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THE RELATIONSHIP BETWEEN DISEASE AND NON-HEALTH-RELATED DEVELOPMENT PROJECTS IN THE DEVELOPING WORLD:

A SURVEY OF THE LITERATURE

A Report Prepared By:
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Part Two

CASE STUDIES

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PREFACE

Health is considered to be a basic human need and right. The physical and mental well-being of a people affects the entire social and economic structure of a nation. In developing countries especially, the status of health has serious implications for population growth, labor force participation, education, housing, agriculture, and economic and sociocultural development.

Health planners, government officials, the medical profession, and others recognize the relationship between poor health and unemployment, landlessness, crowding and inadequate housing, poor environmental conditions, poverty, hunger. The United States Agency for International Development and various bilateral and multilateral aid organizations are working together to develop effective interventions to improve health and nutrition throughout the world. Indeed, they have adopted as their slogan the objective of the Alma Ata International Conference on Primary Health Care (1978): "Health for all by the year 2000."

Today, health planning is an integral part of coordinated programs of development assistance. Both health- and non-health-related projects (e.g., water management, road construction, housing, livestock-raising) have been initiated in Asia, Africa, the Middle East, and Latin America. Until recently, the concern has been the benefits of rural and urban projects for the poor. But it is becoming more and more obvious that some development activities, particularly non-health-related projects, are adversely affecting the health and well-being of the populations being served. This has become a special cause for concern and has stimulated interest in the study of the relationship between development and health.

There is a history of legislation to protect the environment and of programs to control or eradicate disease, to deliver primary health care services to those most in need, to improve domestic water supply and sanitation, to provide economic opportunities, to improve communication, to stimulate the development of local industry. The ultimate objective of these and other similar activities is to distribute income more equitably; produce more crops and increase the supply of food; solve such problems as rapid population growth, malnutrition, and high morbidity and mortality; and raise the standard of living by providing access to basic health services and educational facilities.

In contrast, these very same programs may have deleterious effects on health. For example, it is recognized that the pesticide widely used in agricultural programs pose hazards to the health of persons living in areas where spraying is done frequently. As vectors become increasingly resistant to the pesticides, such diseases as malaria may increase. Schistosomiasis, filariasis, and onchocerciasis are known to occur in areas where dams, man-made lakes, and canals are being built. Other examples of the relationship between development activity and disease may be cited.

The United States Agency for International Development has long been concerned with the effects--both adverse and beneficial--of rural and urban development projects. In recognition of the importance and need of health research, USAID funded this study of the relationship between disease and poor health and non-health-related development projects in the developing world. The author, Steven K. Ault, a member of the Departments of Entomology and Veterinary Microbiology and of the Graduate Group in International Agricultural Development, University of California, Davis, made an exhaustive search of the literature to find quantitative and qualitative evidence of this relationship.

It is hoped that this study will stimulate further discussion of this important subject and prompt concerned agencies to support additional research on the relationship between development and health.

ABBREVIATIONS

AI	Acres International, Ltd.
AID	Agency for International Development (Washington, D.C.)
AJTMH	American Journal of Tropical Medicine and Hygiene
AMC	Anti-Malaria Campaign
AMP	Accelerated Mahaweli Program
BHC	Benzene hexachloride
BOD	Biological Oxygen Demand
CARE	Cooperative for American Relief to Everywhere (New York)
DDT	Dichloro-diphenyl-trichloro-ethane
DOX	Dissolved Oxygen Content
EA	Environmental Assessment
EMPH	Egyptian Ministry of Public Health
EPA	Environmental Protection Agency (Washington, D.C.)
FAO	Food and Agricultural Organization of the United Nations (Rome)
FPS	Feet Per Second
GOG	Government of Guyana
GOS	Government of Sudan
HA	Hectare
HEA	Health
IDRC	International Development Research Centre of Canada (Ottawa)
IEE	Initial Environmental Examination
IMF	International Monetary Fund (Washington, D.C.)
INCAP	Institute of Nutrition of Central America and Panama

IPEAID	International Program on Environmental Aspects of Industrial Development
IPM	Integrated Pest Management
JPE	Japanese B Encephalitis
KFD	Kyasanur Forest Disease
LDC	Less Developed Country
MAD	Mosquito Abatement District
MOH/GSL	Ministry of Health/Government of Sri Lanka
NAS	National Academy of Sciences (Washington, D.C.)
OC	Organochlorine
OP	Organophosphate
PAHO	Pan American Health Organization (Washington, D.C.)
PCI	Practical Concepts, Inc.
PID	Project Identification Document
PP	Project Paper
RVF	Rift Valley Fever
SLE	St. Louis Encephalitis
TRSTMH	Transactions of the Royal Society of Tropical Medicine and Hygiene
UMDA	Upper Mazaruni Development Authority
UN	United Nations (New York)
UNESCO	United Nations Educational, Scientific and Cultural Organization (New York)
USAID	United States Agency for International Development (Washington, D.C.)

Part One

A SURVEY OF THE LITERATURE

I. INTRODUCTION

I. INTRODUCTION

The various materials which the author obtained, examined, and used vary in both quality and quantity. The author relied primarily on scholarly and academic journals and monographs, in addition to scientific and administrative literature with limited distribution. Among the latter were:

--sovereign government documents (U.S. Environmental Protection Agency (EPA), U.S. Agency for International Development (AID), International Development Research Centre of Canada (IDRC), etc.);

--international agency documents (World Bank, World Health Organization (WHO), including the Pan American Health Organization (PAHO), Food and Agricultural Organization (FAO) of the United Nations, etc.); and

--documents published by private, non-profit organizations (Resources for the Future, etc.).

Among the author's other sources of information were numerous personal interviews (discussions of personal experiences and viewpoints) and some popular literature. Because of time constraints, it was difficult to obtain certain information with limited distribution and to review the immense quantity of literature on such subjects as water resources development. For this reason, the author was able only to survey, and not review, information. The author selected a number of case studies (see Part Two) for critical review. These constituted a readily available source of material.

For quantitative and qualitative case studies, the author sought primary sources where available, but otherwise used secondary or tertiary sources. Most of the readily available material is qualitative. The use of quantitative data is noted.

Of the diseases described in the literature, schistosomiasis and malaria generally are the most serious and a common cause for concern in areas where water resources development projects are under way. This is partly a reflection of the wide geographic distribution of the two diseases, their severity, and the rapidity with which outbreaks occur. Most of the survey is, accordingly, devoted to a discussion of these two diseases. The author does not attempt to discuss in any detail particular disease control strategies, except where they are part of a general plan to reduce the significance of the diseases in the case study or where they should form part of general river basin or rural development health planning efforts.

A Measure of Change: Incidence, Prevalence, Patterns of Geographical Distribution, and Significance

One of the purposes of the survey was to find in the literature examples of changes in disease patterns among a given people as a result of a development activity. These changes may be qualitative, quantitative, or both.

The author noted references in several documents to a change in the general "level" or "amount" of a disease. Such general terms usually are used in popular literature. They are not particularly meaningful or useful to the epidemiologist. At the most, they imply some quantification of change, but quantification is more properly and usefully expressed in epidemiological terms, usually as "incidence" and "prevalence."

The quantification of changes in disease patterns is the basis for quantitative epidemiology, epidemiology being the study of the distribution and determinants of disease or illness in populations, as opposed to individuals. A population may include persons who are healthy or well, sick or ill, symptomatic or asymptomatic, infected or infective, or dead, depending on the question one is asking.

a. Prevalence and Incidence

A quantitative change in a disease pattern among a given population can be expressed as a comparison of two prevalence rates (rate implies a time factor). A prevalence rate (or, simply, prevalence) is the number of cases of a disease in a population at a specific time or during a short interval of time (e.g., week of January 1, 1980) divided by the number of people in the population at that same time (e.g., week of January 1, 1980). Prevalence is thus a cross-sectional measure of the "amount" of an illness present in a population at any given time.

Another common, but different, expression of the frequency of illness is the incidence rate (or, simply, incidence) which is the number of new cases of disease arising in a population during a longer, specified period of time (e.g., per year) divided by the average number of people in the population at that same time. In other words, incidence is the rate of change of healthy persons, or uninfected persons, to infected persons over a long interval of time (e.g., one year).

If one is looking for quantitative evidence of the public health effects of a given development activity, one would look for data that indicate a change (i.e., increase or decrease) in the prevalence or incidence rates of a given illness in a given population of people. For example, if the prevalence rate of vivax malaria in the village of Ajoya, Mexico, was 4 cases among 800 people (i.e., 4/800) in the first week of 1978 and 8/800 in the first week of 1979, one can say there was a change--an increase--in the prevalence of vivax malaria in the people of Ajoya between the first week in 1978 and the first week in 1979. Nothing, however, is known about the changes that might have occurred in the interim. Such a change in prevalence might be linked to the construction in Ajoya in 1978 of a new stock watering pond which could have become a breeding ground for the malaria vector.

If the observer stayed in Ajoya for the entire time and counted the number of new cases of vivax malaria in the 800 people (assuming, ideally, that no one was born or died, emigrated or immigrated, during that time) he might have counted 200 cases. The observed incidence of vivax malaria in the people of Ajoya would then be 200/800 during the specified period. This figure differs from the two prevalence rates because it is a different kind of measure taken over a different period of time (53 weeks versus two separate one-week periods).

Conclusions about the "seriousness" of tne increase in vivax malaria in Ajoya would probably differ, depending on the rate used. The incidence rate would give a more accurate picture of the increase than would the prevalence rate. Both rates are useful for the purposes of this paper. The incidence rate is the most useful of the two, but the prevalence rate is the most commonly found.

To test the hypothesis that a hydroelectric dam or lake in Ajoya "produced" an "increase in malaria" in the people who lived near the dam or its reservoir, data would be needed on the prevalence of malaria in those people before and after the dam was constructed. Data on the incidence of malaria before and after construction of the dam would be needed as well. If the prevalence rate increased after the dam was constructed, and if the incidence rate also increased (i.e., if there were more new cases per year), one could reasonably conclude that the construction of the dam or the presence of the new reservoir contributed to the change in the frequency of malaria in Ajoya's people. How carefully one excludes other possible causal factors in the system affects the conclusion one draws; thus, one must control for other factors.

This approach to "experimental epidemiology" (Schwabe, et al., 1977) has rarely been applied to the kinds of development activities that concern AID and which are the subject of this paper. Because such studies are rarely undertaken, it is difficult to define and trace the exact linkages in a "cause-and-effect" chain. One cannot simply say that "building a dam in area x where people y live will (or did) cause an increased frequency of occurrence of disease z in those people." More than the mere presence of a dam and its reservoir is involved, and many of the other variables cannot be held constant. Disease problems have multiple determinants and are multivariate.

One can argue only that there is a likely or statistically significant correlation between the presence of certain water resources development projects (or other activities) and the increased prevalence or incidence of diseases (e.g., schistosomiasis and malaria). However, one must understand the entire system of interactions and conditions before one can say that a change in components a, b, and c of the system is chiefly responsible for an increased prevalence or positive incidence rate of a disease. This philosophical position* is particularly relevant to disease prevention and control programs. Lave and Seskin (1979) have discussed the problem of proving the cause of such public health problems as air pollution and the difficulties of translating epidemiological evidence into acceptable public policy.

Two other tools can be used to measure quantitative and qualitative changes in public health. These are geographic patterns of distribution and significance.

B. Distribution Patterns

Even though data on prevalence and incidence in a given region or population may not exist, changes can be determined in the mere presence or absence of a given disease in a given geographic location. This can be done in, say, a river basin development project. The geographic area of the basin would be divided into a certain number of equally-sized (or equally-weighed) units and the change would be determined by counting the number of units containing even one person who recently became negative or positive for a given parasite or disease. If the number of units has increased, one can say that disease x has "spread" or changed its pattern of distribution. This exercise is a step in measuring a change in the incidence and prevalence rates of a disease. It differs slightly from the exercise to measure such rates. Changes in the geographic patterns of distribution can be noted not only for a disease, but also for a disease vector (e.g., *Anopheles* mosquitos) or an intermediate host (e.g., *Bulinus* snails), part of "vector sampling" (see Muirhead-Thompson, 1968; Service, 1976). Persons who specialize in such studies, and particularly in actual mapping, as opposed to sampling, are medical geographers (see McGlashan, 1972). In development projects, they should form an important part of a public health planning team.

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* This kind of systems-thinking is discussed in Ackoff and Emery, 1972; Bateson, 1972, 1979; Beishon and Peters, 1972; Churchman, 1968, 1971, 1979; Emery, 1969; Lovelock, 1979; Michael, 1973; van Gigch, 1978; and Weinberg, 1975. See also Lave and Seskin, 1979.

C. Significance

The last general category of the measurement of change in public health status is significance. This concept is vaguely implicit, but nowhere explicit, in epidemiological and public health thinking. It is related to the epidemiological concept of population-at-risk and to the socioeconomic concept of risk-avoidance behavior.

One measurement of change in the public health status of a given population is change in the significance of a given disease to a given people. Usually, this is considered to be a qualitative measure, although it can be quantified. In this measurement of change, one asks: "What changes in human behavior (or human or environmental conditions) lead to an increase or decrease in the significance of this disease to these people?"

The answer to this question tells us many things. The presence of an appropriate, vertically-managed disease control program can reduce the significance of the disease. By reducing either the incidence, prevalence, or geographic pattern of distribution of malaria, the presence of a new primary health care (PHC) system in the community can reduce the significance of malaria also, even without a reduction in the prevalence, incidence, or geographic pattern of distribution of malaria (indeed, it can occur even if there is an increase in the measure of the three other parameters). People can seek help from the PHC system which, in the short term, can reduce the severity and length of the malarial attack (this depends on prompt and proper nursing or chemotherapy), and even prevent death. In the long term, the PHC system may also reduce the measure of the other three parameters, or mortality rates, as would a vertical disease control program.

The concept of significance may incorporate the other three parameters, but it may also differ from them. Any series of events or changes in human behavior which leads to a decline in the nutritional status of a people can increase the significance of certain infectious diseases and interrelated diseases (e.g., malaria, measles, ascariasis).* This may be a result of increased severity of disease or length of illness, or it may occur in the absence of any increase in the other three parameters. Usually, such an event will be followed by an increase in one or more of the three parameters.

Planners might ask about the factors in a question about the significance of a given disease problem. It is possible to think about any disease problem as follows (after Joy, 1979):

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* For a discussion of nutrition-infection interactions see Beisel, 1972; Chandra, 1979; Diamond, et al., 1978; Faulk, et al., 1974; Latham, 1975; Latham, et al., 1977; Mata, 1975; Murray and Murray, 1977; Murray, et al., 1975, 1976, 1980a, 1980b; McMurray, et al., 1979, 1981; and Suskind, 1979).

- Many people are suffering various deprivations (e.g., parasitic infection or malnutrition). This is the manifest problem, and it is unacceptable to us.
- A segment of the population (i.e., a pool of those at risk at this time) is at unacceptably high risk of becoming infected or malnourished.
- There may be a trend in the number of people in the pool through time (i.e., more people will be produced--population growth rate--who will be at risk of infection).
- Society may not be sufficiently sensitive to the problem or effective in responding to it; that is, those who are deprived or poor may have more difficulty in getting a system (e.g., a national health care system) to respond adequately (if at all) to their felt and unfelt needs.

Four planning tasks correspond to these ideas:

- The infected, malnourished, or ill must be identified and treated.
- The number of people exposed chronically to the risk of infection, malnutrition, or illness must be reduced.
- Those forces which are responsible for the increase in the number of people at risk of infection, malnutrition, or illness must be reduced or offset.
- Society must become more sensitive and respond more appropriately to these deprivations (after Joy, 1979).

D. Summary

Four parameters can be used to measure a change in the status of public health following the completion of a given development activity. These are incidence, prevalence, pattern of geographical distribution, and significance. Each parameter can be linked to the other. Any development activity which has led or may lead to an apparent disease problem can be measured, either quantitatively or qualitatively, with these four parameters. For planners, the term "significance" may subsume the other three parameters and provide a valuable framework for planning measurements of change in public health. These four parameters are used in this paper to discuss the impact of certain development projects on public health.

II. WATER RESOURCES DEVELOPMENT

II. WATER RESOURCES DEVELOPMENT

Introduction

People have been involved in the development of water resources for thousands of years. Historically, this activity has been associated with the development of agriculture and the evolution of more complex social systems (Moran, 1979). Indeed, the so-called "hydraulic, or irrigation, societies," which still exist in the Nile Valley, the dry zone of Sri Lanka, the Negev Desert, and the cold, arid highlands of the Andes, have long been the subject of research by social anthropologists and human ecologists. One interesting anthropological theory, the "Wittfogel hypothesis" (named for its author), is that large-scale irrigation leads to the centralization of political power and despotic centralized states. Other authors have presented opposing views (Moran, 1979). More pertinent to this paper is a theory proposed by Nicholls (1921) and others that malaria was one of the major contributing factors in the decline of the ancient dry zone irrigation civilization of Sri Lanka, which began about the 10th century A.D. The historian de Silva (1977) believes that malaria "defeated all attempts at large-scale resettlement [of the dry zone] till the advent of [the use of] DDT in Sri Lanka."

Water resources development includes all phases in the impounding of water: planning, construction, use and maintenance of man-made structures (dams, barrages, canals); water control (creation of lakes, reservoirs, etc.); and use of controlled bodies of water.

The literature on the public health aspects of water resources development is extensive. Jacques Deom, a scientist employed by the Division of Malaria and Other Parasitic Diseases, WHO, has prepared a bibliography on the subject that contains more than 1,000 references (Deom, 1976, 1977). Numerous local, national, and international seminars, symposia, and conferences have been held to review and discuss the subject (see Ackermann, et al., 1973; Farvar and Milton, 1972; Panday, 1979; Worthington, 1977).

Water is a chemical crucial to the survival and health of humans. Natural bodies of water contain numerous other chemicals and organisms, some of which are harmful or sometimes lethal to people and other living organisms. Often, the presence of dangerous amounts of these chemicals and organisms is a result of human activity in the nearby ecosystem.

Water Classification Systems

In 1978, the WHO published the Report of the Seminar on the Prevention and Control of Vector-Borne Diseases in Water Resources Development Projects.

The authors of this document classified four roles of water in relation to human health (WHO/VBC/EM, 1978). Water is viewed as:

--the source and vehicle of disease (water-borne gastroenteric microbial diseases);

--the habitat of disease vectors (malaria, schistosomiasis, yellow fever, onchocerciasis, filariasis, etc.);

--a man-made health hazard (carrier of organic and inorganic wastes, such as pesticide residues, radioactive isotopes, nitrates, etc.), and

--a means for promoting personal and community hygiene (potable water for domestic use, clinic use) (see also USAID, 1980).

Various other systems for classifying infective and communicable diseases associated with water are discussed in White, et al. (1972) and Feacham, et al. (1977, 1978). The most useful system was designed by Bradley (1977). Table 1 illustrates Bradley's classifications.

Table 1

CLASSIFICATION OF INFECTIVE AND COMMUNICABLE WATER-RELATED DISEASES

Category	Examples	Relevant Water Improvement
1. Water-Borne Infections		
a. Classical	Typhoid, Cholera	Microbiological Sterility
b. Non-Classical	Infective Hepatitis	Microbiological Improvement
2. Water-Washed Infections		
a. Skin and Eyes	Scabies, Trachoma	Greater Volume Available
b. Diarrheal Diseases	Bacillary Dysentery	Greater Volume Available
3. Water-Based Infections		
a. Penetrating Skin	Schistosomiasis	Protection of User
b. Ingested	Guinea Worm	Protection of User
4. Infections with Water-Related Insect Vectors		
a. Biting near Water	Sleeping Sickness	Water Piped from Source
b. Breeding in Water	Yellow Fever	Water Piped to Site of Use
5. Infections Primarily of Defective Sanitation	Hookworm	Sanitary Fecal Disposal

This classification was revised by Feachem (1977), who separated all fecal-orally transmitted diseases from other water-related diseases and placed them in a new category. Bradley (1977) had assigned such diseases to two different categories: water-borne and water-washed. Feachem's (1977) improved classification is illustrated in Table 2.

Table 2

A CLASSIFICATION OF WATER-RELATED DISEASES

Category	Example
1. Fecal-Oral (Water-Borne or Water-Washed)	
a. Low Infective Dose	Cholera
b. High Infective Dose	Bacillary Dysentery
2. Water-Washed	
a. Skin and Eye Infections	Trachoma, Scabies
b. Other	Louse-Borne Fever
3. Water-Based	
a. Penetrating Skin	Schistosomiasis
b. Ingested	Guinea Worm
4. Water-Related Insect Vectors	
a. Biting near Water	Sleeping Sickness
b. Breeding in Water	Malaria

Source: Feachem, 1977.

Feachem, using his 1977 classification, lists 36 "genera" of diseases related to water. These are listed in Table 3.

Table 3

WATER-RELATED DISEASES, BY WATER ASSOCIATION AND PATHOGENIC AGENTS

Water-Related Disease	Category From Table 2	Pathogenic Agent
Cholera	1a	C
Leptospirosis	1a	E
Typhoid	1a	A
Amoebic Dysentery	1b	C
Ascariasis	1b	D
Bacillary Dysentery	1b	A
Balantidiasis	1b	C
Diarrheal Disease	1b	H
Enteroviruses (some)	1b	B
Gastroenteritis	1b	H
Giardiasis	1b	C
Hepatitis (infectious)	1b	B
Paratyphoid	1b	A
Tularemia	1b	A
Conjunctivitis	2a	H
Leprosy	2a	A
Scabies	2a	H
Skin Sepsis and Ulcers	2a	H
Tinea	2a	F
Trachoma	2a	B
Yaws	2a	E
Louse-Borne Relapsing Levers	2b	E
Flea-, Louse-, Tick-, and Mite-Borne Typhus	2b	G
Schistosomiasis	3a	D
Clonorchiasis	3b	D
Diphyllobothriasis	3b	D
Fasciolopsiasis	3b	D
Guinea Worm	3b	D
Paragonimiasis	3b	D
Arboviral Infections (some)	4b	B
Dengue	4b	B
Filariasis	4b	D
Malaria	4b	C
Onchocerciasis	4b	D
Trypanosomiasis (African)	4a	C
Yellow Fever	4b	B

Code: A = Bacteria; B = Virus; C = Protozoa; D = Helminth; E = Spirochaete; F = Fungus; G = Rickettsiae; H = Miscellaneous

Source: Modified; from Feachem, 1977.

Dennis Warner is revising the classification system shown in Table 3 (personal communication, December 1980).

This chapter is concerned primarily with water-based and water-related, insect-vectored diseases (categories 3 and 4), particularly schistosomiasis, malaria, filariasis, onchocerciasis, certain arbovirus infections (e.g., dengue, yellow fever, encephalitis), and guinea worm and hookwork infections.

Ecological Changes and Disease Control

A water resources project, such as one involving the construction of a man-made dam and an impounded lake, is part of a multivariate system of changes in the affected ecosystem. What elements of the ecosystem change and what bearing do they have on tropical diseases? To answer this question, Stanley and Alpers (1975) and others have identified certain physical conditions that should be considered by a water resources development planning team.

Any seepage from canals and lakes or, alternatively, poor drainage of adjacent soils, should be monitored. The presence of these conditions depends on local geology and the composition, structure, and texture of soil. Breeding sites for mosquitoes, Tabanid flies (e.g., horseflies), and molluscan hosts of schistosomiasis and other parasitic diseases may be created in areas where water seeps from canals and lakes. When the U.S. Bureau of Reclamation installed the supply canals which feed water from the Central Valley Project (California) to irrigation districts and other contractors, it accepted the responsibility for controlling mosquitoes coming to inhabit the seepage. The Bureau contracted with local mosquito abatement districts (MADs) and provided funds to cover the cost of necessary mosquito control programs (Kramer, 1975).

Certain snail hosts of schistosomiasis are better adapted to well drained gravel or sandy soils, as opposed to clay soils (Charters, 1975). Soils in lakes or along canals that are well drained may be suitable habitats for schistosomiasis snail hosts, but they would be poor habitats for mosquitoes and Tabanid disease vectors because seepage from adjacent bodies of water would be percolated. Clay soils with poor drainage are poor habitats for certain schistosomiasis snail hosts, but in the rainy season they might readily form shallow pools of water in which mosquitoes could breed. The drainage of any kind of soil, including well draining soils, is affected by the height of the local groundwater table. In lakes and large, earthen-bottom water canals, the local groundwater table may rise to a level that prevents proper soil drainage. When this happens, pools of water may form, and local habitats may then change to accommodate certain disease vectors or intermediate hosts.

All bodies of water have certain physiochemical properties that can affect the habitat's suitability for disease vectors or intermediate hosts. The properties that are often measured are water temperature, pH, biological oxygen demand (BOD), dissolved oxygen content (DOX), and the presence of various salts, metals, and other elements (P, N, C, Ca, nitrates, etc). Today, some of these properties can be measured easily using the portable water chemistry kits available from numerous manufacturers. A background in limnology (the study of freshwater bodies) and aquatic and soil chemistry is needed to interpret the data (see Ruttner, 1963; Needham and Needham, 1962; Wetzel, 1975). It is difficult to predict the bearing of these data on the ecology and populations of various arthropod vectors, parasites, and their intermediate hosts. Nonetheless, this question can be answered. Data are available on the tolerance of various species of mosquito larvae and snails in aquatic environments; they are interpreted by using such parameters as pH, temperature, and insolation (see Horsefall, 1972). Such information, which may be extracted from the scientific literature or gathered by an environmental assessment team, may provide justification for anticipating an increased population of disease vector x or snail intermediate host y when the expected pH, water temperature, etc., of a new man-made lake or canal are calculated. The data may also be useful in a disease-monitoring system to identify increased populations or to detect the expanded distribution of species of vectors or intermediate hosts.

As an example of the usefulness and importance of physiochemical data, let us consider the status of Schistosoma mansoni in the Amazon basin, its intermediate hosts, Biomphalaria glabrata and Biomphalaria straminea (in most locales), and the likelihood that the organism will spread to other areas. S. mansoni, the only species found in Brazil, is uncommon in the Amazon basin proper, apparently because the water and pH content of the soil are unsuitable to Biomphalaria (Farnworth and Golley, 1974). Most Amazonian springs, creeks, and streams are acidic (pH 5.5) and tend to dissolve the calcium carbonate shells of any snails attempting to establish colonies (Sioli; see Farnworth and Golley, 1974). The pH level can be increased and the constraint to spreading removed in several ways. As a part of its plans to "open up" the Amazon basin, the Brazilian government is encouraging agricultural activities in several colonized areas along the new Trans-Amazonian roads. Lime, a base, is being applied to make the acidic soils of the basin more suitable for agriculture. The lime leaches and runs off into adjacent streams and ponds, the pH level rises, and in a number of sites, notably Altamira, B. straminae populations begin to "thrive" (Bousfield, 1979). Farnworth and Golley (1974) hypothesized in 1974 that this very sequence of events would occur. They also discussed other probable physiochemical changes with implications for public health that would occur as human activity expanded in the basin. They noted that nutrient influx from runoff from fertilized land or the wastes of humans and livestock would favor increased populations of water phytoplankton and macrophytes, which could then raise pH values by the photosynthetic uptake of carbon dioxide (CO_2). Water impoundment behind small or large reservoirs in the basin would also favor increased populations of phytoplankton and result in an increase in pH values. The level of pH may increase if soils in areas where the Amazonian forest canopy is replaced by open agriculture are increasingly insolated. This complex chemical process is described by Farnham and Colley (1974). B. straminae is also well adapted to semi-arid, highly insolated habitats (Bousfield, 1979; Wright, 1973).

The salinization of irrigated lands, which usually occurs when water drains inadequately from soils, produces a local soil-and-water habitat that is unsuitable for most disease vectors and intermediate hosts, although salt-tolerant malaria vectors, such as Anopheles melas in West Africa, may be present. The concentration of certain forms of nitrogen in potable groundwater or surface water occurs naturally but is aggravated by the heavy use of nitrogen fertilizers in agriculture (Kramer, 1975; Strathouse and Sposito, 1980). A portion of the nitrate content of such fertilizers is reduced to nitrite, a chemical that, like the action of carbon monoxide, inhibits oxygen uptake in the blood, interferes with muscle tissue in the heart, and has been linked to cancer (Caro and Lever, 1981; Kramer, 1975; Strathouse and Sposito, 1980). Man-made chemicals that are found in a water supply (lakes, groundwater, etc.) and various pesticides present another set of health hazards, usually acute or chronic toxicity, mutagenicity, teratogenicity, or carcinogenicity (Harris, et al., 1977).

Water velocity is another physical property of running water. It, too, affects the appearance of public health hazards in water resources development projects. Mosquitoes, blackflies, and the snail hosts of schistosomiasis are affected directly by water velocity. Aquatic mosquito larvae and pupae normally can exist only in water of very low velocity, be it canal, pond, stream, river, or lake water. When the velocity of the water is temporarily or permanently increased, these immature mosquitoes either are washed away or find it difficult to filter-feed or obtain surface oxygen. The new Mahaweli Ganga irrigation scheme in Sri Lanka takes advantage of this fact. During the dry season, dam waters are periodically released, causing powerful flooding. In the forceful flow of water through the usually dry canals and the small, adjacent stagnant bodies of water, immature mosquitoes breeding in the sites are swept away.

Blackflies, some species of which are vectors of onchocerciasis and other filarial nematode infections, arboviruses (bluetongue, etc.), and protozoa, are unlike aquatic-stage mosquitoes, for they require during their aquatic larval stage fast-flowing, or at least highly oxygenated, waters to respire and filter-feed. Dam and barrage spillways often are ideal locales for these larvae (Burton and McRae, 1965).

The intermediate snail hosts of schistosomiasis are similar to mosquito larvae and eggs. They, too, require water sources of low velocity. Normally, water velocities greater than 1.1 feet per second (fps; 30-35 cm./sec.) immobilize or dislodge these snails from their substrate, though, as McJunkin (1975) noted, there may be present various complicating factors, such as substrate morphology, snail shell morphology, peripheral versus mean water velocity, and peak cercariae-shedding water velocity.

Various biological changes in the watersheds of water resources development projects may aggravate public health problems. They are part of a set of parameters that should be considered by an environmental assessment and planning team. Many of the changes have been linked directly to the physiochemical changes discussed above (aquatic vegetation, lake eutrophication), but others are somewhat distinct (attraction of waterfowl and wildlife to a body of water). In the presence of a new man-made lake, several species of pelagic (surface-dwelling) plants soon spread. These species may become the food and provide the shelter for the snail hosts of schistosomiasis, fascioliasis, heterophyiasis, and other diseases, as well as for the eggs, larvae, and pupae of certain vector mosquito species (e.g., Mansonia spp., on the aquatic plant, genus Pistia, a vector of filariasis in Malaya). For example, in Lake Volta, Ghana, Pistia and the pelagic grass, Scirpus cubensis, spread over much of the sublittoral shores of the lake within three years. They harbor Bulinus and other snail genera and the malaria vector Anopheles funestus (Obeng, 1975).

A pattern of physiochemical and biological changes in man-made and natural lakes emerges over time. This succession, or "aging," of the lake is known as eutrophication. Increased loads of nitrogen and phosphorus (from the runoff of agricultural fertilizers) trigger a bloom of algae. This is followed by changes in lake fauna, a reduction in DOX, increased BOD, massive pelagic plant growth, and changes in pH. Each of these biological and physiochemical changes affects the mix of species of various arthropod vectors and molluscan intermediate hosts in or near a man-made lake. Thus, where it is expected that humans will speed up the natural process of eutrophication through intensive use of agricultural fertilizers in the lake basins and watersheds, lakes should be monitored for the expected rapid changes in invertebrate animal populations.

Any body of fresh water will attract certain waterfowl and wildlife (as well as humans) to its shores or surface. Water impoundment results in changes in the distribution and number of birds (Lavery, 1975). Such changes sometimes facilitate contact between mosquito and non-human vertebrate hosts of viruses, not only birds, but also mammals, including rodents (Surtees, 1975). In Kenya, several species of heron, ibis, and stork proliferated in a newly irrigated area, outnumbering those in surrounding areas. Two of the species were involved in arthropod-borne virus (arbovirus) transmission cycles in southern Africa, giving Surtees (1975) cause to be concerned about a new focus of arboviral transmission in Kenya. In Panama, the number of St. Louis encephalitis (SLE) virus isolations and seroconversions from waterfowl increased after a new, large water impoundment was created, and nearby mammal and bird populations also increased (Adames, et al., 1980). Man-made lakes and canal systems should be monitored for changes in populations of local vertebrates, especially mammals and birds, that carry and transmit disease, and fishes, which can act as intermediate hosts for some human parasites.

Schistosomiasis and Water Resources Development

A. Biology

Schistosomiasis (bilharziasis) is the medical term for the state of infection of an animal with any of several species of the parasitic fluke (trematode) genus *Schistosoma*. There are three major and at least five minor species of schistosomes (blood flukes) that infect humans. Of the three most important species, *Schistosoma haematobium* lives part of its life cycle within the capillaries on the wall of the bladder. The other two most prevalent species, *Schistosoma mansoni* and *Schistosoma japonicum*, inhabit for part of their life cycles the blood vessels of the large intestine (colon).

The five species of lesser importance are *Schistosoma mekongi*, a recently discovered species or subspecies found in the basin of the Mekong River in Southeast Asia (Kruatrachue, et al., 1979); *Schistosoma bovis*, primarily a parasite of ruminants that is restricted to Africa (Zimbabwe, Uganda, etc.); *Schistosoma matthei*, the primary hosts of which are ruminants, baboons, and various wild game in South and East Africa; *Schistosoma intercalatum*, found in Zaire, Gabon, Cameroon, and other African countries; and *Schistosoma rodhaini*, whose primary final hosts are African wild rodents (Kenya, Uganda, and Zaire). Other less common species that infect humans also exist (Faust, et al., 1970).

B. Life Cycle

The adult worms normally reside in the blood vessels of the bladder wall or of the colon. There, the adult males and females reproduce. The female worm lays her eggs in the blood vessels. The eggs pass through the adjacent tissues into the lumen (open cavity) of the bladder or colon and eventually are expelled from the body in the urine or feces. At this point in the blood fluke's life cycle, water must be present. The eggs must reach water within 30 days to hatch. In this way, water supplies can be contaminated by infected human urine or feces, either directly or from contaminated soil runoff. Once it is in water, which may be fresh or stagnant, still or flowing, the egg will hatch, and the organism will enter the stage known as miricidium (pl., miricidia). The miricidium must find and penetrate an appropriate intermediate host--a freshwater aquatic or amphibious snail--within 24 hours or die. Usually, the intermediate host of a given species of schistosome is a specific genus of snails. Those of the three major species are (see McJunkin, 1975):

Schistosome	Genus of Snail	Characteristics of Water Source of Snail
S. mansoni	*Biomphalaria* spp.	Running Water; Aquatic
S. haematobium	*Bulinus* spp., *Physopsis* spp.	Stagnant, Slow Water; Aquatic
S. japonicum	*Oncomelania* spp.	Any Water Source; Amphibious

The miracidia reproduce asexually after they penetrate the appropriate snail. A single miracidium often produces thousands of cercariae, the next stage in the organism's life cycle. These cercariae actively emerge from the snail, and at this time they may infect humans. The organisms directly penetrate a person's skin, and infection occurs within 15 minutes. A person may be infected while _in_ or when _drinking_ cercariae-contaminated water. Any part of the body (skin, nostril, mouth, throat) may be penetrated. For the life cycle to be completed, a person must be infected by cercariae of _both_ sexes. Once inside the body, the cercariae immediately change shape (they are at this stage called schistosomules) and begin to migrate through the capillaries and tissues into the central circulatory system, which transports them, by way of the heart, lungs, and liver, to the colon or bladder (Rosenfield, 1979).

C. Pathology

Pathology in humans is related to the species and stages of the life cycle. Invasion of the skin or mucous membranes by the cercariae may be accompanied by mild or intense itching or swelling. Usually worse in infections with bird or livestock schistosome species, it is called "swimmer's itch." Maturation of immature schistosomes in the liver may cause fever and abdominal pain. Egg production in the vessels of the colon and bladder causes local inflammation, rectal ulcers, bloody diarrhea, abdominal pain and cramps, or painful, bloody urination. Fibrosis of the liver and spleen and calcification of the bladder occur in heavy chronic infections and interfere with blood circulation to the liver and spleen, which begin to swell. Severe anemia and sometimes heart disease occur. A form of bladder cancer appears to be associated with this stage in heavy S. haematobium infections (Wilcocks and Manson-Bahr, 1972).

D. Distribution

S. haematobium is found in the Nile River Valley, much of Africa, Madagascar and Mauritius in the Indian Ocean, and much of the Middle East to the west coast of India. S. mansoni is found in the Nile Delta, much of sub-Saharan Africa and Madagascar, the Arabian peninsula, the Caribbean, Brazil, and much of northern South America. S. japonicum is confined to various locales in the Far East (Faust, et al., 1970). (See Part Two, which contains case studies on schistosomiasis that has been linked to various water resources development projects. Changes in the various ecological systems are also discussed.)

Filariasis and Water Resources Development

Filariasis is the infection of vertebrates with any of the nematodes in the superfamily Filarioidea (filarial worms). Four species of filarioids commonly infect humans: Wuchereria bancrofti (Bancroftian filariasis), Brugia malayi (Brugian or Malayan filariasis), Onchocerca volvulus (onchocerciasis, or river blindness), and Loa loa (loiasis). Any of the first three may cause elephantiasis. Dirofilaria immitis (dog heartworm) also is recognized occasionally in humans. With the exception of Loa loa, which is transmitted by deerflies of the genus Chrysops, filarial worms are transmitted by certain mosquito species in the process of biting. The larvae and pupae of these insect vectors are found in fresh water. The eggs are laid in or near water. The adult vectors usually associate with humans near aquatic environments.

Onchocerciasis is a widespread and serious disease, and is discussed in a separate section. The other diseases are discussed below.

Bancroftian filariasis is largely an urban and suburban disease, owing to the habits of its principal vector, Culex pipiens quinquefasciatus (Culex pipiens fatigans). Other important mosquito vectors are Anopheles gambiae, Anopheles arabiensis, and Anopheles funestus in Africa; and the Aedes pseudoscutellaris complex and various Anopheles in the South Pacific (Harwood and James, 1979; WHO, 1974). The vectors breed in various aquatic environments, including hoofprints, paddies, and canals. Humans are the only vertebrate host of W. bancrofti.

Brugian or Malayan filariasis is restricted primarily to small loci of rural human populations in India, the Far East, and the South Pacific. The periodic strain of B. malayi is transmitted by certain night-biting species of Mansonia, Anopheles, and Aedes (Harwood and James, 1979). The sub-periodic strain is transmitted by certain swamp forest Mansonia, which feed at any hour and maintain a reservoir in various forest mammals. Thus, it is a zoonosis (Harwood and James, 1979). The mosquito vectors breed in various aquatic environments, depending on the species.

Loa loa is transmitted during the biting process by Tabanid flies of the genus Chrysops (often called deerflies). The disease is restricted to Central and West Africa. The larvae and pupae of the fly vector are found in the wet soil near rice field overflows, roadside ditches, and marshy ponds (Harwood and James, 1979).

Edeson's (1975) discussion of filariasis in relation to man-made lakes and water impoundments is the most complete one available. Few case studies exist.

Leentvaar (1973), citing van Theil (1962), discussed Lake Brokopondo, a man-made lake in Surinam (formerly Dutch Guinea) in northeastern South America. He wrote that, as of 1973, "the disturbance of the biological equilibrium in the original tropical forest and the formation of the lake environment have not resulted in explosions of disease such as malaria, filariasis and bilharzia." A team of parasitologists from the University of Leiden prepared a report on filariasis and the Lake Brokopondo project. Van Theil (1962) discussed in detail the ecology of Surinamese An. darlingi, a known vector of filariasis. He plans to control the species around the lake.

Raheja (1973), too, has discussed Bancroftian filariasis in relation to Lake Nasser. A WHO team studied the incidence of W. bancrofti among lake fisherman. Raheja (1973) stated that they found no cases in the immigrant fishermen who were studied in 1970, although the parasite was found in the native villages of the fishermen who had migrated to the lake from Sohag and Qena governates. The density of Culex pipiens was the highest of the five species of culicine mosquitoes found around the lake and at downstream areas. In a report on the findings (1973), the editor stated in a footnote that "as the reservoir has continued to fill, limnological and biological conditions have changed, and social and economic conditions have been affected as a result" (see Raheja, 1973).

Lewis (1948) studied the mosquito fauna of the Jebel Auliya Reservoir and Dam on the White Nile in Sudan from 1937 to 1946. He collected An. gambiae s. l., Culex pipiens, and C. p. molestus at the Kosti section of the reservoir, and An. funestus at the Jebelein and Kawa sections. The breeding season was prolonged because the lake was filled, and small pools suitable for An. gambiae s. l. larvae were formed by the seepage of lake water held at a constant level (Lewis, 1948). The reservoir also interrupted the passage along nearby villages of mosquito larval-infested mats of papyrus. Thus, mosquito breeding (of some species at least) declined near local villages. Lewis (1958) also recorded the presence of An. gambiae s. l. in the Gezira and Sennar areas of the Blue Nile Valley between 1935 and 1955.

Edeson (1975) categorized the influences of dam construction on filariasis as direct effects and indirect effects. Indirect effects were described as the presence of asymptomatic microfilaria carriers among human laborers and camp followers. These carriers could supply microfilaria to local vector populations. According to Edeson (1975), where sanitary conditions were poor, or where sanitation facilities in new (temporary or permanent) villages close to the dam site were in disrepair, C. p. fatigans often bred extensively. As infected people moved away from the labor sites, infection spread. Edeson categorized as direct effects the changes in water availability, which might prolong the breeding season of the vector, and the invasion of the lake by aquatic plants (e.g., Salvinia, Eichhornia, and Pistia) that provide shelter for Mansonia spp. Edeson (1975) cited several examples of water plants that harbor Mansonia and explosive outbreaks of aquatic plants in man-made lakes. Mitchell (1973) also has discussed in great detail aquatic plants that thrive in man-made lakes.

Edeson (1975) suggests that C. p. fatigans is unlikely to breed intensely in man-made lakes because the organism prefers urban areas and polluted waters. He says, however, that there may be problems in unsanitary lake shore settlements. He notes also that An. gambiae s. l., the most widespread and efficient vector of malaria in much of Africa, "is not likely to be allowed to become a serious menace in the transmission of filariasis" (Edeson, 1975).

In Edeson's view (1975), dams are not likely to be constructed in areas where loiasis is endemic. He notes that, as of 1975, there had been no reports of the disease associated with dams. Edeson's conclusion may be premature. Faust and others (1975) have cited records of Loa loa from Angola, equatorial Sudan, Zaire, Nigeria, and Cameroon. Several of these countries are planning or constructing dams, perhaps in areas where loiasis is endemic.

The WHO Expert Committee on Filariasis (WHO, 1974) mentioned briefly the association between water impoundment projects and filariasis. In a discussion of areas of increased prevalence, the committee noted that "other potential man-made breeding sites [i.e., other than unplanned and uncontrolled urbanization], particularly for anopheline vectors, include dams such as those constructed for hydroelectric and irrigation purposes, seasonally flooded excavation sites, and pools and streams in areas that have been deforested for agricultural purposes." In Recommendation No. 7, the committee stated that "the development of water resources for irrigation and domestic use often results in an increase in the number of vectors of human and animal diseases, including filariasis." The committee recognized WHO's role in preventing such health hazards and recommended that due consideration be given to filariasis when such projects are being planned.

Onchocerciasis and Water Resources Development

Onchocerciasis (river blindness) is a disease of humans caused by the filaroid roundworm, *Onchocerca volvulus*. It is limited to parts of the Arabian peninsula, tropical Africa, and Central and South America (Faust, et al., 1970). It is transmitted by certain species of the biting, infected *Simulium* (blackfly). In West Africa, infected humans develop severe eye lesions and blindness. Elsewhere, subcutaneous nodules form, and the host may exhibit a variety of reactions. Various other ocular complications often develop (Faust, et al., 1970). In their immature stages, the fly vectors "breed" in highly oxygenated, and therefore fast-flowing, fresh water, particularly smaller, fast-flowing rivulets, as opposed to main river courses. The adult flies (the vector stage) prefer moist, forested, or bushy riverine areas, where most biting occurs, and they can feed on animals other than humans (Faust, et al., 1970).

Simulium also breeds at the spillways of dams. This activity has been reported since at least 1904 (Burton and McRae, 1965). Water speeds between 2.0 feet and 4.0 feet per second seem to be optimal for *Simulium* breeding (Burton and McRae, 1962).

The adult blackfly population is often affected when bushes and trees are cleared from dam and lake sites because the number of sites for resting are reduced (Edeson, 1975). The particles that are washed into a river during the construction of a dam inhibit the creation of conditions suitable for the rock-clinging, filter-feeding, aquatic larvae of *Simulium*. As a result, the population disappears temporarily (Carlson; see Edeson, 1975). The population can be controlled also by closing a dam's gates--this action slows down and de-oxygenates downstream river waters--and by filling a lake, which floods the upstream resting and feeding sites of the adult *Simulium*. Frequent changes in the level of lake water and the volume of water let through a dam are reflected in frequent changes in the level of river water below the dam. These changes, too, discourage blackfly-breeding (Edeson, 1975).

Raybould and White (1979) reviewed the distribution, bionomics, and control of onchocerciasis vectors in East Africa and the Yemen. Crosskey (1979) studied onchocerciasis in Nigeria, and PAHO (1974) studied the disease in Latin America and Africa. (See Part II for case studies on onchocerciasis.)

African Trypanosomiasis and Water Resources Development

African trypanosomiasis of humans, or sleeping sickness, is caused by the protozoan parasites, *Trypanosoma gambiense* and *Trypanosoma rhodesiense*, both of which are transmitted to humans by certain species of the biting fly genus, *Glossina* (the tsetse fly). *T. gambiense* is limited to tropical West and Central Africa. It is transmitted primarily by the riverine group *Glossina palpalis* of tsetse (*Glossina palpalis*, *Glossina fuscipes*, and *Glossina tachinoides*). The vertebrate host is man, but the disease may be a zoonosis. *T. rhodesiense* occurs only in East-Central and East Africa. It is transmitted primarily by the woodland tsetse flies, *Glossina morsitans*, *Glossina pallidipes*, and *Glossina synnertori*. These fly species feed on domestic and wild animals, as well as humans, and some are responsible for transmitting animal trypanosomiasis (*Trypanosoma brucei*, *Trypanosoma vivax*, etc.)

Many believe that animal trypanosomiasis in particular has interfered with the productive exploitation of much of tropical Africa by agricultural and water engineers. Others think the disease has benefited Africa (see Ford, 1979; Lambrecht, 1972; Ormerod, 1976).

There have been few discussions of the effects of large-scale water projects on African trypanosomiasis. Hutchison (1971) found that the epidemics of trypanosomiasis which occurred in Ethiopia in 1967-1970 spread to the Blue Nile and Omo River Valleys and were probably carried by the people themselves.

Near the man-made Lake Kainji in Nigeria, Waddy and others examined 85,482 people. They reported no infections and found no breeding foci on the Niger River down to the dam in the early 1970s (El-Zarka, 1973; Imevbore, 1975; Waddy, 1973).

The WHO study team at Lake Nasser surveyed for trypanosomiasis, but Raheja (1973) mentioned no cases.

Brown and Deom (1973) noted that the number of harborages for tsetse flies increased as high vegetation grew along the shores of Lake Kossou (Ivory Coast) and Lake Kariba (Zimbabwe and Zambia). They observed that the road from Kossou to the resettlement area at San Pedro goes through a tsetse fly belt and that tsetse were found near San Pedro. They also noted an increase in bovine trypanosomiasis between 1962 and 1966 at Lake Kariba (Brown and Deom, 1973).

Webster (1975) noted that in the Middle Zambezi River Basin a significant number of Tonga cattle had contracted and died from bovine trypanosomiasis before Kariba Dam and Kariba Lake were constructed. Some cases of human trypanosomiasis in the Kore-Kore people who lived near the site of the dam were reported also. During the construction of the dam, aerial insecticide sprays were used four months of the year (during the cool season) to protect the laborers. This spraying and the efforts of fly control teams who worked along the roads "eliminated" the tsetse from the area for a time (Webster, 1975). The rising waters of the lake pushed back the tsetse population, but along the south bank of the lake, the flies invaded nearby communities and "sporadic cases" of human trypanosomiasis were reported (Scudder, 1975; Webster, 1975). In Lusitu, below the dam, Scudder (1975) reported that several persons had died from the disease. Scudder (1972) also described in detail how bovine trypanosomiasis spread in the 1960s. In Gwembe District and elsewhere, the cattle population had increased in the early 1960s. By 1963, the margin of the lake shore had begun to stabilize, the tsetse population had relocated to new areas, and vegetation along the edge of the lake, especially Colophospermum mopane, had begun to retain leaves for longer periods of time and to provide more of the double canopy of shade that Glossina morsitans and G. pallidipes prefer (Scudder, 1972). Immediately below the dam, the people of Lusitu lost 13 percent of their cattle in a single outbreak of trypanosomiasis in 1967. In Munyumbwe, the cattle population declined from 8,139 in 1962 to 3,977 in 1966 (Scudder, 1972).

In northern Ghana, where T. gambiense is endemic, various "sleeve epidemics" had extended south along the main travel routes. One such sleeve crossed Lake Volta at Yeji (Kuzoe, 1973). The disease at "low incidence" was recorded in the Volta River Valley, where Akosombo Dam was built in the early 1960s (Kuzoe, 1973). The rising lake flooded many breeding places of the local riverine vectors, G. palpalis and G. tachinoides, and the Daka River Valley (a tributary of the Volta River), once an important tsetse site (Kuzoe, 1973; Obeng, 1973). Obeng (1973) noted only one T. vivax infection in the flies he surveyed, but four infections of unnamed species (Obeng, 1975). Kalitsi (1973) mentioned that surveillance of breeding sites, flies, and "incidence of clinical cases" had continued during the early 1970s. With the construction of Lake Volta, the number of available riverine and forest breeding sites around the lake decreased, but "it is too early to observe the effect that this reduction in tsetse habitats will have on the prevalence of trypanosomiasis in the region surrounding the lake" (Kuzoe, 1973).

Wijers (1974) discussed the complex epidemiology of Rhodesian sleeping sickness in Kenya and Uganda, especially around Lake Victoria, a huge natural African lake. He noted the lack of T. rhodesiense cases on Mfangano

Island, even though the islanders regularly visit endemic areas on the mainland. He believes that in these endemic regions people are infected mainly by G. pallidipes, in the more inland areas, and rarely by G. fuscipes fuscipes, at the lake shore. Wijers concluded that nearly all women and children, cultivators, fishermen, and fish mongers become infected while they are some distance from the lake shore--while visiting, passing through, or living in areas where G. pallidipes thrives.

Evidence to support the hypothesis that large man-made water reservoirs account for the increased prevalence or incidence of human trypanosomiasis in Africa is mixed. Furthermore, the quality of that evidence varies significantly. The prevalence of bovine trypanosomiasis increased in certain areas near Lake Kariba, as did human trypanosomiasis, but other factors in the system may have contributed to the increase. A review of the data on other man-made lakes in Africa reveals that the disease either remains as important as ever or has declined in significance. Surveillance is necessary, however, because the ecology of the tsetse in human-changed environments continues to be complex, subtle, and localized. AID continues to support research on the ecology and control of tsetse flies. In Mali, for example, it is collaborating on a project with the Government of Mali and Texas A & M University.

Malaria and Water Resources Development

Malaria is a communicable disease. It is transmitted to a susceptible vertebrate host by infected, biting mosquitoes. Caused by protozoan parasites of the genus Plasmodium, four species of Plasmodium infect humans: Plasmodium vivax (vivax/benign tertian malaria), Plasmodium falciparum (malignant tertian malaria), Plasmodium ovale (benign tertian malaria), and Plasmodium malariae (benign quartan malaria). Humans occasionally are infected with species of primate malaria. Plasmodium vivax and P. falciparum are the most common species that infect humans worldwide. P. ovale is not uncommon in Africa. P. malariae occurs in various parts of Central and East Africa, Asia, and the Caribbean and tropical Latin America (Faust, et al., 1970). All human Plasmodium are naturally transmitted by certain species of (infected, infective, female) biting mosquitoes of the genus Anopheles. In tropical Africa, the major vectors of human malaria are Anopheles gambiae, Anopheles funestus, and Anopheles arabiensis. Rozeboom (see Harwood and James, 1979) has listed other prominent malaria vectors in Africa, Asia, Latin America, and elsewhere.

The life histories and vectorial capacities of species of malarial Anopheles vary considerably. The larval and pupal stages live in aquatic environments that range from mild salt water to polluted fresh water. Anopheles gambiae larvae are known to breed in the water-filled hoof prints of livestock, in roadside barrow pits, in the furrows left by tire treads, and in other unusual environments.

Malaria has long been associated with swampy land and rice cultivation; Sir Richards Christophers coined the phrase "man-made malaria" to describe the latter (Audy, 1961). Farid (1977) has discussed irrigation and malaria in arid lands and has observed 17 vector species in arid zones. He notes that in arid, subtropical climates the introduction of perennial irrigation and wet cultivation sets the stage for malaria epidemics and post-epidemic hyperendemic situations. He cites as examples the Nile Delta, irrigated parts of Syria and Iraq, and Khouzestan Province in Iran. Farid (1977) has also described the threat of invasion by *Anopheles gambiae* in Egypt. He has linked this to the construction of the Aswan High Dam, and in particular to Lake Nasser, along the edge of which *A. gambiae* could pass from the Sudan into Egypt. To stem the spread of vectors, Egypt concluded an agreement with the Sudan to maintain an *A. gambiae*-free buffer zone south of Lake Nasser. This area is under continuous surveillance.

Other Communicable Diseases

The parasitic worm *Dracunculis medinensis* is commonly known as "guinea worm." It can infect humans when they swallow an infected intermediate host, a fresh water crustacean called *Cyclops*. This simple, direct transmission cycle can be broken easily by boiling or filtering drinking water and by providing a supply of safe water for drinking and domestic use. Obeng (1973, 1975) reported on the presence of guinea worm near Lake Volta, but he did not associate it directly with the lake. Belcher and others (1975) have reported on the spread of guinea worm in villages that use pond water and at the site of USAID's Danfa Project, in southern Ghana. The presence of the organism has had a negative impact on agricultural production because workers have become disabled during peak agricultural activity. Apparently, increased incidence was not associated with increased numbers or sizes of ponds.

Hookworm, a parasitic infestation caused by *Necator americanus*, *Ancylostoma duodenale*, and related species in various parts of the world, is usually contracted by humans who walk barefoot on damp, sandy, infested soils. The infestation rate for workers at the Kariba Dam, who had contracted the disease elsewhere, was found to be high, and the workers were treated (Webster, 1975). Ancylostomiasis was a concern of workers at labor camps at the Aswan High Dam (Farid, 1975). Local aborigines were found to suffer from hookworm contracted near the Ord River Dam (Stanley, 1975).

The hookworm *Angiostrongylus cantonensis* prevalence rate was 30.5 percent in three permanent fishing villages in the irrigation area of Ubolratana Dam in Thailand. The prevalence rate in the local rodent population was approximately 5 percent. Infective larvae were found in 3.2-5.2 percent of Pila snails. Both rodents and snails are hosts of this zoonotic species of hookworm (Harinasuta, 1975). Ancylostomiasis was found to be one of the three most important diseases among fishermen at Lake Nasser, but, apparently, the appearance of this disease is not related directly to the lake itself (Raheja, 1973).

Leptospirosis, a zoonotic bacterial disease caused by strains of Leptospira interrogans, is most often associated with ricefield and canefield environments (Wannan, 1975). Infection occurs during contact with any neutral or slightly alkaline fresh water source that has been contaminated by a carrier animal's urine (domestic or wild vertebrates, especially rodents). The disease has been found in people dwelling in the irrigated areas around Ubolratana Dam in Thailand (Harinasuta, 1975). Apparently, no cases were reported for the fishermen surveyed at Lake Nasser (Raheja, 1973). This disease, like guinea worm and hookworm, could become associated with, say, the zone around the shore of a man-made lake or canal, but no other such relationship has been established.

Various arboviruses (arthropod-borne viruses) have been linked to water projects. The majority of arboviruses are transmitted by infected biting mosquitoes and ticks of certain species, though other blood-sucking arthropods are involved also in the transmission of certain arboviruses. All mosquitoes and certain other common arbovirus vectors (some biting midges and other flies) breed in aquatic environments. There are more than 300 recognized arboviruses.

The arbovirus that many people recall first is yellow fever virus, which usually is transmitted by Aedes aegypti, the urban yellow fever mosquito. In forested areas, yellow fever is transmitted often by other Aedes species, and by mosquitoes of the genus Haemagogus. They maintain a natural reservoir in various tropical forest primates. "Jungle fever," or "sylvan yellow fever" (a zoonosis), is the name of the human infection contracted in jungles or wooded areas. The story of the construction of the Panama Canal by the French and Americans at the turn of this century is well known. The French lost 1,048 employees to sylvan yellow fever between 1881 and 1904 while trying to build the Panama Canal through man-made Lake Gatun, an area where sylvan yellow fever is endemic (Elton, 1952). Colonel W. C. Gorgas of the U.S. Army formed a team that tried to reduce sites for breeding, fumigated homes, and screened the sick. The team's heroic efforts resulted in the eradication of yellow fever from the Canal Zone in 16 months (1904-1905) (Elton, 1952).

Apparently, yellow fever was monitored at Lake Nasser (Farid, 1975), Lake Kainji (Imevbore, 1975), and Lake Volta (Obeng, 1975). At none of these sites were cases reported. Today, even with two excellent yellow fever vaccines, yellow fever is a constant problem in certain locales in Latin America and Africa, where the disease is endemic. Water projects that impinge on sylvatic yellow fever zones (e.g., in Panama) can expect problems with the disease unless preventive measures are taken.

Dengue virus, in all its various forms and manifestations (e.g., dengue haemorrhagic fever), is primarily transmitted by Aedes aegypti. It has become a growing problem in parts of Asia, India, the South Pacific, and especially the Americas and the Caribbean (PAHO, 1979). The vector is associated with aquatic habitats, but the author found only one reference that specifically associates dengue with water resources development projects (see Surtees, 1970). This is to be expected. Aedes aegypti normally breeds in small vessels, such as barrels and abandoned tires. It does not breed in larger bodies of water, such as man-made lakes (Brown and Deom, 1973).

The more well known encephalitic arboviruses (Venezuelan, Eastern, St. Louis, Western and Japanese B) and many other viruses are transmitted by mosquitoes, and some have been associated with water resources development projects. Washino (1980), Hess and others (1970), and Surtees and others (1970) have discussed the role of expansion of irrigated rice cultivation in the transmission of an arbovirus. They are among dozens of other authors who have addressed the same subject. (Surtees (1975) has prepared a useful list entitled "Arboviruses Transmitted by Mosquitoes Favored by Dam Construction and Irrigation.")

The author discussed earlier the change in SLE virus activity in birds measured before, during, and after the construction of a dam in Panama (see Adames, et al., 1980). Arbovirus surveillance continues around Lake Nasser (Raheja, 1973), especially for Rift Valley Fever (RVF) virus (Craven, et al., 1980). RVF is a zoonotic virus; recently, it has been linked to human ocular disease (Siam and Meegan, 1980) and abortions (Abdel-Aziz, et al. 1980) in Egypt, and in 1976 to an epizootic in the Sudan (Eisa, et al., 1980). RVF virus was responsible for an unprecedented epidemic in Egypt in 1977 and 1978 (see Eisa, et al., 1980). Brown and Deom (1977) have been concerned that one vector of RVF virus, Aedes caballus, could multiply in irrigation systems and water impoundments. They also are concerned that Culex tritaeniorhynchus, the rice-field vector of the Japanese B encephalitis (JBE) virus, could appear during the construction of dams in the Mekong Valley (Brown and Deom, 1977).

Various other communicable diseases or disease agents are associated with canals and other small water impoundments. Among them are infectious hepatitis, cholera, typhoid, pathogenic amoebae and certain other protozoa, and various human flukes. Various non-Schistosoma flukes of humans are commonly associated with aquatic environs (e.g., Fasciolopsis buski, Paragonimus westermani, Clonorchis sinesis, and Heterophyes heterophyes), and they may pose serious problems in some locales, mainly Southeast Asia. These and the other organisms named above should be the subject of a separate paper on diseases resulting from poor sanitation and food preparation.

III. LIVESTOCK AND CROP PRODUCTION

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Pesticides and Disease

Health and ecological problems have been linked to the use of agricultural and veterinary pesticides (Cerneli, 1975). Acute and chronic toxicity and the unsafe disposal of pesticide residues and empty pesticide containers are constant hazards. In projects involving pesticides in LDCs, AID requires that users be educated in their use. Certain seed treatment chemicals, such as alkylmercury, have caused deaths and intoxications (poisonings) in some LDCs. In Iraq in 1972 an alkylmercury-treated wheat seed shipment was consumed that resulted in 6,350 hospital admissions and 459 deaths (FAO/WHO, 1974).

The use in AID projects of commercial petrochemical fertilizers may affect the levels of toxic nitrates in local soils (used for crop production) and waters (used for drinking) (Berwick, 1979). AID funds intensive (feedlot-style) livestock production projects that must be properly planned and managed to prevent the creation of manure breeding grounds for large populations of fly pests and disease vectors or disease agents (e.g., eye gnats, houseflies, blow flies, flesh flies, stable flies, horn flies) of humans, livestock, and poultry.

Heilman (1973) has surveyed pesticides in surface waters. The runoff from pesticides and fertilizers into adjacent irrigation canals may be cause for concern if the irrigation water is also used for drinking. The author has observed the use of irrigation water for drinking among peoples in squatters' camps in rural Mexico. The practice is common even in the United States (Sandhu, 1981). Evidence supports the argument that the provision of a safe supply of domestic water should be a required component of AID's health sector policy because it reduces such hazards.

Agriculturalists at AID should recognize that certain improved varieties of seeds (commonly--and incorrectly--referred to as "Green Revolution" varieties) may require the use of larger amounts or different kinds of pesticides and petrochemical fertilizers, which may be the cause of some of the health problems mentioned above. Often, when certain of these varieties of seeds are planted, more irrigation water (irrigation water implying canals and associated diseases) must be used. The negative impact of certain improved seed varieties on human nutrition has been recorded in LDCs (Fleuret and Fleuret, 1980).

Selection of Food Crops

Even the choice of a new food crop can entail health risks. Fleury (1980), writing in the Canadian magazine, "IDRC Reports," discussed the health risks of cassava production, a highly toxic food crop which, if it is improperly cooked, can result in cyanide poisoning. Furthermore, IDRC-funded research in LDCs indicates that the consumption of cassava can cause goiter and mental retardation if a person's iodine intake is low.

Irrigated land, especially where rice and sugarcane are grown, may become the breeding ground of mosquito vectors of malaria and other mosquito-borne diseases. The transmission of schistosomiasis has been associated also with the irrigation of rice paddies in Japan (Ito, 1970) and Surinam (Reijenga and Van Asselt, 1968) and of sugarcane fields on sugar estates in Ethiopia (Duncan and Lemma, 1976) and Tanzania (Crossland, 1963; Fenwick, 1971; Fenwick and Jorgensen, 1972; Foster, 1967). Fasciola hepatica, the liver fluke of humans and ruminants, has been associated with the production of rice (Ueno, et al., 1975) and other irrigated crops (Van der Schalie, 1972).

The promotion of aquaculture, which involves the construction of fish ponds, has been associated with the transmission of parasitic diseases in Central Africa (DeBont and DeBont-Hers, 1952), Kenya (Lockhart, et al., 1969), and India (Mathavan, 1973). Fish ponds can become breeding grounds for various mosquito vectors, and some vertebrate and invertebrate fauna of such ponds may act as intermediate hosts of certain human flukes and tapeworms.

Livestock and Zoonotic Disease

When planning any livestock production effort, AID should ascertain whether the project, which may be extensive or intensive, drylot or irrigated production, will aggravate the transmission of zoonotic diseases, such as bovine tuberculosis, fascioliasis, anthrax, brucellosis, trichinosis, Q fever, hydatid disease, rabies, etc. A thorough discussion of zoonotic diseases is found in the work of Hubbert and others (1975). Appropriate abattoirs and the inspection of animals by public health officials should be required in livestock production projects involving meat animals. In expanded rangelands of grazing animals, the zoonotic disease foci of trypanosomiasis, scrub typhus, etc., may be encountered by humans.

Some AID projects may involve the loan or purchase of animal feed containing antibiotics. This grain is used in the routine feeding of cattle, swine, sheep, goats, and poultry. When such grain is used, AID should be concerned about the creation or spread of infectious drug resistance (R-plasmid transfer resistance). The massive, indiscriminate use of antibiotics may result in the transfer of antibiotic-resistant mutant strains of (often pathogenic) bacteria from animals to human bacteria (Levy, et al., 1976). The problem has been summarized by Hirch, who wrote that "we are confronted with . . . the spectre of a completely harmless bacterial strain, like E. coli, which lives in the gut of warm-blooded animals, becoming resistant to a certain antibiotic, and then passing on that resistance to harmful bacteria, which cause diseases such as Salmonella [sic] or gonorrhea in humans" (Hirch; see Schell, 1980). The problem also was discussed in a National Academy of Sciences (NAS) study (NAS, 1980). The authors observed that in the absence of data, "the postulated hazards to human health from the use of antibiotics in animal feeds were neither proved nor disproved by review of the evidence. The lack of data, however, must not be equated with proof that hazards do not exist" (Anonymous, 1980a).

Several research scientists and practitioners in the field are even more concerned about the problem than the NAS report would suggest. Indeed, certain former members of the NAS committee strongly expressed their views in a minority opinion (Schell, 1980; Hirsch, University of California, Davis, personal communication, 1981). The problem of transferable drug resistance in livestock has been reported in certain LDCs (Harold, 1972). Several European governments (Great Britain, the Netherlands, West Germany, Norway, Sweden, and Denmark) are so concerned about the problem that they have banned or restricted the addition of antibiotics to feeds for animals if the drugs are also commonly used in human therapy (Schell, 1980). Some members of the U.S. Congress are also very concerned about this problem (Dingell, 1980).

Pest Control and the Recrudescence of Vector-Borne Disease

Recent evidence reveals that the application of pesticides to control agricultural pests sometimes has unexpected effects on pest populations of public health importance and associated control programs. Often, these effects are detrimental, but occasionally they are beneficial, depending on the specific circumstances (NAS, 1976). In this section, the author surveys the literature on this relationship and concludes with a discussion of possible management strategies to reduce the detrimental effects of applied pesticides. The author's primary purpose is to encourage AID agricultural planners and others to recognize and share the concerns of veterinarians and public health planners and practitioners. The discussion (see Ault, 1980) is focused on agro-ecosystems, and not geographical regions or categories of disease and insecticides.

Agro-ecosystems, or crop systems, are unique in nature. They are characterized in part by the presence and distribution of cash crops and plant pest and disease problems; human-defined boundaries in space and time; human-directed homogeneity in crop phenology; and a stability (or instability) that is maintained primarily by management practices and inputs (see NAS, 1976).

All systems, including agro-ecosystems, are conceptual tools (Churchman, 1968, 1971, 1979). The definition of the boundaries of an agro-ecosystem is thus a creation and product of human reasoning. As Smith and Reynolds (1972) have observed:

> The physical limits of a cotton agro-ecosystem are rarely precise. Very few, if any, agro-ecosystems are self contained. For the practical purposes of pest control, rather arbitrary limits are determined. However, the area included must be large enough so that the more significant populations can complete most of their major biological activities within its limits. Thus crudely delimited, the cotton agro-ecosystem will usually include a group of agricultural fields (cotton as well as other associated crops) together with their marginal areas, and often certain other intermixed areas as woods, streams, and weedy or uncultivated areas. As agricultural practice creates a large amount of disturbance, there is typically much movement of species within, into, and out of the system. . . .

Unfortunately, agricultural and other planners fail to recognize this subjectivity when they look for the possible detrimental effects of technological inputs into an agro-ecosystem. The primary, secondary, tertiary, or nth-order consequences of such inputs (see Janzen, 1973), especially those of importance to public health, may also not be observed. Too often, planners accidentally overlook the presence of public health pests in agro-ecosystems, and for two reasons. One, such pests are deemed to be <u>insignificant</u> members of the agro-ecosystem when viewed in relation to proposed technological inputs or changes. Two, such pests are <u>excluded</u> from planners' definition of "agro-ecosystem." In either case, they are relegated to an "environment" over which we either do not or choose not to exercise control. In systems science this is known as the environmental fallacy (Churchman, 1979).

A good example of the failure to recognize nth-order consequences is the application of insecticides to control agricultural pests (hereafter referred to as agricultural spraying) that has undesired effects on the incidence, prevalence, or significance of arthropod-borne diseases and pest infestations of man and animals. Specifically, one of the major problems facing veterinarians and public health officials in many developed and underdeveloped countries is the selection of populations of arthropod disease vectors and pests that resist the pesticides used to control them. The resistance of the housefly and Culex fatigans molestus to DDT was first discovered in Italy in 1947 (Brown and Pal, 1971). As of 1971, 104 arthropod vectors or public health pests had been found to be resistant to one or more insecticides in various parts of the world (Brown and Pal, 1971).

Workers in public health programs are concerned about four categories of resistance: to DDT, to certain cyclodiene derivatives (e.g., dieldrin and gamma-BHC), to certain organophosphates (OPs), and to certain carbamates (NAS, 1976). Apparently, resistance has been the single most important problem in malaria eradication and control programs (Brown and Pal, 1971), although other disease control programs face similar problems (PAHO, 1972a, 1972b).

Resistance is a result of intense selection pressure on the pest population's gene pool over time. The chemical species, the amount and intensity of the applied insecticide, the routes of application, intake, sequestration, and metabolism of the chemical in the pest, and the physical environment (temperature, relative humidity, light intensity, etc.) may all play a significant role in the process. Theoretically, from a management perspective, many of these factors can be manipulated, and all are subject to various constraints. Thus, the agricultural planner might wish to consult with agricultural and medical entomologists, toxicologists, meteorologists, medical geographers, agricultural engineers, and others to develop a system that will eliminate or at least reduce the selection pressure on the targeted (and non-targeted) pest populations. This concept may be applied also to populations of agricultural or public health pests.

Phenomenologically, it is not always apparent why pests develop a resistance to insecticides. "In certain cases, however, it is evident that agricultural use of pesticides is the primary cause" (NAS, 1976). Correlative data on agro-ecosystems in various parts of the world support this statement. Hamon and Garret-Jones (1962, 1963), in a discussion of the causes of vector resistance in Africa, were the first to propose this hypothesis in the scientific literature.

Agro-Ecosystems

A. The Cotton Agro-Ecosystem

Cotton, Gossypium spp., is the most important vegetable fiber cultivated by man, and it is grown in almost every tropical and subtropical country where conditions are suitable (Cobley and Steele, 1976). The cotton agro-ecosystems in parts of Upper Volta and Central America were the two agro-ecosystems cited in the first description of the relationship between agricultural spraying and the development of resistance in public health pests. Hammon and Garret-Jones (1962, 1963) and Hamon (1972) discussed the correlation between an increase in the proportion of endrin-resistant Anopheles funestus, a key vector of malaria and filariasis (White, 1974), in the early 1960s and slight and scattered endrin application on cotton fields near a small village in Upper Volta.

Almost all cotton in Central America is grown on the fertile Pacific coast plain that extends from Tapachula, Mexico, to the Guanacaste Province in Costa Rica, with the exception of certain districts in Honduras (Mobley, 1955). Only since the mid-1950s has cotton been grown in large-acreage monocultures (Georghiou, 1972). The significant increase in cotton acreage is a result of land reform, government-supported cotton prices, and the opening of new land following the construction of roads and, ironically, the initiation of malaria control (Mobley, 1955). According to Georghiou (1972), this practice has been accompanied by intensive sales efforts by agrichemical firms, "the abandonment of cultural pest control practices, and the tendency of growers to apply insecticides more frequently and at higher doses than absolutely necessary. . . ." Several OP insecticides (e.g., parathion, methyl parathion, malathion, trichlorophon) have been applied heavily (almost weekly for six months of the year) to the cotton crops (Breeland, et al., 1970). In the cotton zones in several areas in Central America, farmers have applied more than 50 treatments of such insecticides (especially methyl and ethyl parathion) to a given field in a single season (Smith and Reynolds, 1972).

Smith and Reynolds (1972) have discussed the occurrence of severe outbreaks of certain cotton pest populations in the 1960s. These outbreaks were attributed to insecticide resistance, sub-normal rainfall, poor agricultural practices (especially for cultural control), the increasing incidence of cotton diseases, and, in some areas, inadequate soil fertility. Cotton yields have declined since the peak season of 1964-1965 (Smith and Reynolds, 1972).

The major human malaria vector in Central America is Anopheles albimanus. The first signs of resistance to OPs in the field appeared in 1965 in Guatemala and Nicaragua, where populations were suspected of showing slightly improved tolerance to malathion (WHO, 1966). In March 1969, Breeland and others (1970) demonstrated in a field-cage experiment that field populations of A. albimanus, from La Libertad, El Salvador, were significantly more tolerant to aerial applications of malathion than was a laboratory population of the same species. They pointed out that only field populations from areas on or adjacent to intense cotton cultivation showed decreased susceptibility to malathion (Breeland, et al., 1970). Various people in Central America (Pletsch, 1970; Ariaratnam and Georghiou, 1971; Georghiou, 1972, 1976; PAHO, 1972; Garcia Martin and Najera-Morrondo, 1973; Georghiou, et al., 1971, 1973; Rachou, et al., 1973) quantitatively tested the original hypothesis of Breeland and his colleagues. They observed the same strong, positive correlation between an A. albimanus OP-resistant population and pesticide-intensive cropping of cotton. Georghiou (1972) observed drastic declines in A. albimanus populations during the cotton-growing season, despite abundant rainfall, which usually favors the increased population of larval A. albimanus (Horsfall, 1972). This reflects the severe selection pressure of agricultural sprays on A. albimanus populations (Georghiou, 1972). Horsfall (1972) has noted that Culex interrogator, Aedes taeniorhynchis, Aedes sollicitans, and Anopheles crucians larvae are often associated with A. albimanus larvae in the aquatic habitat. It would be interesting to test the appearance of the same correlations between agricultural spraying of cotton and OP resistance in populations of these four species.

In West Africa, Hamon (1970) stated that Anopheles populations developed resistance when cotton in the middle belt of the area was dusted with DDT and endrin. In the Republic of Mali, populations of Anopheles gambiae s. l. and Anopheles funestus are resistant to DDT and dieldrin; "[i]n this area no insecticide has ever been used in houses against anophelines, nor against any other pests of humans. Everything comes from cotton dusting" (Hamon, 1970). Members of the Anopheles gambiae complex and Anopheles funestus are the major vectors of malaria and filariasis in much of sub-Saharan Africa (White, 1974).

In hindsight, Brown and Pal (1971) and Zahar (1974) believe that the extensive application of DDT and toxaphene to cotton and rice in the Nile Delta of Egypt in the late 1950s and early 1960s was responsible for the unexpectedly high resistance of populations of the malaria vector Anopheles pharoensis to DDT and dieldrin. By 1964, these levels of resistance had begun to decline, probably because the organochlorine (OC) compounds were replaced by carbaryl and trichlorfon (Brown and Pal, 1971).

Stewart (1977) found contrasting results in a preliminary experiment. In the San Joaquin Valley in California, cotton is grown in an intensively managed monoculture. It is a major crop covering thousands of acres of land. In terms of farm value, cotton is ranked the third highest commodity in the state (Division of Agricultural Sciences, University of California, 1976). In Kings County, the pesticide DEF^R (s,s,s, -tributyl phosphorotrithioate) is sprayed extensively on cotton (Stewart, 1977). Because populations of the southern house mosquito, Culex pipiens fatigans (a vector of St. Louis encephalitis of man, and a livestock, dairy, and human pest), are resistant to OPs, Stewart (1977) mixed chlorpyrifos with DEF and tested it as a mosquito larvicide. The results of his "crude experiment" indicated that adequate control could be achieved in dairy wastewater drains, but he noted that the effects of agricultural spraying of DEF on C. p. fatigans populations are not known (Stewart, 1977). At the time, Stewart (1977) felt that "[s]ince control was achieved in the drains tested with DEF, agricultural spraying of DEF apparently [did] not [affect]" the larvicidal efficacy of the mixture.

B. The Rice Agro-Ecosystem

The rice agro-ecosystem is one of the most important and extensive systems in the world. Rice, Oryza sativa, is grown extensively in parts of Asia, Africa, the South Pacific, and the Americas (Grigg, 1974; Cobley and Steel, 1976) under diverse conditions (see Hanks, 1972). Georghiou (1972) described the increase in acreage under rice production in Nicaragua and El Salvador in the late 1960s as intensive rice cultivation began to replace the intensive cultivation of cotton in certain areas. At that time, rice was not subjected to as many varied applications of insecticides as was cotton, but it was treated, primarily with carbaryl and methyl parathion (Georghiou, 1972). The intensity of insecticide spraying in rice fields was increasing, and Georghiou (1972) noted that the level of OP and carbamate resistance in the malaria vector A. albimanus "appeared" to be higher in such areas. He stated that the implication of rice in A. albimanus resistance may be either a true cause-effect relationship or coincidental, and cautioned that the hypothesis has yet to be proven (Georghiou, 1972). In the Rio Viego Valley of Nicaragua and in El Salvador, a correlation between A. albimanus resistance to propoxur and aerial application of propoxur to rice was noted (PAHO, 1972a).

The effects of applying DDT and toxaphene to rice in the Nile Delta of Egypt and the relationship to A. pharoensis (Brown and Pal, 1971) were described above.

A National Academy of Sciences study team analyzed the relationship of the transfer of agricultural technology for rice production to its effects on public health in Asia, especially Southeast Asia (NAS, 1976). The excessive use of pesticides in Asia can be documented (an example is the Bimas Gotong Rojung Project, a scheme initiated and abandoned in Indonesia) (NAS, 1976). The study group believed that the application of pesticides to rice was declining in Asia. Thus, it was difficult to demonstrate either the positive or negative health effects of change (NAS, 1976). Nevertheless, the study team developed a good planning strategy, and discussed the three most important arthropod-borne diseases of humans associated with rice production in Asia: malaria, filariasis, and Japanese B encephalitis. In a brief review of the epidemiology of these three diseases, the team suggested that it is necessary to be aware that the use of agricultural insecticides in rice production may increase vector resistance (NAS, 1976).

C. The Maize Agro-Ecosystem

Maize, Zea mays, a large annual monoecious grass that is thought to have originated in Central America, is a major crop in many parts of Latin America and North America. It has replaced such ancient, local food crops as sorghum and millet in many areas of Africa and Asia (Cobley and Steele, 1976). In Central America, maize is a staple crop for many rural households. Georghiou (1972) mentioned that the application of insecticides (e.g., certain OPs and carbamates) to these maize crops may contribute to the selection pressure on A. albimanus for insecticide resistance.

D. The Sugarcane Agro-Ecosystem

Sugarcane, Saccharum spp., is cultivated in many tropical and sub-tropical areas of Asia, including India, Australia, Africa, the Americas, and the South Pacific (Cobley and Steele, 1976). In Central America, where cotton has been replaced by sugarcane, a crop rarely treated with insecticides, there is considerably reduced selection pressure on mosquito populations (Georghiou, 1972). The first confirmed report of DDT and dieldrin resistance in A. gambiae s. l. in East Africa came from the El Guneid sugar estate in the Sudan in 1970 (Zahar, 1974). It is believed that the application of pesticides to cotton crops before sugarcane was planted and the use of pesticides on cotton plantations that still surround the sugarcane estate created high selection pressure (Zahar, 1974).

E. The Coffee Agro-Ecosystem

Coffee, Coffea spp., is an important beverage crop. Although it originated in Africa, it is now grown also in numerous locations in Asia and Latin America (Cobley and Steel, 1976). Hamon (1970) noted that in the southern belt of West Africa the use of BHC dust on coffee created most of the insecticide-resistant populations of Anopheles that are important to discussions of public health. An interesting twist to this pattern has been observed in Burundi, East Africa, where malathion resistance in (body or head?) lice developed after malathion, which originally was to have been used to control coffee pests, was withdrawn for personal louse-control use (NAS, 1976).

F. The Cocoa Agro-Ecosystem

Cocoa, Theobroma cacao, is another important beverage crop. It is thought to have originated in the equatorial rain forests of the eastern

Andes Mountains of South America. Today, it is also grown in Africa (Cobley and Steel, 1976). The dusting of cocoa with BHC in the southern belt of West Africa has been correlated with BHC resistance in populations of Anopheles spp. in that area (Hamon, 1970). In Mali, it was expected that the application of propoxur to cocoa would select for resistant populations of malaria vectors and thus interfere with malaria control efforts (Hamon, 1970).

G. The Groundnut Agro-Ecosystem

Groundnuts, Arachis hypogea, are an important leguminous food crop which were first domesticated in South America. They are now an important subsistence and cash crop in West Africa and the Philippines (Cobley and Steel, 1976). The dusting of groundnuts with DDT and BHC in the northern belt of West Africa has been cited as a major cause of DDT and BHC resistance in Anopheles populations in that zone (Hamon, 1970).

H. The Date Palm Agro-Ecosystem

The fruits of the date palm, Phoenix dactylifera, have been a key staple in the diet of peoples in the hot dry regions of Arabia, the Middle East, and North America for thousands of years. Today, the crop is also grown in Spain and parts of the Americas (Cobley and Steel, 1976). In recent years, carbamates, notably carbaryl (Sevin), dimethoate (Perfekthion), bromophos (Nexion), and phospharmidon (Dimecron), have been used to control date palm and other pests in Fars Province in southern Iran (Eshghy, 1978). It is believed that the double resistance of Anopheles stephensi, a major vector of malaria in Fars, to DDT and dieldrin and its tolerance to malathion are associated with the spraying of this agricultural pesticide (Eshghy, 1978).

I. Other Agro-Ecosystems

The use of agricultural pesticides has contributed to the development of resistance to DDT and dieldrin in Anopheles sundaicus and Anopheles aconitus in Java and in Anopheles quadrimaculatus in the United States, according to Schoof (1970). Anopheline vector resistance has been correlated, in part, with the use of agricultural pesticides in Greece and Iraq (NAS, 1976). Resistance to dieldrin and tolerance of DDT were found to be prevalent in certain A. pharoensis populations in the Sudan at Sennar, Kosti, Managil, and the Gezira between the Blue and White Niles (Haridi, 1966). Agricultural insecticides were considered to be responsible (Haridi, 1966).

Senanayake (1977) described the relationship between the use of insecticides and the development of resistence in malaria vectors in Sri Lanka. Malaria control planners recognized the danger in creating greater insecticide resistance in the vector Anopheles culicifacies. In 1975, the national malaria control program switched from DDT spraying to malathion spraying, and it simultaneously banned the use of malathion in all agricultural activities. But, as Senanayake (1977) observed in 1976, malathion was pilfered from government stocks and sold surreptitiously to the farming community.

Zahar (1974) implied that the use of agricultural pesticides may be associated with DDT resistance in the malaria vector Anopheles sacharovi in parts of the Arab Republic of Syria. Roy and others (1978) found that Anopheles stephensi populations in certain urban areas of Tamil Nadu, India, had become tolerant of propoxur. A. stephensi, a species that usually breeds in wells or cisterns in the area, is a major vector of urban malaria and filariasis. Lacking a better explanation, Roy and his colleagues (1978) concluded that the organism had become tolerant of propoxur because of cross-resistance from the agricultural use of carbaryl in nearby agricultural zones. Larval populations of Culex pipiens in urban and suburban areas in the south of France have become resistant to certain chlorinated hydrocarbon and organophosphorous compounds. Sinegre and others (1977) believe that resistance developed because agricultural pesticides were used in nearby areas.

Kulkarni and his colleagues (1977) stated that the resistance to DDT of Aedes aegypti, which caused an epidemic of dengue in Amalner Town, Marahashtra, India, may be attributed to the use of DDT in agriculture.

Agro-Ecosystems and Technology: The Management of Disease

A. Benefits

Although the use of agricultural insecticides on rice and other crops apparently affects public health adversely, it may also have beneficial effects. The NAS (1976) reviewed a number of positive incidental effects.

1. Following the application of granular fensulfothion, or carbofuran, to control rice water weevil in Arkansas, mosquitoes were brought under complete control (Lancaster and Tugwell, 1969).

2. The use of granular carbofuran and the carbamate Bux produced similar results in Louisiana. When these materials were used to treat rice seeds, partial control of Psorophora larvae resulted (NAS, 1976).

3. The application of toxaphene to control the fall army work in Louisiana eliminated Psorophora larvae (NAS, 1976).

4. When herbicides are applied to rice fields, the larvivorous fish Gambusia affinis is able to reach the mosquito prey more easily (Craven and Steelman, 1968).

5. Insecticides (e.g., fentrothion, EPM, phenthoate, and trichlorfon) can be applied to rice paddies in South Korea to control a rice stem borer and two species of leafhopper. When these insecticides are used, complete but temporary control of Culex tritaeniorhynchus, a major vector of JBE virus in man, results (Bang and Self, 1971; Self, et al., 1971a, 1971b).

6. In northern Taiwan, an ultra low volume (ULV) spray of malathion may be used to control the green rice leafhopper. It also results in short-term reductions in populations of Culex annulus, another vector of JBE (Mitchell, et al., 1972).

B. Management Strategies

One can expect that, with the diffusion of more intensive agricultural technologies, such as use of pesticides, agro-ecosystems will continue to be affected in undesirable ways. Whole books have been devoted to a discussion of this problem (see Carson, 1962; Rudd, 1964; Office of Science and Technology, 1971; Farvar and Milton, 1972; Tallian, 1975; van den Bosch, 1978). For the agricultural planner, or others who are concerned about avoiding or managing such phenomena, the first step may be to read the literature on the subject to become more aware of and sensitive to the problems created by agricultural technology.

To more carefully delineate other management strategies, a unique agromedical seminar was held in El Salvador in December 1973. The seminar was jointly sponsored by the Government of El Salvador, the University of

California/USAID Pest Management Project, and the Pan American Health Organization (NAS, 1976). This multidisciplinary group offered several recommendations to manage the public health problems that arise when agricultural spraying is done. The recommendations for El Salvador (NAS, 1976) are summarized below.

1. Organize a central interagency commission on pesticide use. The committee should include representatives from the Ministries of Agriculture, Public Health, Labor, Economy, and Defense, and from the national university and private industry. The objectives of the commission will be to develop pesticide residue tolerances, create legislation to control the importation of new pesticides, and thoroughly investigate pesticide-protection plans.

2. Join and comply with the requirements of the Codex Alimentarius Commission of the United Nations. This will "require continuous upgrading of laboratory performance and the establishment of a quality control program."

3. Collaborate in activities in Panama and other Central American countries to control pesticide residue.

4. Participate in the work of regional bodies, such as the Institute of Nutrition of Central America and Panama (INCAP) and ICAITA.

5. Establish a Chair of Toxicology in the national medical school.

6. Train regional multidisciplinary pesticide-protection teams in toxicology. These teams should be capable of investigating and analyzing human and environmental pesticide poisonings and reporting these problems to the central commission. They also should be able to perform surveys of blood and adipose tissues in humans and to study crops and livestock.

7. Educate more chemists, public health personnel, and agronomists.

8. Establish an updated pesticide reference library.

These recommendations are excellent, but several gaps exist and other points should be considered.

1. Sensitivity to the Problem

The recommendations proposed in 1973 implicitly suggest that increased sensitivity to the problem of managing the detrimental effects of pesticides will be an outcome of planned strategies in this area. It is important to ask who should be most sensitive to the problem. From a review of the recommendations, it appears that pesticide-protection teams, chemists, public health personnel, agronomists, and certain representatives of government ministries, the university, and private industry (the central interagency commission on pesticide use) will be most cognizant of pesticide problems. But of critical importance is the ultimate decisionmaker in LDCs--the agriculturalist, who will or will not be applying pesticide x in quantity y to the agro-ecosystem. The participants in the agromedical seminar had few suggestions for how the grower himself might be educated about the effects of pesticides. Here, agricultural extension agents, farmer's associations, and community organizations can play a critical role, a role that has not been discussed to date. The sociological implications of information transfer were briefly discussed by the National Academy of Sciences (NAS, 1975).

In developing countries, government agencies and other organizations (e.g., bilateral and multilateral agencies, public or private development agencies, transnational corporations, and religious groups) play an important role in planning and designing an agricultural development package for a given rural area. These packages often are designed to intensify crop production, to increase output per unit area of land. The packages usually are a combination of four general inputs: improved varieties of crops (often requiring changes in crop phenology), water control techniques (often irrigation), fertilizers, and pesticides. Given the backgrounds of those who usually create such packages--the agricultural economists, agronomists, and agricultural engineers--it is highly likely that public health concerns will be excluded from the agro-ecosystem that is defined, or, at the least, they will be deemed insignificant. These errors can be avoided by helping agronomists and other members of a planning team become aware of and sensitive to public health issues in agriculture (e.g., the detrimental effects of pesticides). But it may be more effective to include as members of a planning team a medical geographer and an entomologist. The geographer and medical entomologist could help design strategies to prevent or retard the development of pesticide resistance by mapping and comparing pesticide-contaminated areas and ranges of disease vectors.

2. Monitoring Systems

Any good management strategy requires accurate and rapid information-feedback systems that have been specifically designed for the agro-ecosystem that is being managed. Public health workers need a variety of data to monitor different pest populations. In many cases, these pest populations are water-related (e.g., mosquito and blackfly vectors). Thus, it is particularly appropriate to develop monitoring systems that detect aquatic animal (and plant) kills and pesticide residues in the estuarine waters of the agro-ecosystem (NAS, 1975). Unfortunately, even the World Health Organization planning manual for malaria control does not explicitly state the need for continual monitoring of estuarine systems and vectors to detect the presence of pesticide residues, die-offs, or resistance in vectors (WHO, 1972).

Dr. Bruce Hammock, University of California, Davis, is developing two simple, rapid, and portable systems for analyzing pesticide residues. These systems are based on medical immunochemistry techniques (radioimmunoassay and ELISA) (personal communication, 1980). Currently, residue-analysis techniques depend on a slow, expensive, and complex process known as gas chromatography or require the use of gas-liquid chromatography equipment. Other kinds of non-quantitative monitoring systems (e.g., the purposeful collection of anecdotes about the effects of new pesticide technologies) are useful. Of course, any monitoring system is useless if data are not used to respond quickly and effectively to problems. The coordination of staff of the Ministries of Agriculture, Health, etc., is crucial to effect such responses. It is unfortunate that the critical details of an approach to coordination were not included in the 1973 recommendations.

3. Integrated Pest Management (IPM)

The development and implementation of effective IPM programs (NAS, 1969) are critical to strategies to prevent or delay the development of pest resistance. Implementation of an IPM program neither implies nor guarantees that fewer pesticides will be used in the agro-ecosystem, but an effective IPM program probably will result in the more careful use of pesticides. Metcalf and Luckman (1975) have defined IPM programs and prepared a list of seven general "tools of pest management." These "tools" are:

- Cultural methods, including the use of resistant varieties. "To the extent that insecticide and disease problems can be solved at the [crop] breeding stage, the need for pesticides can be substantially reduced" (NAS, 1976).

- Mechanical methods (trapping, exclusion, hand destruction, etc.).
- Physical methods (use and manipulation of heat, cold, humidity, etc.).
- Biological methods (use of natural enemies (predators, parasites, pathogens) and competitors, in addition to habitat management (Garcia and Huffaker, 1979), etc.). In recent years, considerable experimentation in the field has produced strong evidence that certain pesticides suppress populations of certain natural enemies of some pest species (NAS, 1976).
- Chemical methods (pesticides, insect growth regulators, etc.).
- Genetic methods (sterile insect-release techniques, competitive displacement, etc.).
- Regulatory methods (carefully monitored restrictions on the use of pesticides in agriculture where such pesticides are also part of public health pest control strategies).

The IPM strategist proceeds through a series of general steps to create an effective IPM system (Office of Technology Assessment, 1979). The strategist must:

- Carefully determine the purpose. For example, is the grower interested in maximizing profit or crop yield per unit area of land, or in sustaining yield production for several generations?
- Define the management unit (the agro-ecosystem), bearing in mind the environmental fallacy.
- Identify the pests and other species that are to be managed in the agro-ecosystem (life stages of economic importance, etc.).
- Establish the levels and thresholds of economic (or health) injury.
- Develop reliable techniques to monitor the pests in the agro-ecosystem (natural enemies, etc.).

- Develop descriptive and predictive models for pests and other species of concern.

Advanced pest management systems have been developed for the cotton agro-ecosystem in California (Toscano, et al., 1979). True integrated pest management systems are specific to given geographical locales. This means that for each agro-ecosystem and each pest of concern, a specific IPM program must be developed. Given the worldwide diversity of agricultural practices, which range from intensive monocultures to extensive and diverse forms of multiple cropping (Netting, 1974; American Society of Agronomy, et al., 1976), IPM planners and practitioners have much work to do. AID has begun work in this field (UC/USAID, 1976; USAID, 1977a).

4. Time-Streaming and Sequencing

Joy (1979) discussed the importance of viewing problems and systems in a timeframe or time-stream. These problems may be described as manifest problems (apparent at the moment) that adversely affect human beings; problems of an agro-ecosystem (and associated persons) at risk from probable immanent catastrophes (primary or secondary pest resurgence, flood, drought, etc.); and problems of trends in the number of agro-ecosystems (and their associated persons) at risk from such problems (e.g., how many new acres of land in Guatemala will be used for intensive cotton production?). Potential problems (which arise from changes in pesticide technology) may be categorized in such timeframes for use in planning and managing agro-ecosystems.

C. Management and Risk

Farmers cannot predict completely either the crop yield of the agro-ecosystem they are managing or the prices they will receive for their goods. They must, therefore, learn how to deal with uncertainty. Farmers, particularly subsistence farmers and small-holders in underdeveloped countries, are apt to behave in a way that would minimize risks. Strategies for risk-sharing/risk-spreading/risk-minimization are numerous (see Feder, 1979; Joy, 1965; the literature on economic and social anthropology is also useful). The small farmer who has received a technological package may minimize risk by maximizing (overusing) the amount of insecticide available for use on his crops. Thus, agricultural and public health planners might be interested in promoting strategies of risk-spreading (e.g., access to food supplements during famines; ready access to labor in times of severe labor shortages (during peak weeding or harvesting periods); guaranteed markets; greater access to credit and minimum interest rates). These strategies may help make the farmer and his household feel more secure and perhaps less inclined to maximize the use of insecticides. This hypothesis remains to be tested. It is conceivable that risk-spreading tactics would backfire under the pressure of economies of scale, market-economy expansion, efforts to sell pesticides, or efforts to maximize profits (cash). If the tactics fail, the use of pesticides might increase.

Conclusions

The resistance problem in *A. albimanus* populations in Central America is the only quantitative and well documented test of the original hypothesis of Hamon and Garret-Jones (1962, 1963), to the author's knowledge. Nevertheless, it seems logical that there will be within each agro-ecosystem populations of public health pests that may develop resistance to insecticides following agricultural spraying. The routes of selection for such resistance, be it selection primarily on the larval population (e.g., from runoff from irrigation water) or the adult population (e.g., from spray drift), usually has not, at least in the case of mosquitoes, been determined.* This information is needed to develop appropriate management strategies to control the development or prevent the amplification of resistance in pest populations.

A number of recommendations have been examined and additional management strategies have been proposed. AID should pursue these strategies, further refine the strategies now in use, and design other approaches to the problem. Although there is no solution to this or other such problems (the environmental fallacy; Churchman, 1979), regulation and management can and should be improved.

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* But see Fox, 1980.

IV. GENERAL ISSUES: HEALTH AND DISEASE AND RURAL DEVELOPMENT

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Large-scale development projects may have both positive and negative consequences. Examples of actual and possible negative consequences of some projects were discussed in the preceding chapters. Broader issues that have been discussed by many competent specialists are involved, however, and should be brought to the reader's attention. Among them are migration and labor, mobility, and resettlement.

Migration and Labor

The role of migrant workers in the distribution of schistosomiasis in the Sudan was mentioned earlier (see, for example, Anonymous, 1980b; Bella, 1980; Cheesmond, 1980; and Kellas, 1980). Migrant labor has played a role also in the spread of onchocerciasis throughout Brazil (Rassi, et al., 1976) and the Sudan (Abdalla and Abu Baker, 1975). Infected migrant workers were, it seems, responsible for an outbreak of malaria in Guyana in the early 1960s (Giglioli, 1963) and in Tamil Nadu, India (Dutta, et al., 1979). Other examples may be cited. Haddock (1979) has discussed the role of migration in the distribution of Chagas' disease in Latin America, and in a series of articles and books, R. Mansell Prothero, a geographer at the University of Liverpool, has thoroughly discussed the effects of human population movements and labor mobility on the incidence and prevalence of malaria (Prothero, 1961, 1965), trypanosomiasis (Prothero, 1963, 1972), and diseases in general (Prothero, 1973). Bradley (1968) has discussed the role of migrant fishermen in schistosomiasis transmission in East Africa.

The role of human movements in the Ethiopian trypanosomiasis epidemics of the late 1960s (Hutchison, 1971) was mentioned earlier. There are several general studies on the importance of human migration and its relationship to health and the health of migrant people. Velimirovic (1979) has discussed these "forgotten people." McKinley (1974) has discussed migration, health status, and the use of health services. He noted that one consequence of true voluntary migrations is a change in health services, though not health status. Involuntary migration usually results in a change in health status. Dutt and Baker (1978) studied Peruvian migrants and noted that the incidence of gastrointestinal and upper respiratory tract infections is higher among the migrants than among their non-migrant village counterparts. Teller (1973) described the problems that some migrants have had in gaining access to health care in a city in Honduras. The adaptations of migrants to illness (Hull, 1979) and nutrition-related problems (Freedman, 1973) in new environments have been reviewed. The U.S. Bureau of the Census (1977) has reviewed internal migration issues and policies in developing countries.

Resettlement

Often, resettlement poses problems. Resettlement problems associated with the Mwea irrigated rice settlement in Kenya (Chambers and Moris, 1973), the Volta Dam resettlement (Chambers, 1970), the Aswan Dam Sudanese Nubian resettlement (Dafalla, 1975), and the Zande resettlement scheme in the Sudan (Reining, 1966) have been discussed. More general discussions may be found in Chambers (1969) and Scudder (1968, 1973, 1975, 1980), who have studied river basin development and settlement. In their published works, these authors discuss briefly the impact of resettlement on health. Lengthy and specific discussions are difficult to locate. Warmann (1965) devoted an article to the health problems of settlers in the Volta Dam resettlement project. Other shorter discussions of the health problems of resettled peoples in river basin projects may be found in this paper.

The medical geographer McGlashan (1978) designed a theoretical framework for a systematic approach to disease and resettlement. Though an important issue, it has not been covered adequately in earlier research. Scudder (personal communication, 1980) believes little has changed. Specific, carefully disaggregated and longitudinal studies are needed to identify the beneficial and adverse health effects of resettlement programs on those who are resettled locally and on new lands.

Other Issues

Other issues in large-scale development projects are changes in the nutritional status of beneficiaries of projects (Fleuret and Fleuret, 1980); the disjunction of displaced peoples from traditional or modern health care systems; changes in life expectancy, educational and job opportunities, economic and social status; changes in women's roles and opportunities; the impact of projects on mental health and psychological distress; changes in the general social structure (limits to adaptation, cultural disintegration); and improvements in health and other social services. Each of these issues must be examined for its effect, if any, on the incidence and prevalence of communicable diseases among the beneficiaries of large-scale development projects.

V. INTEGRATED RURAL DEVELOPMENT

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Introduction

Integrated rural development projects often involve a variety of activities with the potential to lead to a deterioration of health: construction or repair of small dams and canals, tube wells, community and household standpipes, excreta and waste disposal units, roads, houses and other structures, and rural power plants. Theoretically, any one of these projects may pose hazards to the health and well-being of people who live in the area.

A. Water Management

Small as well as large dam sites (e.g., the dams being built in the AID Mandara Mountains Project, Cameroon) and canals can provide an environment for schistosomes, malaria vectors, and other disease-carrying organisms. If improperly chosen or managed, small water supplies, such as wells, may be the source of such local health problems as hookworm, typhoid, and cholera. In The Gambia, runoff that contains feces may contaminate unprotected well water, especially during the rainy season (Barrell and Rowland, 1979). Of course, such problems may be solved with various alternative sanitation and water management technologies (Feachem, et al., 1977; Mara and Feachem, 1980; McJunkin, 1970, 1975; and Saunders and Warford, 1976), and in fact have been handled well by DS/HEA.

B. Road Construction

The construction and use of rural roads, especially penetration roads, occasionally has had an adverse effect on human health. Pei-Yang (1945) has discussed the construction of the Burma Road in 1937-1939. Five hundred of 800 workers died during the project. Most of the deaths were attributed to malaria. A recent study (Devres, Inc., 1980) has linked African trypanosomiasis to road use. "Sleeve epidemics" of African trypanosomiasis occur when the tsetse fly, which carries the disease and is attracted to moving vehicles, "hitchhikes" rides in vehicles traveling along roads. The disease spreads from its native area (the shirt) along the road (the sleeve). In Liberia, along the Kissi road, passengers who stop for water at river crossings are sometimes bitten by infected tsetse that inhabit the river area (Abedi and Miller, 1964) and later develop trypanosomiasis. Among the Ashanti of Nigeria, the incidence of trypanosomiasis is highest along roads (Devres, Inc., 1980).

Pinheiro (1974) has discussed a program of surveillance and research on infectious diseases along the Trans-Amazon highway in Brazil. Davis (1977) has noted that the Parakanam, Kreen-Akasore, Yanomamo, and other Amerindian groups in the Amazon have been decimated by influenza, dysentery, measles, tuberculosis, and venereal and other diseases to which they were exposed after roads were built in their homelands. Ramos and Taylor (1979) have documented this finding. Bousfield (1979) is concerned that the continued construction of the Trans-Amazon highway will result in increased distribution of S. mansoni in Brazil via infected workers. Garnham (1976) has mentioned the problems of cutaneous leishmaniasis among Trans-Amazon roadworkers. The general environmental impact of this highway construction project is discussed in Goodland and Irwin (1975), Farnworth and Golley (1974), and Davis (1977).

Donaldson (1977) has written about the debate to complete the Pan-American highway. Some questions arose about the public health consequences of building the highway through Darien Gap to link Colombia with Panama. It is believed that foot-and-mouth disease would spread from South America to Central and North America, which are free of the disease, if the road were completed. The Ministry of Health in Liberia recently reported "an increase in water-related diseases, such as malaria and schistosomiasis, from standing pools of water along clogged road drainage areas" (Cobb, et al., 1980).

With AID funds, CARE and Sierra Leone initiated a series of projects to construct penetration roads. Anderson (1980) evaluated those projects. He noted in the initial environmental examination (IEE) that adequate drainage structures are needed to prevent permanent ponding of water along the sides of roads, which form favorable habitats for mosquitoes, tsetse vectors, and snails, the hosts of schistosomes. No changes in the incidence or prevalence of diseases have been noted. In a recent review of the socioeconomic and environmental effects of low-volume rural roads and the health benefits and problems associated with such roads (Devres, Inc., 1980), benefits were found to outweigh detriments.

C. Housing

Rural housing and other man-made shelters have been associated with certain communicable diseases. The classic urban example--the drastic decline in the incidence of tuberculosis (before drug therapy) following the improvement of housing--is described in McKeown (1976). In rural areas, where windows are unscreened and the condition of housing generally is poor, mosquito vectors have easy access to sleeping humans. Chagas' disease, which affects at least seven million people in Latin America, is often fatal. An acute or chronic parasitic infection (Trypanosoma cruzi), it is transmitted to humans by certain species of the bloodsucking conenose or Triatomine bugs. The bug vectors usually live in the crevices of homes with cracked floors and walls and thatch roofs, and bite at night. Two strategies usually are used to control the disease: residual insecticide spraying of dwellings (this also is done to control malaria) and improved housing (Cedillos, et al., 1980).

The African Tumbu fly (Cordylobia anthropophaga) passes through a bloodsucking larval stage, at which time it is known as the Tumbu floor maggot. It is known to reside on sandy floors of huts in tropical Africa. Ornithodoros moubata s. l., which causes tick-borne relapsing fever (Borrelia recurrentsis), is found in the Meru District of Kenya. The tick vector inhabits the earthen-floored huts and in this way transmits the disease to the dwellers (Walton, 1962).

Various fly pests and vectors are, of course, often found near poor, unsanitary housing. Outdoor shelters for livestock, poultry, or grain have been found to be good resting sites for such mosquito vectors as Anopheles gambiae and Anopheles funestus in Kenya (Clarke, et al., 1980) and Anopheles freeborni in California. Programs to improve housing, such as those funded by the AID Office of Housing, play an important role in efforts to alleviate Chagas' disease, malaria, and other health problems, although the site of new construction may become another locus for disease if the project is not managed properly and the shelter well maintained. Grain storage units that are not properly maintained may become the habitat of large populations of rodent pests, some of which may be part of a zoonotic disease cycle. Furthermore, if insecticides and rodenticides are not used or stored properly, persons in the grain storage areas may be exposed to dangerous poisons. The grains as well may be made inedible.

D. Electrification

In some areas, rural electrification programs (e.g., Kariba Dam in Zambia-Zimbabwe; Ord River Dam in Australia) have required the use of herbicides (Millington, 1975). In Australia, site of the Ord River project, there was concern that the use of significant amounts of herbicides would pose a hazard to human health. As of 1975, however, there had been no sign of adverse effects. Herbicides are used to destroy or inhibit the growth of weeds and other plants below transmission poles and power lines. They also are used for the same purpose along the shores of man-made lakes and canals. The safety of herbicides is a subject of increasing concern in the United States and other countries. One of the most controversial herbicides--2,4,5-T--was cleared for use in the United Kingdom (Hay, 1981), even though its long-term effects are not known.

The use of various commodities in integrated rural development projects may have implications for public health. Acute and chronic toxicity of pesticides, user safety, and safe disposal of pesticide containers may become problems. Any container or vessel, such as an abandoned barrel, a bottle or can, or even a discarded automobile tire, may become a resting or breeding site for Aedes aegypti and other mosquitoes.

E. Forestry: Deforestation, Afforestation, and Disease

In the last decade, deforestation and desertification have received much coverage in the international media and have been discussed exhaustively by the world's scientific community. Concern with these subjects is a response to the massive loss of human lives and livestock following the Sahelian drought. Deforestation, and even the penetration of tropical (especially moist) forests, may affect, both directly and indirectly, the status of public health. The presence of zoonotic disease agents, water availability and quality, the genetic diversity of plant life, and the ecology of man-made reservoirs may all be affected by deforestation.

As early as the 19th Century, it was believed that deforestation was responsible for the spread of the tsetse fly and trypanosomiasis in Sierra Leone (Dorward and Payne, 1975). Audy (1972) has stated that "excessive tree-cutting and hunting-out game, combined with cultivation of the cleared land and retention of narrow galleries of bush beside rivulets, bring tsetse flies into especially close contact with man and have encouraged recrudescence of trypanosomiasis" in the Ivory Coast.

Sylvatic yellow fever (YF), a zoonosis in the tropical Americas and Africa, is a constant threat to unvaccinated peoples. In 1960-1962, a yellow fever epidemic swept through southwestern Ethiopia, leaving 3,000-30,000 dead and 100,000 ill with the disease. This epidemic occurred after a deforested area was replanted with false banana trees which harbored the larvae of a yellow fever vector, Aedes simpsoni (Brès, 1972). Brès (1972) noted that "it appears that in Africa a permanent unrecognized endemic activity of yellow fever in forests tends to produce episodically large outbreaks, principally in savannah areas during the rainy seasons." Cooper and Tinsley (1978) mentioned that yellow fever accompanies the exploitation of tropical rain forests. They found also that the virus known as Kyasanur Forest Disease (KFD) occurs often in deforested areas. This virus is a zoonosis transmitted by ticks to forest workers and wood gatherers in Mysore, India.

Audy (1961) coined the phrase, "man-made maladies," to describe the diseases discussed in this paper. He spent many years studying the epidemiology of scrub typhus, a mite-transmitted rickettsial disease common in Asia. Humans contract this disease while penetrating scrub forests. Seven hundred fifty cases were reported in British troops training in the scrub forests of Sri Lanka in 1943 (Audy, 1961).

Cutaneous leishmaniasis (Garnham, 1976) and other diseases have become problems for workers and settlers in the Amazon forest (Bousfield, 1979; Pinheiro, et al., 1974). Indeed, in parts of Central America cutaneous leishmaniasis, which is transmitted by infected sand flies, is a common occupational hazard among woodcutters and rubber tree gum collectors. It is known as "Chicle's, or gum collector's, ear" because the flies often bite the ear, and it is there that the disease first appears.

The resurgence of malaria in Sri Lanka in the late 1960s has been linked to persons who farmed small chenas (agricultural hamlets) or dug for gems in the forests, became infected, and returned to areas recently freed of malaria (Gabaldón, 1972; Senanayake, 1977). Audy (1961) observed in Malaysian forests that were partly converted for agricultural use a change in the original forest population. Of the 70 species of rodents and shrews in the original population, 20 species remained after conversion. In addition, five new rodent pests and disease-harboring reservoirs appeared.

Much of the research on the effects of deforestation and other agricultural activities which change landscapes has been done by the Russians and East Europeans. In fact, they have devoted an entire volume to the subject, Theoretical Questions of Natural Foci of Disease (Rosicky and Heyberger, 1965). This document describes changes in the distribution, incidence, and prevalence of plague, tick-borne encephalitis, tularemia, Q fever, various mosquito- and tick-borne viruses, African trypanosomiasis, and onchocerciasis. The Russian, E. N. Pavlovsky, has named these studies "landscape epidemiology," or "the theory of the natural focality of infectious diseases." They combine epidemiology and medical geography. Hoogstraal (1972) also has described the influence of human activity on tick distribution, density, and tick-borne diseases.

Deforestation can affect adversely water availability and quality. Changes in the microclimate and local weather patterns may create a more arid environment. Deforestation in the Amazon Basin and elsewhere has led to the breakdown of the moisture-cycling system and is expected to affect world weather patterns (Farnworth and Golley, 1973; Goodland, 1980; Meggers, et al., 1973; Myers, 1979; Spears, 1979). Any reduction in the quantity of water will probably be followed by a reduction in the quality of surface waters (if not groundwater), concentrating whatever contaminants already exist.

Tropical moist forests in particular are the source of many botanically-based drugs (e.g., quinine, the first anti-malarial drug made from the bark of the cinchona tree, which thrives in Andean forests) which are used today by modern physicians and traditional healers alike. Deforestation has negative effects on the genetic and species diversity of plants with known beneficial pharmaceutical properties. It will become more difficult to justify the loss of these and other resources through deforestation as problems with transferable drug resistance increase, as petrochemicals (the source of many drugs today) become scarcer, and as the world's population expands.

Deforestation around the edges of a man-made lake usually increases soil erosion, and as the soils run off into the lake, the rate of siltation increases, making proper operation of the dam more difficult. The rate of lake eutrophication may also increase, producing a nutrient-rich environment for aquatic plant growth, some of which may become food or provide shelter for mosquito larvae or molluscan intermediate hosts of schistosomiasis (Ackermann, et al., 1973; Brown and Deom, 1973).

Afforestation is undertaken to recover denuded areas. A tree crop or other crop system must be chosen with care so that an environment suitable for insect vectors is not created. In Ethiopia, false banana trees were planted which harbored the *Aedes simpsoni* larvae. The result was a massive yellow fever epidemic (Brès, 1972).

Part Two

CASE STUDIES

Case Studies A

WATER RESOURCES DEVELOPMENT AND SCHISTOSOMIASIS

SCHISTOSOMIASIS AND THE LAKE NASSER PROJECT, THE NILE RIVER BASIN AND DELTA, AND THE SADD-EL-AALI (HIGH ASWAN) DAM, EGYPT AND THE SUDAN

The Nile River, 6,825 kilometers in length, is the longest river in the world. The system actually begins in two separate areas and is divided into the Blue Nile and White Nile. The equatorial lakes (particularly Lake Victoria) in Zaire, Uganda, Tanzania, and Kenya are the principal sources of water for the White Nile. The drainage of rainfall from the Ethiopian Plateau combines to create the Blue Nile. The two rivers meet at Khartoum, Sudan, where the main Nile River begins, and flows northward through Egypt, ending in the Mediterranean Sea. (Details on this river system may be found in Waterbury, 1977).

Paleolithic humans inhabited the Nile Valley at least 10,000 years ago (ca. 8,000 B.C., the so-called eotechnic era). They relied on hunting and gathering for their survival (Hamdan; see Waterbury, 1977). About 3,000-5,000 B.C., the first agricultural epoch (the geotechnic era) began as village settlements were established on the raised sand-and-gravel "tortoise-backs" of the flood plain of the Nile Delta (Hamdan; see Waterbury, 1977). It is conjectured that in the geotechnic era people created temporary earthen dikes in the natural basins scooped out by the annual flood to seasonally irrigate their broadcast-sown cereal seeds, among which were barley and wheat (Hamdan; see Waterbury, 1977).

Eventually, a supra-village authority took power, and, by 3,400 B.C. (the Paleolithic epoch), groups of villagers in the Delta had begun to dig off-take canals from the main Nile during the annual flood (August-October). The canals were used to capture flood water in adjacent large basins. The basins held water for 40-60 days. Excess water was drained off, and a crop was planted in the water-saturated soil by mid-October or early November. The crop grew through the temperate winter months and was harvested during the dry, hot spring and summer.

During the neotechnic era, agricultural production in Egypt advanced when people learned how to store water through the dry season and to use that water during the summer months to grow a second season of crops, including cotton, maize, and rice. Two phenomena favored this development: aquifers and a high water table which extends from the Nile Delta through Upper Egypt. These allowed for wells that drew groundwater (using an Archimedes screw) and made perennial irrigation possible (Willcocks and Craig; see Waterbury, 1977). The Egyptian Twelfth Dynasty stored floodwater from the Nile in Lake Moeris and the Fayyum Basin (about 10 kilometers south of Cairo). This water was captured in the offtake canals and redelivered to the Delta during the dry months (Waterbury, 1977). Such perennial irrigation systems, particularly the canal-basin systems, were few and scattered in Egypt until about 150 years ago. In the early 1820s, barrages (low dams) were built on the main Delta canals, and new canals were dug and deepened, all to produce cotton for the Ottoman Empire, which was then ruling Egypt (Farooq, 1967; Waterbury, 1977). It was in that decade that most of Egypt's cultivable area was converted to perrenial irrigation. This culminated in the complete cessation of downstream flooding (below Aswan) in 1964 following the construction of the Aswan High Dam. From the 1820s onward, barrages were built at Aswan, Esna (Isna), Naga Hammadi, Assiut, and in the Delta. By the 1930s, most of the Delta and areas south of Cairo to Assiut were perennially irrigated (Miller, et al., 1978). The first major perennial irrigation scheme was built in the late 1800s. It was located at the very northern end of the Delta, between the towns of Rosetta and Damietta (Miller, et al., 1978).

Schistosomiasis has probably been in existence in Egypt for 4,000 years. Bloody urine (haematuria), one of the signs of human infection with S. haematobium, was reported in the Egyptian papyrus of Kahun, circa 1900 B.C. (Farooq, 1973). Bruijning (1971) has suggested that, as a parasitic disease, schistosomiasis originated in the equatorial lakes region of East Africa. It is not known how it spread to Egypt. The White Nile also originates in the same region. Both humans and birds, which may transport the snail hosts of schistosomiasis on their muddy feet, may have migrated from the area, carriers of the disease.

Ruffer (1910) discovered the calcified ova of S. haematobium in the Twentieth Dynasty (1250-1000 B.C.) mummies from the Nile Valley, 59 years after Theodore Bilharz first discovered S. haematobium in Cairo, and five years before Leiper (1915) discovered, also near Cairo, that Bulinus snails were the intermediate host of the same parasite.

French armies, led by Napoleon, invaded Egypt in 1799-1801 and reported haematuria among the troops (Miller, et al., 1978). In the late 1800s, one in three patients in the Cairo hospital was recorded as having schistosomiasis infections. Thus, schistosomiasis has been a consistent, if not widespread, and serious problem for Egyptians for many centuries.

Orpen (1915) was the first person to associate the geographic extent of surface water with schistosomiasis transmission levels (see Schiff, 1972). Leiper (1915) was the first person to mention the relationship between the expansion of irrigation systems and the dispersal of schistosomiasis. Khalil (1927) and Khalil and Azim (1935, 1938) were the first scientists to show conclusive evidence that perennial irrigation schemes can grossly "enhance [the] transmission" of schistosomiasis (see Miller, et al., 1978). They demonstrated that the prevalence rate of S. haematobium in persons from four different villages in Kom Ombo, Upper Egypt, increased at least sevenfold (to 44-fold) three years after irrigation canals and pumps were installed, but in nearby villages which continued to use only flood-recession irrigation the prevalence rates did not change (see Miller, et al., 1978). Barlow (1937) carried the work of these scientists a step further. He observed a correlation between different kinds of irrigation in Egypt and changes in the incidence of schistosomiasis (see Van der Schalie, 1972).

Since 1910, much has been written about schistosomiasis in Egypt, and about the Aswan High Dam in relation to schistosomiasis in particular. In other parts of Africa and in Asia, evidence has been collected which correlates the presence of large man-made dams and lakes with increases locally in the incidence, prevalence, or distribution of schistosomiasis. The question is, are there similar correlations between the Aswan High Dam and Lake Nasser for people who live in the Nile Valley below Aswan or in the areas surrounding the shores of Lake Nasser? Why or why not?

The idea for the Aswan High Dam was conceived in the early 1900s. By 1902, a dam had been built at Aswan, however. This first dam, the Old Aswan Dam, was built during the British occupation of Egypt (which began in 1882) for "over-year" storage of water to irrigate summer crops. The height of the Old Aswan Dam was raised twice, in 1912 and 1933 (Waterbury, 1977). Even before the dam was constructed, the Egyptians had begun to construct two main barrages immediately north of Cairo (1843-1861; during the French occupation). The British repaired and renovated these Mohammed Ali barrages in 1882 (Waterbury, 1977). Other barrages were built north of Aswan. These were Assiut Barrage (1902), Zifta Barrage (1903), and Edfina (Ed Fina) Barrage (1951) (Waterbury, 1977). Associated with the Old Aswan Dam and these barrages were at least six major permanent canals: Ibrahimia, Bahr'-al-Yussef, Ismailia Sweet Water, Tewfiqia, Beheira, and Menoufia (Waterbury, 1977). This system of dam, barrages, and canals was used to convert much of the Upper, Upper-Middle, and Lower Nile River Valley and Delta to perennial irrigation. This was accomplished by the 1930s. (The Lower Nile Valley extends from Cairo north to the Delta and the Mediterranean Sea; the Upper-Middle Nile Valley extends from Assiut north to Cairo; and the Upper Nile Valley extends from Aswan north to Assiut (Miller, et al., 1978).)

Miller and his colleagues (1978) gathered their own data and critically reviewed the data reported by 21 different groups of authors on the incidence and prevalence of S. haematobium and S. mansoni in Egypt from 1935 to 1977.

In the Nile Delta, the prevalence of schistosomiasis "has always been high, probably for almost a century, increasing at the time the delta was converted to perennial irrigation [in the late 1800s]" (Miller, et al., 1978). Interestingly, the prevalence of S. haematobium declined from 53 percent in 1937 to 46 percent in 1955 to 30 percent in 1966 and to 30 percent in 1976. In general, the prevalence rates of S. mansoni have declined, from 54 percent in 1935 to 31 percent in 1955 to 29 percent in 1966, and, in one area of the Delta, to 20 percent in 1976 (Miller, et al., 1978). The Nile ceased to flood downstream from the Aswan High Dam in 1964. Between 1965 and 1975, the prevalence rate for S. haematobium in the Delta continued to decline, but the prevalence rate for S. mansoni apparently rose during the same period in other areas of the Delta (El Zemeity; see Stek, 1979).

Because infections with S. haematobium outnumber infections with S. mansoni, one can say that, in general, the overall prevalence rate for schistosomiasis has been declining in the Delta since the 1930s. But it is more useful to consider individually the different species of schistosome parasites.

There is evidence that S. mansoni is increasing in prevalence in the south-central Delta, in the Qualyub region (Alamy and Cline, 1977), and in the Gharbia region of the middle Delta (Abdel-Wahab, et al., 1979). Although they agree that S. mansoni infections are "very probably changing in their pattern of distribution and prevalence," Miller and his colleagues (1979) think that it is too early to conclude firmly that the studies of Alamy and Cline (1977) and Abdel-Wahab and others (1979) (nine villages were studied) represent a firm trend for the Delta as a whole. Their conclusion is based on their own sample of seven villages in the Delta in the 1970s, which indicated that S. haematobium infections still outnumber S. mansoni infections (Miller, et al., 1978, 1979), and the work of Scott (1937), Farooq (1957), and Farooq and his colleagues (1966), which indicated that there is a substantial amount of variation in the patterns of human-water contacts and relative infection rates from village to village. The studies also indicated that local irrigation patterns contribute to variations in populations of snail species (snail ratio of Bulinus to Biomphalaria) which, in turn, affect relative infection rates among humans.

Various authors (Alamy and Cline, 1977; Abdel-Wahab, et al., 1979; Malek, 1975; Stek, 1979) have suggested that the hydrology and ecology of the Nile River below the Aswan High Dam have changed because of the presence of the dam, and that this change created conditions which favor the snail host for S. mansoni (Biomphalaria alexandrina) over the snail hosts for S. haematobium (Bulinus truncatus). However, for the reasons stated above, and because human behavioral and other factors (domestic water supply, latrine usage, human-water contact patterns) may influence observable differences, Miller and his colleagues (1978) have concluded that "a fuller understanding of the life cycle and biology of the parasite is necessary before conclusions can be drawn about how the construction of the dam may be affecting the distribution and transmission of S. mansoni."

Concern about the possible spread of Biomphalaria and S. mansoni to other parts of Egypt is warranted, as the above authors would affirm. Indeed, Miller and his colleagues (1978) have recorded a possible focus of S. mansoni infection in Beni Suef, south of the Delta, but below the Aswan High Dam. Natural S. mansoni infections in Egypt are found at this time below the dam in the Delta only. All other cases occur when an individual becomes infected with S. mansoni in the Delta but moves to another locale where the infection is subsequently diagnosed (Miller, et al., 1978).

The Upper-Middle Nile Valley comprises the area south of Cairo to Assiut, which includes the governorates of Giza, Fayum, Beni Suef, Minya, and Assiut (Miller, et al., 1978). The changes in prevalence of the two species of schistosomes in this area were critically reviewed by Miller and his colleagues (1978). In 1935, the prevalence rate for S. haematobium infections in 12 villages varied from 60 percent to 80 percent; that for S. mansoni varied from 0 percent to 17 percent (Azim, 1935; see Miller, et al., 1978). Scott (1937; see Miller, et al., 1978) recorded in different areas during the same year no S. mansoni, but the prevalence of S. haematobium ranged from 41 percent to 90 percent, with a mean of 60 percent. In 1955, the Egyptian Ministry of Public Health (EMPH) made a survey that revealed a 32 percent prevalence rate for S. haematobium for the entire area; prevalence had declined in each governorate since 1935 (EMPH, 1955; see Miller, et al., 1978). Zawahry (1962; see Miller, et al., 1978) took a random sample of children in the area in 1955 and recorded a 25.9 percent prevalence rate. In 1970, Abdallah (1973; see Miller, et al., 1978) surveyed the village of Shanbari in the Giza Governate; he found that the prevalence rate of S. haematobium was 31.2 percent.

In the Fayoum area of the Upper-Middle Nile Valley, the prevalence rate for S. haematobium was between 67 percent and 84 percent in 1935 (Scott, 1937). In 1949, Khalil (1949; see Miller, et al., 1978) found a 65.1 percent prevalence rate for children aged 2-6 years. In 1968, only 45 percent of the entire Fayoum population were infected with S. haematobium. A schistosomiasis control program was begun in Fayoum in 1968 in cooperation with the German Federal Republic. Because of that program, the prevalence rate declined to 8.1 percent in 1975 (Mobarkic, 1975; see Miller, et al., 1978).

The Upper Nile Valley of Egypt includes the area between Assiut and the Old Aswan Dam (near the site of the Aswan High Dam) and the Kom Ombo Plain. Except in the Kom Ombo Plain, inhabitants of the Upper Nile area practiced basin irrigation in the 1930s. At that time, the overall prevalence rate of S. haematobium in the Upper Nile Valley was approximately 5 percent. Khalil and Azim (1935, 1938) recorded a change in the prevalence of S. haematobium infections--from 0-11 percent in 1934 to 44-75 percent in 1937--as a result of the conversion of the Kom Ombo Plain from basin to perennial irrigation. Different authors who have been critically reviewed by Miller and his colleagues (1978) have recorded an increase in prevalence of S. haematobium (e.g., Assiut, 30 percent; Idfu, 75 percent; Aswan, 32 percent) between 1935 and the 1970s. Because of epidemiological errors in the designs of the surveys and in the analyses of the data (e.g., samples were not adjusted for age and gender, self-selection, and high non-response rates), Miller and others (1978) concluded only that S. haematobium infections indeed increased in prevalence in the Upper Nile Valley between the 1930s and the 1970s and that these increases are associated with the expansion of perennial irrigation systems, but not the Aswan High Dam alone. Exact figures and the dates of these increases are unknown.

The Nubia region of Egypt once comprised the area along the Nile Valley from the Old Aswan Dam south to the Sudanese border. It is now inundated by Lake Nasser. Approximately 50,000 people from three separate tribes inhabited the area until 1964 (Miller, et al., 1978). Apparently, they practiced flood-recession cultivation along the banks of the Nile, and, like their kin, the Sudanese Nubians to the South, they used a water-wheel-and-bucket irrigation method to draw water from the Nile at high water (Dafalla, 1975). In 1964, these Egyptian Nubians were resettled in the north, in the Kom Ombo area of the Upper Nile Valley (immediately north of the town of Aswan and the Aswan High Dam) because the rising waters of Lake Nasser had flooded their villages. This resettlement site, an almost exact, though compressed, version of their former home, is called Egyptian New Nubia (Miller, et al., 1978).

In 1964, immediately before resettlement and the filling of Lake Nasser, the prevalence rate for S. haematobium among Nubians was 15.2 percent (Zawahry, 1964; see Miller, et al., 1978). By 1972, the prevalence rate among Nubians who had been settled below the High Dam and in an area of perennial irrigation was 19 percent, according to Dazo and Biles (1972; see Miller, et al., 1978). By 1976, the prevalence rate among Nubians in the villages studied by Zawahry in 1964 (all are now in New Nubia) had declined to 7.2 percent (Miller, et al., 1978). Thus, the results of the only carefully controlled and matched set of studies of a group of people affected by the dam (i.e., the studies of Zawahry, 1964, and Miller, et al., 1978) indicated that S. haematobium prevalence among Nubians actually declined after its construction.

Given the results of these studies, we cannot attribute the increased prevalence of S. haematobium to the construction and presence of the Aswan High Dam. But, because perennial irrigation systems have been clearly correlated with the geographical spread or increased prevalence of schistosomiasis in Egypt and elsewhere, we must ask why the Aswan High Dam, which certainly enhanced the spread and use of perennial irrigation in Egypt, did not simultaneously increase the prevalence of S. haematobium in dwellers below Aswan.

Fortunately, Miller and his colleagues (1978) have an answer to that question. Several factors contributed to the decline in prevalence: improvement in the supply of rural domestic water (convenient standpipe water was supplied; its use was shown in Miller's study); changes in irrigation practices following relocation (in the new villages, the government allowed Nubian villagers to own land (the usual practice was renting or sharecropping), which meant they could, and did, hire other local people, saidies (Upper Egyptians), to till and tend the irrigated fields); strategic construction of new villages at a distance from the canals and fields of the Kom Ombo Plain; and construction of schools, clubs, social centers, electricity, and rural health units and centers at resettlement sites so that health education and health services could be provided (Miller, et al., 1978).

In the Sudan, another 50,000 Sudanese Nubians were left homeless following the flooding of Lake Nasser. The Sudanese government, in cooperation with the World Health Organization, followed Egypt's lead and, using similar measures, apparently reduced the prevalence of schistosomiasis in the displaced Sudanese Nubians. These Nubians were moved from the area near the riverbank of the Wadi Halfa, where Egypt borders Sudan, southeast to resettlement sites in Khashm-el-Girba (Dafalla, 1975). There, a health team set up centers in new villages. Every person received a medical examination. Cases of parasitic diseases were diagnosed and treated continuously ("Bilharzia cases were given special attention"), and a program to clear the riverbank and to control the snail population was instituted along the Atbara River (Dafalla, 1975).

The construction of the Aswan High Dam began in 1960 (Farid, 1975). By 1964, water had begun to fill in behind the dam, creating Lake Nasser. The dam was completed in 1970; the lake had filled completely by 1975 (Miller, et al., 1978). Lake Nasser is 500 kilometers long. It covers approximately 7,000 square kilometers (Farid, 1975; Heyneman, 1978).

Between 1970 and 1974, four separate WHO teams studied the presence of schistosomes in the lake and the prevalence of schistosomiasis among lakeshore dwellers. Scott and Chu (1974) reviewed and summarized these studies. The population of transient fishermen who lived along the shores of the lake was 3,000-5,000. Infection rates for S. haematobium varied from 29 percent to 77 percent. The only permanent group of lake shore settlers, those at Abu Simbel temple, showed a prevalence rate of only 9 percent (Scott and Chu, 1974). Bulinus truncatus snails, the intermediate host for S. haematobium, were found at numerous sites in the lake. Infected snails were found only near the dam itself (Scott and Chu, 1974). Lake surface vegetational growth is increasing, creating a more favorable environment for the breeding and growth of snails (Scott and Chu, 1974). The Department of Health of Aswan Governorate has since established a treatment clinic at Aswan for the lake fishermen. The government may impose more health regulations on these fishermen (Scott and Chu, 1974). Any future settlers along the shores of the lake are certainly at risk of infection (Scott and Chu, 1974).

In sum, contrary to expectations (see van der Schalie, 1972), the prevalence of S. haematobium below the Aswan High Dam has not increased since the construction of the dam. However, there is evidence that the presence in Egypt of earlier (1800s, 1900s) perennial irrigation systems contributed to the geographical spread and increased prevalence of S.

haematobium in particular. In the absence of intervening factors, one can reasonably assume that the prevalence rates for S. haematobium would have increased as more lands were converted from basin or flood-recession agriculture to perennial irrigation systems. In Egypt, however, there have been numerous intervening factors that have combined to contribute to the decline in prevalence of both S. haematobium and S. mansoni.

From the 1940s until 1959, the environmental services branch of the Egyptian Ministry of Health provided protected rural water supplies (groundwater standpipes on a cement slab) to all villages with populations over 1,200 (Miller, et al., 1978). By 1975, almost all villages in Egypt had at least one protected source of water. Latrine programs were less successful (Miller, et al., 1978). Miller and his colleagues (1978) collected data that show a decrease in the prevalence of schistosomiasis following improvement in the quality of the source of drinking water. Fewer people have probably had to visit canals or other unprotected water sources as a result.

Many areas where water is used for bathing. laundry, and the care of domesticated water buffalo are the sites of infection of persons in contact with the contaminated water. Particularly since the work of Farooq and Mallah (1966) studies of the relationship of persons to water contact have been recognized as critical to any schistosomiasis control program. Accordingly, the United Nations Development Program (UNDP), The World Bank, and WHO have held joint workshops and supported research on this subject (see Annual Reports of UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases). Since 1949, WHO has helped operate various schistosomiasis control programs in Egypt. Among these programs are the Fayoum project (1958), the Egypt-49 project, and the Egypt-10 project (Sandback, 1975; Hoffmann, et al., 1979).

Changes in irrigation practices, such as those instituted by Egyptian Nubians, result in the reduced contact of certain population groups with water. These changes have been correlated with decreased prevalence, as has the strategic placement of villages at a distance from canals and irrigated fields. These interventions will work only if a safe, convenient domestic water supply exists. A safe supply of water and appropriate primary health care systems and vertical schistosomiasis control programs (McCullough, 1980) have contributed to the slow decline in the prevalence of S. haematobium in Egypt's Nile Valley since the 1950s.

Through its own efforts, and in conjunction with various U.N. agencies (WHO, UNDP) and multilateral and bilateral organizations (e.g., USAID, IDRC, World Bank) rural Egypt's primary health care system has expanded significantly (Nadim, 1980). By the late 1970s, Egypt had constructed 2,140 rural health units and centers. The availability of pharmaceuticals had improved and "the general awareness by the population at risk of how to avoid infection and how to get treatment [via health education efforts]" increased. All these factors have contributed to the decreased significance and prevalence of S. haematobium among rural Egyptians (Miller, et al., 1978).

An estimated 6.9 million rural Egyptians (1978) are infected at this time with one or both forms of schistosomiasis (Miller, et al., 1978). Population growth (Miller, et al., 1978) and internal and international labor migrations (Waterburg, 1979; Kellas, 1980; Richards, 1980) compound the health problem. It is not known what future trends of S. mansoni and S. haematobium will emerge in Egypt.

SCHISTOSOMIASIS, THE MIDDLE ZAMBEZI RIVER BASIN, LAKE KARIBA, AND THE KARIBA DAM, ZIMBABWE AND ZAMBIA

The history and development of Lake Kariba and the Kariba Dam are documented in a series of papers by Ackermann, et al. (1973), Austin (1968), Balon (1978), Scudder (1972, 1980), and Webster (1975). The idea of a dam on the Kariba Gorge of the Middle Zambezi River was first proposed in 1912 (van der Lingen, 1973). The planning and construction of the dam began in 1955. The site was Kariba Gorge, between Zambia and Zimbabwe. The purpose of this £80 million dam, which was originally intended for irrigation, was to produce hydroelectric power (Webster, 1975). A new lake, Lake Kariba, was created behind the dam. It began to fill in 1958 and reached its maximum size in 1963 (Scudder, 1972). Lake Kariba now covers 55,000 square kilometers and is 280 kilometers long (van der Lingen, 1973).

What is now the lake's floor was once inhabited by 57,000 agro-pastoral peoples, the Tonga, and their cattle and goats. The Tonga grew sorghum, tobacco, and corn (Scudder, 1972; Webster, 1975). Most of these people and the smaller Kore-Kore tribes were resettled along the shore of the new lake in 1957 (Webster, 1975). In the new settlement areas, one hospital and a chain of clinics were built to serve the Tonga, the Kore-Kore, and the 13,000 workers brought in to build the dam (Webster, 1975). Although 233 boreholes were dug in the area to supply the workers and others with safe household water, the water supply and sanitation remained poor. Fly-borne intestinal diseases were among the several major health problems of the workers (Webster, 1975). Webster (1975) mentioned that the Tonga and Kore-Kore suffered from hyperendemic malaria, yaws, smallpox, trypanosomiasis, Bancroftian filariasis, and *Acanthocheilonema perstans* infections. It is his opinion that the health status of these tribes and of the dam workers actually improved, at least for a time, after new medical services were brought to the area.

Schistosomiasis became a problem for some lakeshore dwellers and people who lived nearby. Swept in from tributaries, the floating water fern *Salvinia auriculata* invaded Lake Kariba. It adapted well; the fern mats over approximately 15 percent of the lake's total surface of 55,000 square kilometers and harbors and transports snail hosts of *Schistosoma* (van der Lingen, 1973). Webster (1975) noted that there were no schistosomes in the Zambesi River, but the tributaries were cause for concern. He stated that the inlets and backwaters of Lake Kariba became "heavily infested" with infected snails and that in one area unique human infections became so severe that the problem came to be known as "Katayama syndrome" (Webster, 1975). Van der Lingen (1973) also noted that the host snail populations (*Bulinus globosus* and *Biomphalaria pfeifferi*) increased between 1964 and 1967, particularly in bays and inlets, where transmission to people was "serious." Heyneman (1978) observed another species of host snail, *Bulinus* (*Physopsis*) *africanus*, on the water fern *Salvinia* in the lake. Bulinus globosus and Biomphalaria pfeifferi usually were found less than five meters from the lake's shoreline (van der Lingen, 1973).

Scudder (1972) found that inadequate medical research had been done in the lake area before, during, and after construction of the dam to de-determine specific prevalence rates. In 1959, Blair (see Wright, 1973) recorded prevalence rates for S. haematobium. These ranged from 2.3 percent to 8.8 percent (mean, 6.8 percent). Among those who had resettled along the north bank of the Zambesi, upstream from Kariba, the prevalence rates for S. mansoni ranged from 0 percent to 16.2 percent (mean, 2.4 percent). The author could find no data for the period 1960-1968. Van der Lingen (1973) believed that, before 1964, the rising and fluctuation of the lake waters "inhibited" the snail intermediate hosts. In 1968, Hira (see Wright, 1973) found that, on the lake itself, the rates for S. haematobium ranged from 4 percent to 56 percent among schoolchildren. In the same study, he noted a transmission focus of S. mansoni at Siavonga, on the lakeshore; overall prevalence rates ranged from 0 percent to 17 percent. Among schoolchildren the rate was 15.6 percent (see also Heyneman, 1978). Between 1959 and 1968, it appears that prevalence rates for both species increased slightly. Unfortunately, the available studies are not comparable epidemiologically. It is clear that both species of parasites and their snail hosts invaded the new lake shore, thus extending their range.

Van der Lingen (1973) mentioned that the Ministry of Health is providing hygiene education and spraying shorelines with molluscicides where the incidence of contact with water is high. These actions, in addition to the limited health care available near the lake's shore, may help restrict the significance of schistosomiasis to the Tonga and other lakeside dwellers. Scudder (1980) mentioned that those who live below the dam are experiencing declines in farm production and fishing. In part, these increasingly serious problems have arisen because downstream flooding no longer occurs.

SCHISTOSOMIASIS AND THE VOLTA LAKE PROJECT, THE VOLTA RIVER BASIN, AND THE AKOSOMBO DAM, GHANA

A detailed discussion of the relationship between the Volta Lake project and schistosomiasis and other problems may be found in Ackermann, et al., (1973), Biswas (1973), Chambers (1970), Donaldson (1977), Evans and Vanderpuys (1973), Hart (1979), Hughes (1972), Jones (1973), Joubert (1972), Kalitsi (1973), [illegible] (1967), Obeng (1973, 1975), Paperna (1970), Rosenfield (1979), Steel (1968), Taylor (1973), Volta River Preparatory Commission (1956), Warmann (1965), Webbe (1972), and White (1972).

In 1915, the Government of the Gold Goast had an idea to commercially produce aluminum from bauxite (Hart, 1979). Because much electricity is needed to process the ore, the government decided to construct a dam. The work began in 1962. Volta Lake itself began to form in 1964. It now covers approximately 8,400 square kilometers and is approximately 400 kilometers long. It has a shoreline of approximately 6,400 kilometers (Obeng, 1975). The entire project (including construction, resettlement, and roads) cost approximately U.S.$134 million (Rosenfield, 1975). AID was one of the several agencies that financed the loans for the project. Approximately 80,000 persons in 700 villages were displaced by the rising lake waters; of these 80,000 persons, 65,000 apparently chose to move into new planned government settlements (Kalitsi, 1973; Rosenfield, 1979).

Preliminary disease-control studies began around 1950 (Berner, 1950; Macdonald, 1955), and the Volta River Basin Authority was established in 1961 to research the anticipated public health problems (Rosenfield, 1979). For the first time, public health concerns were raised before a dam project began.

In most, but not all, areas of the basin the prevalence rate for *Schistosoma haematobium* was between 1 percent and 8 percent in the preproject period (Macdonald, 1955; Paperna, 1970). Today, however, schistosomiasis is the most prevalent disease among those who live in the basin; more than two million persons are infected (Rosenfield, 1979). Among lakeside villagers, the average prevalence rate is 75 percent. Among local fisherpeople the prevalence rate is 100 percent in children aged 0-14 years (Rosenfield, 1979). Obeng (1973, 1975) mentioned that the "incidence of schistosomiasis" in children is higher (90 percent) on the western side (shallow shore) of the lake than on the eastern side (steep shore), but it is not clear whether Obeng is referring to an incidence rate or to a prevalence rate. Webbe (1972) recorded a 90 percent prevalence rate two years after the project had begun and the lake had been filled.

Schistosomiasis was not introduced to the local Ghanaian people at the time the lake was created. Obeng (1975) asserts that populations of certain species of aquatic plants had increased significantly by 1968 and that mats of vegetation containing snails of unspecified genera and snail eggs had spread over the lake. *Biomphalaria pfeifferi*, a snail intermediate host of the more pathogenic Schistosoma mansoni, recently was found in the Dayi River, which drains directly into Lake Volta (Obeng, 1975).

Rosenfield (1979) developed a model for schistosomiasis that is based on real data. This model predicted that the prevalence rates at Lake Volta would change from an initial mean rate of 5 percent (pre-construction) to 98 percent (post-construction) by the end of the second year (1969) and that the 98 percent rate would remain constant until the ninth year (1976), when it would begin to decline slightly (see Rosenfield's (1979) Stage II model forecast for Lake Volta). Rosenfield's model has closely matched reality.

Since the early 1970s, WHO and the UNDP have been operating a control program for schistosomiasis at Lake Volta (Hoffman, et al., 1979). A serious problem, the transmission of S. haematobium has been found to be both seasonal and highly focal around the lake (Hoffman, et al., 1979).

In 1964, Kaiser Foundation International established the VALCO (Volta Aluminum Company) medical service in Tema, Ghana, to serve all employees of the company and, later, their families (Joubert, 1972). This medical service has passed through three phases (Joubert, 1972). In Phase I, which lasted from 1964 to 1967, workers who had been injured on the job were treated. During Phase II, non-occupational health care was provided. This phase lasted from 1967 to 1970. The third phase began in 1970. Since then, all dependents of VALCO employees have received health care. Approximately 8,000 people receive non-occupational health care. Included in this category of health care are treatment for schistosomiasis and the prevention or treatment of several other communicable diseases (malaria, pneumonia, shigellosis, typnoid, hepatitis, onchocerciasis, gastroenteritis, cholera, and rabies). Covered by VALCO's pre-paid company medical plan, the 8,000 employees have access to company doctors and nurse-practitioners (Hughes, 1972). It is reasonable to assume, therefore, that schistosomiasis is less significant to these 8,000 people than to many others who dwell along the lake's shores.

The Ghanaian government set up piped-water systems and latrines in 52 resettlement sites. It also sent some public health assistants to the sites (Taylor, 1973), but these workers failed to reach many people.

For many lakeside dwellers, and especially those who do not have access to a primary health care system or who are not participants in the UNDP/WHO schistosomiasis control scheme for the Volta Lake Project (Hoffman, et al., 1979), the parasites continue to be a threat, if not a problem. It is probable that Ghanaians are affected by a synergistic combination of schistosomiasis and malnutrition of varying severity. By 1971, more than 50 percent of the 67,500 people who were resettled after their land was inundated had left the villages established for them by the Volta River Authority (Hart, 1979). Fifteen years after the relocation effort, the "transition period" continues, largely because the resettlement authorities have yet to design a set of economically viable agricultural policies (Scudder, 1970).

Alone, but especially in combination with resettlement problems, schistosomiasis is a highly significant problem for many who dwell along the shores of Lake Volta. It is likely that schistosomiasis will continue to be a major problem for some time. The Volta River Authority maintains that the economic rates of return of the Volta Dam system are satisfactory (Scudder, 1980). One might add that the price in public health problems is also very high.

SCHISTOSOMIASIS AND THE KAINJI LAKE PROJECT THE NIGER RIVER BASIN, AND THE KAINJI DAM, NIGERIA

The Kainji Lake Project is discussed in detail by Awachie (1979), El-Zarka (1973), Daz and Biles (1972, 1973), Imevbore (1975), Mabongunje (1973), Scudder, (1980), Teesdale (1971), and Webbe (1972).

Kainji Dam was constructed between 1964 and 1968. It is a hydro-electric facility. Kainji Lake, which was created by the dam, covers 1,250 square kilometers (Imevbore, 1972). The project cost approximately U.S.$140 million (White, 1972). The area is managed at this time by the Niger Dams Authority (Scudder, 1980).

Before the dam was built, the basin contained three species of Bulinus snails, which acted as intermediate hosts for S. haematobium and S. mansoni (Imevbore, 1975). No figures are available on the prevalence rates for schistosomiasis among basin dwellers before the construction of the dam, but Webbe (1972) believes they would be "low" (Rosenfield, 1979).

After the dam was built, four major lakeside villages were surveyed. It was found that the prevalence rate for S. haematobium was 31 percent one year after the lake had filled (i.e., in 1970), and 45 percent two years later (i.e., in 1971) (Dazo and Biles, 1972, 1973; Webbe, 1972; Heyneman, 1978; Rosenfield, 1979). In 1970, WHO surveyed two separate lakeside locales and found a prevalence rate as high as 70 percent (El-Zarka, 1973). In that same year, the prevalence rate for S. mansoni was 1.8 percent at lakeside (Dazo and Biles, 1972, 1973; Heyneman, 1978).

Walsh and Mellink (1970; see Imevbore, 1975) predicted a spectacular "epidemic" of schistosomiasis among lakeside dwellers, but this did not occur. Between 5 percent and 10 percent only of the shoreline supports snails (Imevbore, 1975). Halstead (1971; see Imevbore, 1975) believes that this is because of the sharp seasonal changes in the level of the water (parts of the lake dry out, leaving the aquatic snail hosts stranded) and the siltiness and turbidity of the lake water. Heyneman (1978) attributes it to "the individuality of each focus of transmission." Imevbore (1975) is concerned that the increasing populations of aquatic weeds in the lake may exacerbate the schistosomiasis problem by providing shade and humidity for estivating snails stranded on the lake's edge during the dry season.

The WHO Inter-Regional Schistosomiasis Research Project, which included Lake Kainji, ended in 1974 (Heyneman, 1978). In 1973, a single 35-bed mission hospital at Yelwa and six scattered dispensaries covered 130 resettlement villages and two towns, as well as other local communities (El-Zarka, 1973). A PHC system now exists in the lake area (Adekolu-John, 1979a, 1979b). With implementation of the WHO plans and access to health care, the prevalence and incidence of schistosomiasis among local Nigerians should decline.

Those who live below the dam--the agriculturalists and fishers--have suffered dramatic decreases in domestic food production, fish catches, and livestock grazing areas (and income as well) since the construction of the dam, which put an end to annual flooding (Adeniyi, 1973; see Scudder, 1980). These declines may or may not be related to the schistosomiasis problem. It is reasonable to assume that the nutritional status, and hence the general health status, of these people has declined, at least temporarily, as well.

SCHISTOSOMIASIS, THE GEZIRA-MANAGIL AND RAHAD IRRIGATION SCHEMES, THE SENNAR DAM, AND THE BLUE NILE RIVER BASIN, EAST CENTRAL SUDAN

Gezira Province lies between the Blue Nile and White Nile. The Gezira-Managil irrigation schemes are 60 or more kilometers southeast of Khartoum. Amin (1977) noted that the Gezira area was once a semi-arid plain with no schistosomiasis, although it lies adjacent to the Blue Nile, which begins at Lake Tana (in highland Ethiopia), the source for 80 percent of the water for the main Nile River (Waterbury, 1977).

As an experiment, a pump-irrigation system was introduced to the area in 1910-1911 to irrigate cotton (Amin, 1977). In Sennar, in 1925-1926, a dam was constructed 250 kilometers south of Khartoum (Amin, 1977). Since 1950, the amount of irrigated land in Gezira Province has been increased by canalization (Amin, 1977). According to Donaldson (1977), when cotton was almost the only crop under production, peripheral irrigation canals were dried out once a week to control mosquitoes (and possibly snails). This practice was abandoned as the production of secondary crops (millet, wheat, rice, etc.) expanded. Today, motorized pump-irrigation is common throughout Gezira and Sudan (but not in Egypt). Two other forms of irrigation, flush and gravity-flow, are also common (Waterbury, 1977).

Today, approximately two million of the three million irrigatible acres in Gezira are irrigated (WHO/EM/SUD/VBC/001, 1980). Gezira's population has grown from 135,000 ("before irrigation") (Amin, 1977) to approximately 1,700,000 permanent residents and 500,000 seasonal migrant laborers (WHO/EM/SUD/VBC/001, 1980). Gezira is thus the most densely populated agricultural site in Sudan (Donaldson, 1977). In the 1920s, traditional patterns of land tenure in the Gezira changed with the introduction of the irrigation scheme. Today, all Gezira cultivators are tenants of the state-owned scheme of lands (Waterbury, 1977).

The Gezira contains three kinds of water-distribution canals. Main and major canals are used solely to transport water. The minor canals and field channels, called Abu eshreens and Abu sittas, respectively, are used to irrigate fields (Amin, 1977). In the Gezira, as elsewhere, minor canals are the primary foci for the transmission of *S. mansoni*. These canals contain large snail populations and are the sites of frequent person-water contacts (Amin, 1977).

Schistosomiasis is one of the major public health problems in the Gezira. The early prevalence data for the Gezira are often contradictory (cf. Wright, 1973, and Amin, 1977). Amin (1977) stated that overall *S. haematobium* prevalence rates in the Gezira were less than 1 percent between 1925 and 1944; when combined with the prevalence rates for *S. mansoni*, they are less than 2.5 percent. These data, which were probably drawn from Sudanese government medical reports of 1926-1939, are complementary, but independent parallel surveys in 16 villages show that *S. haematobium* infections were 15 percent in adults and 45 percent in children (WHO/EM/SUD/VBC/001, 1980). Amin (1977) noted that, between 1942 and 1944, the prevalence of *S. haematobium* was 21 percent in Geziran adults and 45 percent in Geziran children, with wide variations from village to village; overall, the prevalence rate of *S. mansoni* was 5 percent. In 1946-1949, another study revealed a 28 percent infection rate (presumably, *S. haematobium*) (WHO/EM/SUD/VBC/001, 1980). In 1952, the overall prevalence rate in Gezira was 8.86 percent for *S. haematobium* and 8.77 percent for *S. mansoni*; the former was 15 percent to 18.5 percent in children, and the latter was 12.6 percent to 13.1 percent in children (Amin, 1977).

In another source the prevalence rates of an unidentified species of schistosome parasite were listed as 16 percent in 1951, 12 percent in 1952, and 8 percent in 1954 (WHO/EM/SUD/VBC/001, 1980). From 1951 to 1960, prevalence rates in schoolchildren declined from 28.3 percent to 3.3 percent (Farooq; see Wright, 1973). In the WHO source, a 6 percent infection rate in the new Managil extension of the Gezira scheme was noted in 1957-1958. The Managil canal was opened in 1959.

Chemicals were first used to control snails in the Gezira in 1951. This explains the 1951-1954 decline. Despite snail control and other efforts, the transmission of schistosomiasis has been increasing since 1955. The overall infection rates in the Gezira for unidentified species of schistosome parasites are approximately 50 percent at this time (WHO/EM/SUD/VBC/001, 1980). The WHO report states that "the breakdown of control [probably] was caused by an inadequate number of diagnostic teams for the 1.6 million people, inadequate water supplies and sanitation, no provision for migrants and incomplete control strategies." An improved WHO control program has existed in the North Gezira Region since 1968. Nevertheless, as Amin (1977) has recorded, the prevalence rate of *S. mansoni* was as much as 60 percent in 1972 and more than 70 percent in three villages in 1973. In 1977, the overall prevalence rates were 8.3 percent to 82.2 percent in males (these peaked in the group of 15-19-year-olds) and 2.3 percent to 79.6 percent in females (these peaked in the group of 10-14-year-olds). In the 1980 WHO document the prevalence rate for *S. mansoni* was 50 percent to 70 percent for the overall scheme in 1977. Amin (1977) has observed that it has cost L.S.500,000 to treat infected people in the Gezira.

The Gezira scheme has been the site of molluscide experiments which have compared the effectiveness of drip-feed and aerial and ground applications (Amin, 1977). Aerial molluscide has been applied regularly to one million acres of the Gezira at a cost of $1/person/year. To date, there has been "no substantial reduction in prevalence" in the basin where the project is located (Hoffman, et al., 1979). It appears that prevalence rates in the Gezira, especially for *S. mansoni*, have been increasing since at least the 1960s. These increases are believed to be the result of the expanded construction of canals and greater use of pump-irrigation below the Sennar Dam without sufficient control measures.

The production of cotton in the Gezira-Managil scheme provides approximately 40 percent of Sudan's total national revenue and as much as 60 percent of its foreign exchange. Schistosomiasis, malaria, and diarrheal diseases are considered to be the major impediments to production in the scheme (WHO/EM/SUD/VBC/001, 1980). To address these and other growing problems, WHO and the Government of Sudan (GOS) implemented in April 1979 the $155 million, 10-year Blue Nile Health Project (Jobin, 1980). In July 1976, REDSO-USAID/S submitted a Project Identification Document (PID) for the $8.6 million Health Constraints to Rural Production Project (Project No. 698-0408) for FY 1978-1982. The former project is discussed in detail in Jobin (1980) and WHO/EM/SUD/VBC/001 (1980). The Sudanese part of the AID project began in the summer of 1980. A design team visited the Gezira area at that time to locate and begin planning an applied field research project and to prepare a section on the initial environmental examination (IEE) for the Project Paper (PP) (incoming cables, Department of State, Khartoum, Nos. 4479, 4661, and 5024). It is hoped that as a result of these projects and the provincial health services now present in the area (see WHO/EM/SUD/VBC/001, 1980), the significance, prevalence, incidence, and distribution of schistosomiasis in the scheme will be reduced during this decade.

One of the most difficult tasks facing the GOS, and WHO and AID personnel, is to manage the 500,000 migrants of various categories who move about the area annually to pick cotton (Anonymous, 1980b; Bella, et al., 1980). Prevalence rates for S. mansoni have been recorded by Bella and his colleagues (1980). The rates, standardized for age, are 63 percent for male migrant Westerners and 61 percent for male Arab nomads in molluscide-treated areas; 74 percent and 51 percent, respectively, for males in untreated areas; and less than 58 percent for females in all four classes. Cheesmond (1980) has disaggregated the "migrant Westerners" into two separate classes.

The Blue Nile Health Project will include the new Rahad irrigated scheme, which consists of approximately 300,000 square acres of land on the east bank of the Rahad River. The Rahad River originates in highland Ethiopia, at Lake Tana, and feeds into the Blue Nile near Wad Medani, a town approximately 150 kilometers southeast of Khartoum. The Rahad scheme draws its water from the Blue Nile through a supply canal that is 80 kilometers long and feeds into the Rahad River and Rahad barrage. From the barrage a second main canal that is 90 kilometers long feeds the project area (WHO/EM/SUD/VBC/001, 1980). Approximately 50,000 people live in the area at this time; another 50,000 seasonal laborers live in the area during the cotton harvest. There are plans to resettle an additional 100,000 people.

The transmission of schistosomiasis did not occur before the construction of the barrage and canal. However, persons from infected areas of the Gezira have migrated to the area of the Rahad scheme. A 1978 sample of these new residents showed a 20 percent prevalence rate, mostly for

S. mansoni (WHO/EM/SUD/VBC/001, 1980). One purpose of the project is to prevent the transmission of schistosomiasis in the Rahad scheme. Health services are available in the scheme (there are 11 schistosomiasis-control personnel and various curative health units). Schistosomiasis may be of only minor significance now, but WHO estimates that 3,000 infected people are living in the scheme.

SCHISTOSOMIASIS AND THE KHASHM-EL-GIRBA SCHEME, THE ATABARA RIVER BASIN, AND THE KHASHM-EL-GIRBA DAM, EASTERN SUDAN

The Atabara River, a tributary of the main Nile River, begins in the Ethiopian highlands northwest of Lake Tana and enters the main Nile near Atabara, in eastern Sudan. The Khashm-el-Girba scheme is located approximately 290 kilometers (180 miles) southeast of Atabara on the west bank of the Atabara River. It was established by the Sudanese government in the early 1960s as a resettlement site for 50,000 Sudanese Nubians of the Wadi Halfa and neighboring tribes. These persons had been forced to leave their flooding lands as Lake Nasser filled in 1962-1963. The scheme was initiated in 1956 by the Sudanese Minister of Irrigation. The construction of Khashm-el-Girba Dam, part of the scheme, began in 1960; it was completed in 1963 (Dafalla, 1975). Resettlement was completed by the end of 1963 (Farid, 1975); it is discussed in detail by Defalla (1975). The scheme was planned in five phases. Resettlement occurred in the first phase; the other four phases involved various expansions of the irrigation system. In 1977, the scheme covered 182,000 acres (Amin, 1977). The irrigation system is gravity-fed (pumps are not used). Cotton, groundnuts, wheat, sorghum, vegetables, sugarcane, and other crops are grown (Amin, 1977; Waterbury, 1977).

Wright (1977) mentioned that "the snail host for S. mansoni is known to occur in the Zeidab agricultural scheme at the confluence of the Atabara River with the Nile," which is approximately 400 kilometers northwest of Khashm-el-Girba. Amin (1977) stated that before irrigation, Khashm-el-Girba was a "schistosomiasis-free area," but that both S. haematobium and S. mansoni are now prevalent among the population. The former was introduced primarily by the Wadi Halfa, and the latter was "imported" from the Gezira and the White Nile (presumably via migrants). Unfortunately, Amin (1977) gave no current prevalence or incidence values for either form of schistosomiasis. Dafalla (1975) has, however, observed that the Ministry of Health has set up treatment centers in the new villages and has initiated "river bank" and snail-clearance operations. He stated that the MOH gives "special attention" to bilharzia cases. Unfortunately, Dafalla (1975) recorded no data on the incidence, prevalence, or distribution of schistosomiasis. With health care services available on site, schistosomiasis may not become a significant problem.

SCHISTOSOMIASIS AND THE JONGLEI CANAL PROJECT, THE WHITE NILE RIVER BASIN, AND THE SUDD SWAMP, SOUTHERN SUDAN

In Sudd Swamp, a region in southern Sudan, live more than one million Nilotic Dinka and Nuer. These agro-pastoral tribes have several million cattle and smaller livestock (Scudder, 1980). Because of the increased desertification to the west (the Sahel), and as a result of local warfare with Kababish Arabs, the Baggara people of northwestern Sudan are encroaching more and more on the lands used by the Western Dinka (Scudder, 1980). Rainfall on the equatorial East African lakes gives rise to the annual flooding of the White Nile (Bahr-el-Jebel), which in turn floods 6,000 square kilometers of the Sudd, turning it into a papyrus fern swamp (Waterbury, 1977). The Dinka and Nuer move upland to cultivate savannah crops from April to December (McNeil, 1972). When the waters ebb, the Dinka and Nuer return to the Sudd to graze their livestock during the dry season on the grassy riverine meadows and pastures, or toich (Scudder, 1980). These meadows contain *Echinochloa* grasses of high nutritional value, but, as Scudder (1980) has conceded, the toich pastures "are probably associated with more disease than upland pastures," in particular, disease among livestock. Indeed, various 19th Century British explorers remarked on the severe disease problems which they and their animals experienced while passing through the Sudd (cf. Moorehead, 1960).

In the 1800s, the Sudd Swamp proved to be a formidable barrier to British exploration and control of southern Sudan (Moorehead, 1960; Collins, 1975). The first "permanent" channel through the Sudd Swamp was made in 1899 (Moorehead, 1960). In 1902, Sir William Barston of the Egyptian Public Works Department proposed a solution to the problem of navigating the river and stemming the water evaporation losses from the White Nile (these were more than 50 percent annually): dredging and improving the small Bahr-el-Zeraf river channel of the Bahr-el-Jebel (White Nile), which runs between the towns of Bor and Malakal, thus bypassing the Sudd altogether (Waterbury, 1977). Barston's idea was translated into the Equatorial Nile Project, or the Victoria-Albert-Jonglei Scheme (McNeil, 1972). Lakes Victoria and Albert and the other equatorial East African lakes feed the White Nile, but the latter contribute only 5 percent to 14 percent of the main Nile River waters (Waterbury, 1977). The Sudd Swamp, which is 6,000-8,000 square kilometers, acts as a relief valve for the lower Nile in high flood (McNeil, 1972).

In 1954, the Jonglei investigation team prepared detailed plans for this canal (McNeil, 1972). The present Jonglei Commission is an outgrowth of the Ministry of Irrigation (Scudder, 1980). It will oversee the construction and management of the 65-100 meter-wide, 350 kilometer-long canal (Chatfield, 1979). Construction, which began in 1978, should be completed in 1985 (Myers, 1979). The project has a budget of $350 million, much of which is contributions from Arab states (Myers, 1979). The canal will reduce Sudd Swamp to 1,000 square kilometers (McNeil, 1972), thus making the site a grassland for better stock-grazing. Some people believe it will convert the nearby acacia tall grass forests to a more arid-adapted community of acacia shortgrass scrub plants (Malek, 1958; Myers, 1979). French and Dutch engineers are involved in the construction of the canal, and a Dutch firm is preparing a "limited" environmental impact analysis (Chatfield, 1979; Myers, 1979), which may or may not address public health concerns.

The Environmental Liaison Centre in Nairobi is concerned that the canal will block the annual migration of 65,000 local members of the Shilluk, Nuer, and Dinka tribes (Chatfield, 1979). Others are apparently less concerned about this problem. According to Scudder (1980), in its first phase, the Jonglei Canal Project may become the _first_ large river basin development project to have a major _positive_ impact on a local population, depending upon the "alignment of _the canal_ and the nature of Phase Two," because the various tribes are a strong organization, able to influence local politics, and because their interests are considered. Scudder (1980) reported that from 1976 to 1978 the number of small Nuer-owned stores doubled. The Nuer have switched their source of income from pure livestock-herding to commercial fishing (presumably in the canal itself), and this has become a lucrative industry. It is also expected that grain will be grown on 16,000 square kilometers of new land (Myers, 1979) which, it is presumed, will be irrigated with water drawn from the canal.

Indications of positive local impacts aside, the author is concerned about the apparent lack of discussion in the literature about the public health ramifications of the project, and especially about schistosomiasis and malaria.

Malek (1958), in a thorough review and survey of the snail hosts of schistosomiasis in the Sudan, noted the following snail hosts immediately around the Malakal and the _toich_ lands of the Sudd:

Genus	Location
Bulinus (_Bulinus_) spp.	Malakal, Bahr-el-Ghazal River, Sudd
Bulinus (_Bulinus_) _forskalii_	Jonglei south of Malakal
Bulinus (_Physopsis_) _ugandae_	Bahr-el-Ghazal (in _toich_), Jonglei
Biomphalaria spp.	Jonglei south of Malakal
Biomphalaria _sudanica_ _sudanica_	Malakal
Biomphalaria _rüppellü_	Bahr-el-Ghazal west of Malakal

Because he was conducting a taxonomic survey of the snails, Malek did not dissect many snails to examine them for schistosome infections, but he did remark that "the form of bilharziasis endemic along the White Nile, where B. (Physopsis) ugandae prevails, is, in the main, bilharziasis mansoni and not bilharziasis haematobia" (Malek, 1958). Wright (1973) also has discussed schistosomiasis and snail hosts in southern Sudan.

As more canals are built, as irrigated agricultural production and fishing expand around the canal, and as migrant workers begin to appear (Bella, et al., 1980; Cheesmond, 1980), the geographic expansion and increased incidence and prevalence of schistosomiasis may pose a major threat to the area.

The WHO's new Blue Nile Health Project, the planning for which began in 1979 (see WHO/EM/VBC/23, 1980), does not include the White Nile Jonglei Canal Project, although it may include neighboring schemes, in addition to the targeted Gezira-Managil and Rahad irrigation schemes (see WHO/EM/SUD/VBC/001, 1980).

In the author's opinion, the GOS schistosomiasis control program and other appropriate agencies should carefully monitor the Jonglei Canal Project, if they are not doing so at this time.

Case Studies B

WATER RESOURCES DEVELOPMENT AND ONCHOCERCIASIS

ONCHOCERCIASIS, LAKE KAINJI AND THE KAINJI DAM, AND THE NIGER RIVER BASIN, NIGERIA

The Kainji River Basin in Nigeria is an area of metamorphosed rock overlaying a terrane basement layer. It is, in Crosskey's view (see Imevbore, 1975), an excellent breeding site for onchocerciasis because the soils derived from such rock have little capacity to hold water and make for cascading river flows. Large numbers of Simulium damnosum have long populated the basin, and endemic onchocerciasis has limited the concentration of humans in the area, according to Waddy (see Imevbore, 1975). In his survey, Waddy (see El-Zarka, 1973) noted a 6.1 percent blindness rate in a sample of 2,846 people in the basin.

Following construction of the Kainji Dam, which created Lake Kainji, many of the breeding sites of S. damnosum were destroyed. A review of surveillance records kept before the dam was constructed reveals a 5.7 percent prevalence rate of infection in a group studied in 1956 and a 49 percent prevalence rate of infection in a group studied in 1959 (Imevbore, 1975). Post-dam prevalence rates were unavailable to the author.

El-Zarka (1973) has observed that blackfly populations declined, except in three tributaries, after the dam was built. Simulium damnosum stopped breeding in a 10-mile area immediately below the dam and around the immediate lake shore (Imevbore, 1975). This may be attributed in part to manipulated changes in the water level of the lake. Lake Kainji is small compared to the rivers that feed it, and this necessitates constant changes in the flow-through patterns of the water at the dam (Edeson, 1975; El-Zarka, 1973). DDT has been placed in the river since 1962 to control fly breeding. It is used for the benefit of construction workers (El-Zarka, 1973; Imevbore, 1975). Although use of DDT and manipulation of the water level have contributed to the reduction of local blackfly populations, reinfestation from the surrounding bush is a constant problem (Imevbore, 1975). While the dam was being built, labor camps were sited away from heavy breeding areas, a tactic that resulted in a zero-percent incidence of disease among the workers (Imevbore, 1975). Nevertheless, according to Waddy (see Black, 1975), the increased human population in the area has resulted in increased person-fly contacts, and the spread of onchocerciasis.

ONCHOCERCIASIS, LAKE VOLTA AND AKOSOMBO DAM, AND THE VOLTA RIVER BASIN, GHANA

Onchocerciasis is endemic in the Volta River Basin, and historically it has been responsible for some depopulation (Kalitsi, 1973). Simulium damnosum bred in large numbers in the rapids of the river before a dam was constructed in 1965 (Obeng, 1975). The new lake flooded some breeding sites, but breeding continued in the tributaries above and below the lake (Obeng, 1975).

Obeng (1973) has noted that infected flies apparently spread to the north of the lake along feeder rivers. In 1966, 11 species of Simulium were observed in the areas around the lake. Obeng (1975) suggested that this might be evidence of increased diversity in species of blackfly. Lakeside dwellers have become infected, probably by flies blown in with the wind (Obeng, 1975), and some villages that have been moved back, away from the edge of the lake, have also experienced an increase in infections from flies breeding in the adjacent tributaries (Taylor, 1973). Most of the settlements have remained relatively free of blackfly, though there are exceptions. For example, Asukawkaw, on a tributary stream, reported a 90 percent prevalence rate of infection in people over the age of 15 (Kalitsi, 1973). In 1968-1969, DDT was used as a larvicide in the river below the dam; the effort was an apparent failure (Deom, 1975; Kalitsi, 1973; Taylor, 1973). Periodically, much water is released to flush out the breeding grounds below the dam (Kalitsi, 1973). But because the lake is large in comparison to the rivers that feed it, the flow of water through the dam has been rather constant, and the blackfly has continued to breed heavily below the dam (Edeson, 1975).

ONCHOCERCIASIS AND OTHER DAMS

When the Jinja Dam was constructed on Lake Victoria, some cataracts where Simulium bred were removed, and DDT was applied (Black, 1975). But, as the human population in the area of the dam increased, so, too, did person-fly contacts. The result has been the spread of onchocerciasis (Black, 1975).

Neither Van der Lingen (1973) and Webster (1975), who have discussed Lake Kariba and the Kariba Dam in Zambia-Zimbabwe, nor Leentvar (1973), who has discussed Lake Brokopondo and its dam, mention the problems associated with onchocerciasis. Raheja (1973) has noted that onchocerciasis has not been included in surveys of S. damnosum around Lake Nasser, and he is concerned about the situation that has developed near the Old Aswan Dam (below the Aswan High Dam), where exposed rocks in the Nile may create foci for breeding flies. Waddy (1973) recorded a 15 percent blindness rate around the Bandama Dam in the Ivory Coast, where onchocerciasis is endemic, and noted that as the human population in the area of the dam has increased, so, too, has the transmission of onchocerciasis.

Abdalla and Abu Baker (1975) discovered a new focus of onchocerciasis in the Upper Atabara River in Sudan, near the Khashm-el-Girba dam and irrigation scheme. This outbreak occurred after the area was developed agriculturally and attracted infective immigrants from onchocerciasis-endemic areas in northern Nigeria and Chad.

Since 1968, USAID has been working with host countries, the WHO, the FAO, the UNDP, The World Bank, and other agencies to develop a large-scale onchocerciasis-control program, the first of its kind, for the Volta River Basin in Africa. Particular attention is being given to water management and resettlement (Buck, 1974). The project is described in detail in a regional PP for Africa, "ONCHO Control in the Volta River Basin Amendment No. 2" (Project No. 698-0399).

Case Studies C

WATER RESOURCES DEVELOPMENT AND MALARIA

MALARIA AND THE MADURU OYA RIVER BASIN, SRI LANKA

Human malaria apparently spread to Sri Lanka well before the 16th Century, but it is not known how it spread to that country, according to de Silva (1977). Some historians believe that, "coming on the heels of invasion and thriving on disused irrigation works [malaria] played a critically important part in multiplying obstacles to resettlement" of the dry zone after it was abandoned in the 13th Century (de Silva, 1977). Though other historians of Sri Lanka disagree (Nicholls, 1921; Tyssul Jones, 1953), de Silva (1977) emphasizes that "malaria did not cause the original abandonment of the dry zone heartland of ancient Sri Lanka," which had an elaborate irrigation system. De Silva (1977) believes that malaria "defeated all attempts at large-scale resettlement until the advent of the use of DDT in Sri Lanka." DDT was first used in one district in October 1945 (Meegama, 1967; Farmer, 1957) and more extensively from 1946 onward (Meegama, 1967; USAID, 1977b).

In this century, there have been at least 13 major epidemics of malaria in Sri Lanka (Gerberg and Willcox, 1975). By 1968, malaria had "returned as the major health problem in the country" (USAID, 1977b).

In 1977, personnel in the Ministry of Health of the Government of Sri Lanka (MOH/GSL) revised, for at least the second time, their original Malaria Eradication Programme of 1958. They were assisted by teams of consultants from WHO and USAID. The current Anti-Malaria Campaign and the five-year plan (1977-1981) emphasize the control, and not eradication, of malaria. This is in keeping with WHO's new policy on malaria programs in countries where time-limited malaria eradication is impracticable.

As of July 1980, the reported 1979 case level for malaria was approximately 48,000 cases, whereas in 1975 the malaria case rate nationwide was 400,777 cases. The percentage of P. falciparum infections has dropped to less than 5 percent (Brooks, 1980).

The plans for the Accelerated Mahaweli Program (AMP), the country's largest development project, are nearing completion. As specified in the master plan for the UNDP/FAO/GSL project, over the next 30 years, 12 major reservoirs and 5 dams will be constructed, 365,000 hectares (ha) of land will be developed, and hydroelectric power will be generated (World Bank, 1980). It is expected that five dams will be built and 117,000 ha of land irrigated within five years. In Phase I of the Mahaweli Basin Development Program, the Maduru Oya River Basin will be developed. One AID project planned for the basin is known as Maduru Oya-System B Design and Supervision (Project No. 383-0056). During this project, the main and branch canals and main drainage system for System B will be designed for 37,400 ha of irrigated farmland, distributaries and on-farm works will be designed for 4,000 ha, canal construction will be supervised, general technical assistance will be provided, and the environmental impact of System B, as well as other components, will be alleviated (see PP, p. 21).

The TAMS Co. prepared a preliminary environmental assessment (EA) of the Maduru Oya Project in December 1979 (see Annex D, PP). It noted that the combination of new canals, waterway, and settlers (some of whom come from non-malaria-endemic areas in Sri Lanka) could, in the absence of preventive measures, create conditions conducive to increased outbreaks of diseases, chief among which are malaria and its mosquito vector, _Anopheles culicifacies_. It has been recommended that malaria control be made an integral component of the AID project and that surveillance be combined with the timed release of water during the dry season to flush out the breeding sites of _Anopheles_ in or near the canals. It has been suggested also that other measures be considered during planning, design, construction, and operation and that these steps be based on the recommendations in the WHO's _Report on the Seminar on the Prevention and Control of Vector-Borne Diseases in Water Resources Development Projects_ (WHO/EM, 1978). These suggestions were included in the _Environmental Aspects Report_ (see Annex J) on Maduru Oya. This feasibility study was prepared by Acres International Ltd. (AI; 1979). The authors of the AI report (see p. 3) stated that, unless mitigating measures are taken, one can expect, among other things, a dramatic increase in the incidence of disease because habitats conducive to vector-borne diseases will have been created; an epidemic of malaria; and a decline in the productivity of farmers and construction workers who are suffering from malaria. It is planned that the Ministry of Health's Anti-Malaria Campaign (AMC), which is at this time partially funded by AID, will be coordinated with the Accelerated Mahaweli Program.

MALARIA, THE WHITE NILE RIVER, AND
THE JEBEL AULIYA DAM AND RESERVOIR,
SUDAN

Lewis (1948) made a detailed survey of the mosquito populations near Jebel Auliya Reservoir. He particularly observed malarial mosquitoes. According to Lewis, "malaria occurs throughout the area and appears to have increased since the dam was constructed" in the 1930s. In the areas surrounding the reservoir, breeding conditions have changed since the dam was constructed. In the Jebelian Section, which contains *An. funestus*, the reservoir has deepened the swamps and lengthened the period of flooding. New swamps have formed, and floating papyrus plants have declined in number. In the Kowa Section, sedge swamps have greatly increased, new creeping grass swamps have developed, and the flood period has been lengthened, but the mosquito-infested mats of papyrus plants are no longer found in the reservoir, although they used to lie stranded on the edge of the river next to villages. In the Geteina Section, where *An. gambiae s. l.* is found, sedge swamps have increased in size (Lewis, 1948). In the sections of Kowa and Geteina, three malaria vectors, *An. pharoensis*, *Anopheles rufipes*, and *An. gambiae*, have proliferated since the dam was built.

MALARIA, THE SURINAM RIVER BASIN, AND BROKOPONDO LAKE AND DAM, SURINAM

The public health aspects of Brokopondo Lake and Dam are discussed in Leentvaar (1975). In the area surrounding the lake, Anopheles darlingi was the most important malaria vector before the dam was constructed. Malaria was holoendemic in the area (van Theil, 1962). Van Theil (1962) found only the adult species, and no larvae, of the An. darlingi; he also found adults of 11 other anopheline species. Van Theil (1962) predicted that An. darlingi would begin to breed in the new villages surrounding the lake, but he said they would not breed in the lake itself, unless herbicides were used to kill floating plants and thus create open breeding zones for the species. Apparently, van Theil's predictions were accurate, and spraying near the villages has helped to control these populations as well (Leentvaar, 1975). Recently, however, Anopheles nunez-tovari, once a minor local anopheline species, has increased in population, and it has been cited as the cause of severe malaria outbreaks in villages around the lake (Panday, 1979). This species was a notorious problem in Venezuela, where DDT had little effect on its ability to reproduce (Gabaldon; see van Theil, 1962).

MALARIA AND THE UPPER MAZARUNI RIVER HYDROELECTRIC SCHEME, GUYANA

Since 1966, when it became independent, Guyana has been interested in building a dam on the remote upper Mazaruni River in northwestern Guyana, near Venezuela (Crittenden, 1980). The dam is a major part of a $3 billion (G) hydroelectric development scheme to smelt bauxite ore into aluminum. Bauxite accounts for 40 percent of the country's export revenue (Nichols, 1977). The World Bank has loaned Guyana $8 million for feasibility studies on this hydroelectric scheme and four other projects (Crittenden, 1980). The International Monetary Fund (IMF) has contributed $130 million to cover the costs of the scheme(s) (Reuter Press wire, July 24, 1980).

The first phase of the project, which involves the construction of the dam, lake reservoir, and access road, is scheduled for completion in 1982. Road construction (a highway for tourists and industrial transport) was begun in 1975. This effort employs 2,000 workers (Nichols, 1977). The Membaru Valley, behind the dam at Sandlanding, was to have been flooded in 1980 (Nichols, 1977), but this has not occurred because the site for the dam will not be selected until September 1981, although it was to have been chosen by October 1980 (Crittenden, 1980).

One reason for the delay is the likelihood that the rising waters of the reservoir would displace several thousand aboriginal Amerindians, 4,500 Acawani and Arecuna in Guyana-Venezuela, and as many as 12,000 Pemon (Crittenden, 1980; Nichols, 1977). The Guyanese Resettlement Committee was appointed in 1976 to study the many complex issues arising from the hydroelectric schemes, including health concerns (Nichols, 1977).

The Ecology Unit of the Resource Division of the Upper Mazaruni Development Authority (UNDA) is responsible for monitoring airborne and waterborne diseases. In 1977, this unit had "little or no information concerning the river basin system" in a country with "limited technical skills available locally" (Nichols, 1977). An International Hydro Seminar was convened in 1976 by the Government of Guyana (GOG) to discuss the scheme and the various health issues. Dr. Robert Goodland of UNESCO expressed his concern about the development of onchocerciasis and schistosomiasis in the area (Nichols, 1977).

Tikasingh (1979) has elaborated on the presence in the area of onchocerciasis and other potential diseases, and their vectors and hosts. *A. darlingi* and malaria (which are also discussed by Giglioli, 1963), *Lutzomyia* sandflies and leishmaniasis ("bush-yaws" in Guyana), mosquito vectors of yellow fever, VEE, WEE, EEE, and Ilheus arboviruses are found near the river. Tikasingh also has discussed a disease-monitoring system. Wright (1973) has not mentioned that schistosomiasis (*S. mansoni*) has occurred in Guyana, but he has recorded it in adjacent Surinam, Venezuela, and some neighboring Caribbean islands.

The malarial potential of this project seems to be similar to that of the Brokopondo Lake and Dam in Surinam, Guyana's neighbor. This conclusion is based on ecological parallels between the two settings.

MALARIA, IRRIGATED RICE FARMING AND LIVESTOCK, AND THE DEMERARA RIVER ESTUARY, GUYANA

Historically, Guyana (formerly British Guiana), in northeastern South America, has had two notable vectors of malaria: Anopheles darlingi and Anopheles aquasalis, the former being the most important by far (Giglioli, 1963). The aquatic development of both species occurs in similar environments: irrigation canals, irrigated rice fields, sugarcane fields in flood-fallow, drains, ponds, and swamps, but the aquatic A. aquasalis is more numerous and eclectic in its "choice" of habitats. This species tolerates saltwater and actually increases its prevalence and geographic range in years of drought, unlike A. darlingi (Giglioli, 1963). Historically, in Guyana at least, A. darlingi adult females tend to be very anthropophilic, endophilic, and thus anthropophagic (i.e., they are attracted to humans and indoor human shelters, and they usually prefer to feed on humans as opposed to other animals). The A. aquasalis adult female populations may be zoophilic, exophilic, and zoophagic (Giglioli, 1963).

From 1946 until 1950, Dr. Giglioli led a WHO malaria eradication campaign in Guyana that was directed solely against adult mosquitoes. DDT was used as a household residual spray. By 1950, this campaign eradicated A. darlingi from all coastal areas, except in the northwest at the Guyana-Venezuela border; A. aquasalis populations remained unchanged (Giglioli, 1963). The campaign in the jungle interior was weak, and particularly along the border with Brazil. Neither species was eradicated during this effort. Low levels of malaria transmission were recorded throughout the 1950s (Giglioli, 1963). From 1951 until 1961, the transmission of malaria to humans virtually ceased (there was one case) in all the coastal areas, except the far northwest, including the lower Demerara River, which flows through Georgetown (Giglioli, 1963). DDT spraying ended in 1951 along the coast. In 1958-1959 an outbreak of malaria was reported in the Barima estuary in Northwest District; only A. aquasalis was implicated (Giglioli, 1963). In 1959, manganese mine construction workers at a camp in the interior, far up the Barima River near Brazil, experienced an outbreak of two species of malaria, Plasmodium falciparum and Plasmodium vivax. A residual population of A. darlingi was the vector. The workers were treated with chloroquine, which apparently destroyed all P. falciparum, but not P. vivax. In late 1959 and early 1960, the workers were laid off and returned to their homes in Georgetown and to their coastal villages (Giglioli, 1963).

In the 1950s, the Demerara River estuary immediately south of Georgetown underwent rapid change. The human population increased between 50 percent and 164 percent along the two banks of the estuary. Simultaneously, there was a significant increase in housing development (Giglioli, 1963). Furthermore, there was "a huge expansion in [irrigated] rice cultivation." Most available pasture and fallow lands were now at a premium for rice production (Giglioli, 1963). The result was a sharp decrease in populations of cattle, horses, mules, and donkeys (all pastured animals once used to cultivate the rice paddies), especially when the production of rice was mechanized. Other animal populations did not increase significantly, if at all (Giglioli, 1963).

Between June and December 1961, 52 cases of P. vivax malaria were reported in various villages in the Demerara River estuary, which has a total population of 13,004. By far, the most numerous anopheline adult in the area was A. aquasalis. It was also the only species well-blooded and infected with P. vivax. A. darlingi were not found (Giglioli, 1963).

Giglioli (1963), who gathered excellent evidence, surmised that with significant expansion of irrigated rice paddies, an increased human population, and a decrease in the population of host livestock, the large population of A. aquasalis "switched" their source of food from animals to humans, some of whom were the construction workers who returned to their homes still infected with P. vivax. In this way, the local epidemic began.* Giglioli's team instituted control measures which soon brought the outbreak under control. As part of the effort, the team sprayed DDT every six months, conducted systematic passive and active surveillance, and treated those who were suffering from malaria with chloroquine-primaquine and suppressive chemotherapy.

* Giglioli (1963) noted that A. aquasalis "is frequently attracted to brightly illuminated buildings, and may attack quite actively." Though not mentioned, the increased housing, with accompanying household illumination, in the estuary may also have been a contributing factor in the outbreak.

Part Three

BIBLIOGRAPHY

BIBLIOGRAPHY

This selected bibliography is intended to help readers obtain additional information on specific topics and concepts. It should be especially useful to the many active participants in the development process (project officers, program planners, design teams, field staff, ministry officials, etc.) who, of necessity, must be familiar with and display a general knowledge of development and disease, and their interrelationship.

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