education would be set back, with great absenteeism of teachers and students. A general lack of energy to produce and plan effectively would exist among the people. The ancillary costs of sickness and death would place an intolerable burden on the impoverished people.

As the endemicity increased, there would be depreciation of land values, lower rental incomes, forced sales, etc. Tourism, a large source of foreign revenue would decrease or possibly dry up.

A no action program would be catastrophic for the government of Sri Lanka.

9.0 CONSULTATION WITH APPROPRIATE AGENCIES

9.1 Agencies and Individuals Contacted

<u>Anti-Malaria Campaign (AMC), Colombo</u>

Dr. A.N.A. Abeyesundere, Superintendent
Dr. K.M.S.S. Wickramasinghe, Deputy Superintendent
Mr. Mervyn B. Wickramasinghe, Entomologist
Dr. Dias, Stores and Transport
Dr. T.S. Ruberu, Epidemiologist

Ministry of Health, Colombo

Dr. H.A. Jesudasan, Deputy Director of Health Services

Medical Research Institute, Colombo

Dr. W.A. Samarawickrema, Medical Entomologist

World Health Organization, Colombo

Dr. Jun Akiyama, Senior Entomologist
Dr. E.C. Haas, Senior Malaria Advisor
Dr. B. Bisseru, Parasitologist

University of Sri Lanka

Prof. B.A. Abeywickrema, Head-Dept. of Botany
Dr. K.D. Arudpragasam, Head-Dept. of Zoology
Dr. Granville Dharmawardena, Radio-Isotope Center
Dr. A.D.V. de S. Indraratna, Prof. of Economics and Director of Demographic Training & Research Unit
Prof. H.H. Costa, Prof. of Zoology, USL, Vidyalankara Campus

Mahaweli (Dam) Development Board, Polgolla

P.V.P.C. Perera, Engineer in Charge

Colombo National Museum, Colombo

Entomological Curator

Royal Botanic Gardens, Peradeniya

Wildlife Conservation Dept., Colombo

Mr. C.V. Unamboowe, Director

Forestry Department, Colombo

Mr. L.C.A. deS. Witesinghe, Senior Asst. Conservator of Forests
Mr. A.D.R. Ratnarajah, Asst. Conservator of Forests

External Resources Dept., Colombo

Mr. K. Velauythan, Director

Wildlife and Nature Protection Society of Ceylon

Mr. Azziz

Fisheries Department, Colombo

Mr. A. S. Mendis, Deputy Director of Research

10.0 APPENDIX

10.1 Glossary

Active Case Detection is a part of surveillance activities in which the formal malaria project actively searches for malaria cases through the collection of blood slides and epidemiological investigations.

Animism is the belief that all natural objects and the universe itself possess a soul which may exist apart from their material bodies.

Annual Parasite Incidence (API) is the proportion of cases of malaria detected on an annual bases in relation to the unit of population in which malaria occurs.

Anthropophilic refers to the mosquito having a preference toward feeding upon man.

Ayurvedic medical practitioner is the "traditional doctor" who believes that the cause of illness is due to imbalances of bodily forces.

Bioassay test is a means of determining by biological means, the susceptibility of an insect to being killed by a substance or chemical.

Biological Control is a method of controlling mosquitoes using living vertebrate or invertebrate predators, genetic control or parasites.

Bionomics is the study of organisms in relation to their environment.

Biting rate is the proportion of female mosquitoes caught biting on a bait at certain stated times during 24 hours.

Charmers are "medical practitioners" who believe that the cause of illness is supernatural and prescribe ritual appeasements to the "god" causing the illness.

Chemoprophylaxis is drug prophylaxis which implies the use of drugs before infection with the aim of preventing disease.

Chena refers to an agricultural area that has been carved out of the jungle by slashing and burning the forest. These areas are typically used for 2 - 4 years then abandoned by the farmer.

Convectional rainfall is localized precipitation that occurs due to the evaporation of water from land masses with subsequent saturation of the air (clouds) and eventual release back to the ground.

Cytogenetics is the study of hereditary transmission and behavior of chromosomes.

DDT is an abbreviation of the common name Dichlorodiphenyl Trichloroethane, a chlorinated hydrocarbon type of residual insecticide.

Depressional rainfall occurs normally during the intermonsoon season when the barometric pressure falls causing winds containing saturated ocean air to blow over the island dropping their precipitation.

Ecosystem is the relationship and interaction between the organisms (the living component) of an area to its environment (the non-living component - climate, geology, etc.).

Endemicity is a term applied to malaria when there is a constant measurable incidence both of cases and of natural transmission in an area over a succession of years.

Endogamous is a term meaning marrying within the tribe or social plane.

Epidemic is a term applied to malaria when the incidence of case in an area rises rapidly and markedly above its usual level.

Epidemiology in a broad sense is the study of the environmental, personal and other factors that determine the incidence of disease.

Falciparum Malaria is a severe type of malaria caused by Plasmodium falciparum, a species of malaria parasite.

Fauna is the animal life of an area.

Fenitrothion is the generic name of an organophosphate insecticide.

Flora is the vegetative or plant life of an area.

Focal Spraying is residual insecticide house spraying around a malaria focus.

House resting density is an entomological tool to assist the epidemiologist to determine the effect of insecticides on vector populations.

Hyperendemic is a term that means the normal incidence is high, i.e. there is a constant high level of malaria existing in this area with the spleen-rate in children of 2 - 9 years constantly over 50%

Hypoendemic is a term that means the normal incidence is low, i.e. there is a constant low level of malaria existing in this area with the spleen-rate in children 2 - 9 years from 0-10%.

Incidence is the number of cases of disease occurring during a given time period in relation to the unit of population in which they occur.

Indigenous refers to originating in and characterizing a particular region, i.e. native population.

Larvicide is a substance used to kill the aquatic larval stage of the malaria mosquito by ingestion, contact or respiratory blockage.

Maha season refers to the southwest monsoon season characterized by high rainfall during May through September.

Malaria Control is an operation aimed at reducing the prevalence of malaria to a level at which it is no longer a major public health problem.

Malaria Eradication is the ending of the transmission of malaria and the elimination of the reservoir of infected cases in a campaign limited in time and carried out to such a degree of perfection that when it comes to an end there is no resumption of transmission.

Malaria focus is a defined and circumscribed locality situated in a currently or formerly malarious areas and containing continuous or intermittent malaria transmission.

Malaria Parasite is a colloquial term for any of the protozoan organism causing malaria infections.

Malariogenic Potential is the degree to which an area is conducive to malaria based on cumulative epidemiological data collected from each area regarding the parasite load, vector density, water logging, climatic conditions, population movement and factors causing man-made malaria.

Malariometric indices are a quantative measure of the incidence of malaria.

Malathion is an organo phosphorus compound residual insecticide.

Mesoendemic is a term that means the normal incidence is median, i.e. there is a constant middle level of existing malaria in the area with the spleen-rate in children of 2 - 9 years at 11-50%

Monsoonal rainfall is seasonal precipitation and wind that blows from the southwest in summer and northeast in winter.

Montane is the lower vegetation belt on mountains.

Morbidity rate is the relative frequency of illness or sickness.

Mortality rate is the relative frequency of death or death rate.

Parasite rate is the percentage of persons showing malaria parasites by blood smear examination.

Parous rate is an entomological term describing the proportion of female mosquitoes in a population which have laid one or more egg batches, i.e. have fed at least once.

Passive case detection is a part of the surveillance activities in which the public health and medical services other than the regularly constituted malaria service, assist surveillance activities by actively searching for malaria cases by the collection of blood slides and epidemiological investigations.

Perennial house spraying involves the spraying of dwellings on an every 3 months schedule or 4 times per year.

Presumptive treatment is initial drug treatment given in a suspected malaria case at the time when a blood sample is taken for examination.

Prophylactic drug protection refers to a method of protection from disease by chemotherapy (pills).

Propoxur is a carbamate insecticide with some residual properties.

Radical treatment is treatment to completely eliminate the parasite from the body so that relapses cannot occur.

Relative humidity is the ratio of the amount of water vapor in the air versus the total amount of water vapor that the air could hold at the same temperature when saturated.

Relict pool is a small body of water left behind when the water level of a river or stream recedes.

Residual insecticide is an insecticide which when suitably applied on a surface, maintains for considerable time its insecticidal activity by either contact or fumigant action, i.e. DDT.

Resistance is the development of an ability in a strain of insects to tolerate doses of toxicants which would prove lethal to the majority of individuals in a normal population of the same species.

Savanna is an area of grassland in which are scattered trees or shrubs but little or no breaks in the continuity of grassland cover.

Seasonal house spraying involves the spraying of homes only when the expected population of mosquitoes would be high.

Social heterogeneity is having unlike beliefs or customs pertaining to the life and relation of human beings in a community.

Surveillance is that part of a malaria program aimed at the discovery, investigation and elimination of continuing transmission and the prevention and cure of infections.

Total spray coverage is the application of residual insecticide during one spraying cycle to all sprayable surfaces in all sprayable houses within a given operational area.

Ultra low volume (ULV) spraying is a method of insecticide dispersion by special air or ground equipment using very small amounts of finely dispersed particles of insecticide.

Unicameral refers to having a single assembly or legislature.

Unstable malaria refers to those areas where there are frequent outbreaks with the general incidence remaining at low levels.

Vector in malaria is any species of mosquito in which the malaria parasite completes its sexual cycle in nature and which is thus able to transmit the disease.

Vector density is the number of female Anopheline mosquitoes in relation to the number of specified shelters or hosts or to a given time period specifying the method of collection.

Vector resting place is the surfaces on which mosquitoes rest before or after blood meals, i.e. walls, ceilings, thatch, etc.

Vector Susceptibility represents the degree to which a species of mosquito develops resistance to the effects of insecticides.

Vivax malaria is recurring type of malaria caused by *Plasmodium vivax*, a species of malaria parasite. Vivax malaria is characterized by paroxysms on alternate days (tertian malaria).

Water management involves the reduction or elimination of sources of mosquito breeding through filling, draining, diking, changes in water level, flushing, canal trimming and other engineering methods.

Window trap is a screened box - like trap used to collect mosquitoes that exit from a building.

Yala season refers to the northeast monsoon season characterized by high rainfall during December through February.

Zoophilic is the host preference of mosquitoes to feed upon cattle or animals rather than humans.

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10.3 Acknowledgements

The writers wish to acknowledge with thanks the assistance and cooperation of the many individuals and agencies contacted in Sri Lanka and the United States. Invaluable assistance was provided by members of the AMC, particularly Dr. A.N.A. Abeyesundere, Dr. K.M.S.S. Wickramasinghe and Mr. M.B. Wickramasinghe. Dr. J. Akiyama, the WHO Entomologist was extremely helpful throughout our stay in SL.

The AID mission in SL, particularly Mr. Tom Arndt and Mr. Clark Billings and their staff provided the much needed support for this project.

Mr. Alan Jacobs, Bill Ackerman and Tom Rishoi in the Washington AID office arranged and organized the project to operate in an efficien manner.