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Environmental Assessment

Use of the Molluscicide Bayluscide in a Pilot Program to Control Schistosomiasis in Kaele Division, Extreme North Province, Cameroon

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by

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1. Executive Summary

The proposed pilot schistosomiasis control program for northern Cameroon seeks to develop decentralized, cost-effective, sustainable measures for reducing the transmission of *Schistosoma haematobium* to levels insufficient to cause morbidity in the human population. Controlling the bulinid snails that transmit urinary schistosomiasis, primarily in small, temporary waterbodies in this area is an important component of the program. The method chosen for controlling snails is focal application of the molluscicide Bayluscide (active ingredient niclosamide), strategically timed to interrupt the highly seasonal transmission pattern in this arid region.

Other components of this project are education of local people to maximize their compliance in treatment programs and minimize opportunities for transmission, and development of simplified, decentralized mechanisms for diagnosis and treatment. A long-term goal is to establish practices that could eventually be used in larger, perhaps countrywide, control programs.

As part of an experimental design to compare the efficacy of Bayluscide with that of other interventions, this compound is to be applied to transmission sites in and around approximately 20 villages in the Kaele Division, Extreme North Province. The habitats to be treated are small, so the total amount of Bayluscide to be used is also relatively small (It is estimated at about 50 kg of wettable powder of Bayluscide per year).

The toxicological properties of niclosamide are relatively well-known because this compound has been used therapeutically in humans for several years to kill adult cestodes. The compound is classified as a restricted use pesticide and is registered by the U.S. Environmental Protection Agency (EPA Reg. No 3125-136) as a molluscicide. It is biodegradeable, has low acute toxicity, is poorly absorbed, and is rapidly excreted in both humans and domestic animals. It does not accumulate in animal tissues and has no known long-term mutagenic, carcinogenic or teratogenic properties. It is an irritant of mucous membranes and is mildly irritating to skin. Molluscicidal concentrations, which are much lower than the well-tolerated therapeutic doses, pose no danger to people or livestock drinking treated water and do not irritate skin.

It is concluded the use of Bayluscide poses no substantial danger to the health of humans and livestock. It has no obvious effect on any important vascular food plants. As the proposed use is entirely aquatic and there are no aquatic food plants grown in the immediate area of the project, there is little reason to think that crop production will be affected in any way.

The principal concern raised by the use of Bayluscide relates to its well-known toxicity for fish, amphibians and some non-molluscan invertebrates. This compound cannot be condoned for use in areas where pisciculture comprises an important element of the local economy. It was the unanimous view of all people interviewed, a view with which the author concurs, that the small temporary waterbodies where Bayluscide is proposed for use do not support a significant fishery. These habitats are also extensively modified by human activities and are far-removed from pristine areas in national parks. Lists of endangered aquatic species are not available for this region, but many habitats supporting comparable flora and fauna exist in this general area. Such untreated habitats can, and almost certainly will, serve as a source of colonizing organisms to repopulate treated environments. It is concluded that the use of Bayluscide on a relatively small scale as proposed in this pilot project does not pose a serious or permanent environmental threat.

Details about the storage, mixing, application, and disposal of Bayluscide are provided in the project proposal. Also provided are details pertaining to training of personnel involved in handling the chemical and procedures for monitoring continued safe usage.

To justify the use of molluscicide in this and other programs, it will be necessary to monitor the efficacy of mollusciciding in reducing or eliminating infected snails in treated waterbodies and in lowering actual transmission to children. Incidence rates will have to be measured. Measurements of morbidity in selected individuals before and after treatment would be desireable as yet another way of assessing the benefits resulting from the use of molluscicides. It will also be necessary to provide a detailed accounting of the actual costs involved not only in importing the chemical, but in distributing it, and training handlers. The proposal considers all of these important questions and outlines satisfactory protocols for answering them.

For the purposes of this pilot project, it is concluded that Bayluscide is safe, and that it should be used as proposed so that its role in future control efforts in Cameroon can be accurately assessed. Careful documentation will be required to determine its cost-effectiveness compared to other measures.

Finally, regarding future and potentially larger-scale control efforts, the following considerations should be borne in mind:

1. It is likely that yearly applications of molluscicide will have to continue because of the excellent colonizing abilities of the target snails.

2. The use of Bayluscide is likely to be cost-effective only in areas where focal control is possible and transmission is highly seasonal. Much of the transmission of schistosomiasis in Cameroon is of this nature. Some transmission sites such as large lakes or streams cannot be effectively treated with molluscicidal chemicals (see Duke and Moore, 1976a-c, for a discussion of this problem as it relates to Cameroon). Eventually, alternative strategies will have to be sought for such habitats.

3. It is unlikely that mollusciciding by itself will be able to break the cycle of schistosomiasis transmission without simultaneous application of other control measures, including health education, chemotherapy and sanitation.

2. Background

2.1 Purpose

The purpose of this activity is to conduct an Environmental Assessment for the proposed use of the molluscicide Bayluscide (niclosamide) to control schistosome-transmitting snails as part of a pilot schistosomiasis control project in northern Cameroon. The proposed project represents a three-year extension of the Health Constraints to Rural Production (HCRP) project currently underway and due to conclude in December 31, 1990.

2.2 Scoping process and scope of work (SOW)

According to A.I.D. Environemntal Procedures (22 CFR Part 2, 216.3 (4)), a written statement of the Scope of an Environmental Assessment (EA) that identifies potentially significant issues is prepared and cleared through the Bureau Environmental Officer and Mission. The SOW for this activity is presented in Appendix 1.

2.3 Project description (adapted from Project Paper)

The HCRP has identified schistosomiasis as a major public health problem in Cameroon, particularly in the northern half of the country. The goal of the proposed extension is to capitalize on this newly-acquired information to develop cost-effective, sustainable control measures designed to reduce schistosomiasis morbidity to acceptable levels. The proposed location of this pilot project is in the Kaele Division of the Extreme North Province of Cameroon, a region of over 5000 square kilometers that is heavily afflicted with both *Schistosoma haematobium* and *S. mansoni*. The major emphasis is to be placed on control of *S. haematobium*, primarily because it is more likely to cause measureable morbidity, it can be more readily diagnosed, and it can be treated with the relatively inexpensive drug metrifonate. The following specific objectives have been developed:

- To emphasize public health education to motivate villagers, particularly children from ages seven to 19, to seek treatment. Stimulation of community-based efforts to reduce the risk of transmission through improved sanitation and by limiting water contact at transmission sites is also an important goal of this educational effort.

- To develop simplified, standardized methods of diagnosis and decentralized mechanisms for delivery of drugs to infected individuals.

- To implement control of schistosome-transmitting snails through focal application of the molluscicide Bayluscide in small, temporary ponds and streams that are major transmission sites in the Kaele Division.

The project will be staffed largely by individuals from the Cameroon Ministry of Health. Many of these individuals received higher degrees from Tulane University during the seven-year tenure of the original HCRP. Tulane's School of Public Health will provide technical support and in-country training as it did during the original HCRP. Some of the key individuals to be employed by this project include a medical anthropologist from Tulane and consultants in the areas of drug distribution systems, training, laboratory quality control, and snail control. Two Peace Corps volunteers will also be requested.

2.4 Need for the EA

Largely in response to a request by the USAID/Yaounde Mission Director, an EA has been undertaken to assess potential impacts of Bayluscide (niclosamide), a molluscicidal chemical not previously authorized for use in an A.I.D. sponsored project in Cameroon. The Initial Environmental Evaluation resulted in a positive determination because this chemical is known to be toxic to fish and other aquatic organisms besides snails. Given the potentially wide areas over which it would be applied in northern Cameroon, an EA was deemed necessary.

3. Alternatives – Including the Proposed Action

Alternative: No action taken to control snails

Schistosomiasis, particularly urinary schistosomiasis, is a major public health problem in Cameroon, where more than 300,000 people are believed to be infected. It is very unlikely that long-term efforts to control schistosomiasis can succeed without some attempt to control the intermediate host snails (see discussion of WHO Expert Committee, 1985). For example, efforts to control the disease through the use of chemotherapy alone are unlikely to have any lasting impact because 100 percent of infected people (and any infected animal reservoirs) would have to be repeatedly treated to prevent infection of snails. Even if the number of infected snails is drastically reduced as a result of drug treatment infected people, transmission to people would probably continue, aided by the extensive ability of schistosomes to reproduce asexually in snails.

Without some type of snail control, it is likely schistosomiasis will continue to inflict an unacceptable burden of suffering on the citizens of Cameroon. It is particularly unfortunate that much of the brunt of infection is borne by children. It is concluded that this situation is intolerable and that the course of "no action to control snails" is neither cost-effective nor humane.

Alternative: the use of bayluscide to control snails

As stated above, the inclusion of snail control in schistosomiasis control programs greatly enhances the prospects for long-term reduction in morbidity and prevalence. One means of snail control is the use of molluscicidal chemicals. The only commercially available molluscicide is Bayluscide.

Bayluscide has been used for nearly three decades in schistosomiasis control programs in Africa, South America and Asia. It has been used in both area-wide application programs, particularly in Egypt and the Sudan, and focal programs. Although the cost of Bayluscide is becoming prohibitive for area-wide applications, its use in focal applications is feasible and has an important role to play in control (see review by Klumpp and Chu, 1987). Because habitats to be treated in the project area are both small and temporary, the use of Bayluscide is considered feasible. Bayluscide is toxic to fish, but pisciculture is not practiced in the habitats in Cameroon where its use is proposed. It is concluded that for the purposes of this pilot program, where one of the important goals is to determine whether snail control can be a cost-effective compo-

nent of the overall control effort, the use of Bayluscide is a viable alternative.

Alternative: the use of other molluscicides

Non-synthetic molluscicides derived from plants are being actively considered as possible alternatives to expensive, imported compounds (Kloos and McCullough, 1982). One of the most prominent of these is endod, a saponin derived from the berries of the plant *Phytolacca dodecandra*. Although the use of plant-derived molluscicides has been considered a cost-effective alternative control strategy for some habitats in Ethiopia and Zimbabwe, it does not appear to be a feasible option at present for northern Cameroon. Indigenous molluscicidal plants have not been adequately characterized and studied. Also, many of the plant-derived molluscicides are broadly toxic to other aquatic organisms. Additional toxicity testing, particularly of long-term cumulative effects on both vertebrates and invertebrates, is required. Complicated extraction processes may be required to refine the molluscicidal components from the source plants. Therefore, the use of alternative molluscicides does not seem to be a viable options at this time. Such alternatives should be more fully explored in future research projects on snail control in the West African region.

Alternative: other methods of snail control

Other options exist for the control of freshwater snails, including environmental modification and biological control (reviewed by Brown, 1980). Modifications of habitats, including clearing of vegetation, steepening of banks, increasing the rate of water flow, and deliberate manipulation of water levels, are really not feasible options in the small, ephemeral, rain-filled habitats that are the primary targets for the proposed control operations. There is virtually no way to control the flow of water into or out of these habitats, which often do not last long enough to develop substantial macrophyte populations. Mechanical methods for removal of macrophytes are not available for the local villagers, and manual weed control would increase human water contact and possibly exacerbate transmission. In habitats such as irrigation canals in rice-growing areas of northern Cameroon, habitat modification, primarily by periodic drying and cleaning of canals, may well be feasible. This possibility is clearly acknowledged in the proposal and would not pose any environmental problems in such man-made habitats.

Biological control of target snails through the use of predators, parasites or competitors is an attractive concept for several reasons: avoidance of use of toxic chemicals; potentially low cost; and sustain-

ability of control. Unfortunately, the habitats in which schistosomiasis transmission occurs in northern Cameroon are not readily amenable to the use of biological control, primarily because of their ephemeral nature. Successful biological control of freshwater snails is generally considered to require permanent, relatively stable habitats where biotic interactions such as predation or competition assume more significance. Successful biological control also requires the availability of a safe, efficacious control agent. No such agent has been identified for use in northern Cameroon.

4. Affected Environment

The proposed location for this project is in Kaele Division, Extreme North Province, Cameroon. This division encompasses an area of approximately 5033 square kilometers, and contains a total population of about 230,000. Its population density is about 46 per square kilometers. Approximately 10 percent of the inhabitants of this division live in the towns of Kaele, Mindif and Guidiguis. The remaining 90 percent live in small villages. The major ethnic groups are the Foulbe, Toupouri, Moudang and Guisiga. Most of the inhabitants are poor pastoralists or agriculturalists. In 1986, the HCRP estimated the prevalence of *Schistosoma haematobim* in this district as 50.5 percent and *S. mansoni* as 9.0 percent.

This area is characterized by low rainfall (<500mm per year) which falls primarily during a single rainy season (May-August). This seasonal rain creates many small, temporary bodies of water, which have been shown by the HCRP to be the major schistosomiasis transmission sites in the area. Typically these small ponds (less than 100m in diameter) and residual pools in the temporary streams, or "mayos," hold water from the onset of the rains in mid-May until they dry in December. Two species of bulinid snails involved in transmission of *S. haematobium* inhabit these waterbodies, *Bulinus (Physopsis) globosus* and *Bulinus senegalensis*, both of which are able to aestivate in dried mud during the long dry season. Seasonal studies performed as part of HCRP indicate that transmission is at a relatively low level during the rainy season and picks up abruptly in September-October at the onset of the dry season. The transmission season is concluded in December with the drying of most of these habitats.

Human contact with water in these habitats is assured by a number of activities, including collection of drinking water, watering of domestic stock, clothes washing, small-scale irrigation projects, and recreational use. The habitats are too short-lived to support populations of fish of sufficient size to be feasibly exploited for human consumption. Fish are present in these environments but they represent small species that enter the pools during floods, subsequently become stranded, and die. Other prominent components of the fauna of these temporary waterbodies include tadpoles and frogs, a large variety of aquatic insects, and small crustaceans such as copepods, cladocerans, amphipods, tadpole shrimp and glass shrimp. Representatives of the latter two groups are too small of be of any economic value.

5. Environmental Consequences: Issues, Analysis and Mitigation Measures

This section addresses the list of questions pertaining to the use of pesticides under A.I.D. Regulation 216.3 (b)(1) specifically adapted to the proposed use of Bayluscide as part of an extended HCRP project.

Bayluscide (Niclosamide)

5.1 General background and the USEPA registration status of Bayluscide

A detailed review of the chemical properties and biological effects of this molluscicide has been published by Andrews et al. (1983). Madsen (1987) has also provided a helpful, pragmatically oriented review with extensive handling and mixing instructions. Both documents should be consulted for additional details. Niclosamide is registered with USEPA (EPA Reg. No. 3125-136 for the 70% wettable powder) and is classified as a restricted use pesticide. In the United States, it is approved for use as a molluscicide only by public health officials and other trained personnel of public health programs. This use has been solely in Puerto Rico, the only U.S. locale with schistosomiasis.

The molluscicidal ingredient is niclosamide or its ethanolamine salt, depending on the formulation. Niclosamide kills juvenile and adult snails and snail eggs. It also kills the free-living stages of the schistosome life cycle, miracidia and cercariae. Niclosamide has also been marketed as an adult cestocide (e.g. Yomesan) and it has been used for control of lamprey eels in the United States and Canada. Additional information about its technical characteristics is presented in Appendix 2 and a copy of the U.S. label, including instructions for safe use, is provided in Appendix 3.

Bayluscide is manufactured by Bayer, Inc., in the Federal Republic of Germany, and by Mobay Corporation, a U.S. subsidiary of Bayer (Agricultural Chemicals Division, Kansas City, Missouri, 816-242-2582). It is formulated as a 25% emulsion concentrate (Bayluscide EC 250) or as a 70% wettable powder (Bayluscide WP 70) for use as a molluscicide. The latter formulation is proposed for use in the HCRP extension. It contains 81% (W/W) niclosamide ethanolamine

salt corresponding to a niclosamide content of 70%. The wettable powder wets readily when added to water and suspensions are easily applied to moving or impounded waters. Suspensions require continuous agitation to ensure even application. The manufacturer's recommended dose for niclosamide as a molluscicide is 0.5 ppm in stagnant water and 0.5-1.0 ppm in flowing water. These concentrations should be maintained for at least 24 hours.

Niclosamide is stable thermally but is subject to photodegradation. For example, Bruaux and Gillet (1961) found that the activity was reduced by 80 to 90 percent after 24 hours of irradiation of solutions containing molluscicidal concentrations of Bayluscide. It is also biodegradeable; solutions of Bayluscide containing bacteria or fungi begin to lose their activity after 48 hours (Etges et al., 1965, 1969). Niclosamide can also be degraded in soil.

5.2 Basis for selection of the requested pesticide

As previously stated, the long-term efficacy of schistosomiasis control is likely to be greatly enhanced by simultaneous use of chemotherapy to kill adult worms and molluscicides or other measures to kill intermediate host snails and the free-living stages of schistosomes. During the project's first seven years, HCRP succeeded in describing the geographic distribution of schistosomiasis, the snails involved in transmission, and seasonal aspects of the dynamics of transmission.

The stage is set to begin pilot control efforts based on this knowledge. Unfortunately, there are very few viable options to consider for snail control. The only commercially available molluscicide is Bayluscide and the expense of this compound is prohibitive for use in blanket coverage of all potential transmission sites. It is best suited for applications where waterbodies are small, where application does not have to be continued throughout the year, and where fish culture does not provide a major source of protein for the local inhabitants. It is precisely this set of conditions that exists in the proposed project area, providing the justification for use of Bayluscide.

As stated in the proposal, one of the project's goals is to determine whether the use of Bayluscide can be cost-effective and practical under these circumstances. The present plan calls for the application of Bayluscide to habitats in the vicinity of approximately 20 villages in the Kaele District. It is estimated that each village will have approximately four water contact

sites requiring treatment at the most twice per year. A total of 160 applications per year are contemplated. If it is assumed that the water volume of each site is small (approximately 200m^3 per habitat), each requiring an estimated 300 g of Bayluscide to achieve a working concentration of 1 ppm, then a total of 48kg of Bayluscide will be required per year. At an estimated cost of approximately $40.00 per kg, the total annual estimated cost of usage is only about $2000 per year. The cost obviously depends on the volume of water to be treated and would quickly become unmanageable if larger or more numerous waterbodies were to be treated.

5.3 Extent to which the proposed pesticide use is part of an integrated pest management program

The concept of integrated pest management, although generally considered in the context of arthropod-transmitted infectious agents, is also validly applied to the control of snail-transmitted parasites such as schistosomes. Accordingly, snail control represents only one part of the proposed extension of the HCRP. Another important component of the project is health education, which will motivate villagers to seek treatment and reduce the risks of exposure and contamination of the environment by more enlightened water use practices. Another important goal is to develop simplified, decentralized procedures for diagnosis and drug delivery. These activities can be integrated with the primary health care system already in place in Kaele Division. Other possible components of an integrated control program, such as biological control of snails or environmental modification of transmission sites, have also been considered and generally are not applicable to the particular circumstances of transmission in this area.

5.4 Proposed method of application, including availability of appropriate application and safety equipment

The Bayluscide formulation to be used is supplied as a wettable powder and will initially be dispensed from a 55 gallon drum, which will be stored in a locked and guarded area within the regional headquarters of the Department of Preventive Medicine, MOH, in Maroua, Extreme Northern Province. A medical technician at the division level will receive specific training from technical staff in the proper handling of this compound and will be employed to prepare pre-weighed packages of Bayluscide. These packages will be

distributed to designated subdivisional health workers who will also receive specialized training from technical staff on the safe handling of Bayluscide. It should be added here that one of the goals of the project is to develop simplified methods of molluscicide application so that relatively unskilled workers can perform this task. This is an important part of making the use of molluscicides cost-effective.

Water contact points requiring treatment will be determined by the technical team. This information will be relayed to the health workers trained to apply molluscicides. To keep costs at a minimum, all contact points will be treated without specific verification of the presence of snails or their involvement in transmission. The size of each contact site will be determined by workers, who will pace the circumference of the sites. A chart provided by the technical staff will be used to relate the number of pre-weighed bags of Bayluscide to be applied to the number of paces in the circumference of the site. The worker will then mix the Bayluscide in a simple garden watering can holding 10 liters of water. The mixture will be applied by pouring from the can along the fringe of the habitat, completely using up the contents of the can in one full circuit of the site.

Details on dispensing and applying Bayluscide to the habitats are specified in the project paper and are summarized here. The most important consideration is that the Bayluscide powder (which is an irritant to mucous membranes) should not be allowed to blow into the nose, mouth, or eyes of the handlers. This would be of particular concern to handlers working in very confined spaces or in windy areas where the powder could blow into their faces. Accordingly, a disposable mask to cover the nose and mouth and safety goggles or a face mask should be mandatory safety items for individuals handling this compound. Although Bayluscide is not a strong skin irritant, long-sleeved shirts and full-length trousers rather than shorts are appropriate garments for handlers. Gloves should be worn to prevent contact while weighing and dispensing Bayluscide powder.

Once the formulation is mixed and ready to apply, workers should wear boots and gloves to prevent contact with the water so they do not contract schistosomiasis. This would also minimize any skin contact with water containing relatively high concentrations of Bayluscide.

Although the safety requirements specified are relatively simple, it will nonetheless probably be necessary to deliver disposable gloves, safety masks, rubber boots and gloves, and watering cans to the project site. These items are unlikely to be available locally.

5.5 Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use

The proposed use of Bayluscide as a molluscicide is not expected to present acute or long-term toxicological hazards to humans. This compound has been used for many years and has been relatively well-characterized toxicologically (again, refer to the review of Andrews et al, 1983). The active ingredient, niclosamide, has very low acute oral toxicity (oral LD^{50} > 5000 mg/kg in rats) and is absorbed slowly across the intestine or through mucous membranes or the skin, regardless of formulation. As noted, it is an irritant of mucous membranes however. In short-term investigations, it has no cumulative toxic effects when orally or cutaneously administered to laboratory animals. Long-term studies have revealed no carcinogenic, mutagenic or teratogenic effects.

Studies of niclosamide in humans have been undertaken, particularly because of its utility as a cestocide. These studies have shown that it is only partially absorbed from the intestine; serum concentrations following administration of a 2000 mg dose to volunteers peaked at 0.25-6.0 ug niclosamide per ml serum. Elimination via the urine and feces was almost complete by one to two days in the same volunteers (Duhm et al., 1971). With respect to acute toxicity, no reports of damage have been reported even though niclosamide has been in use as a cestocide throughout the world since 1960.

Andrews et al. (1983) conclude that even prolonged contact with niclosamide will not result in cumulative toxicity. They also conclude that niclosamide does not accumulate in skeletal muscle of domestic animals or fish and therefore does not pose a risk to humans eating meat or fish products. The risk involved in drinking or contacting Bayluscide-treated water is considered to be negligible. It has been calculated that a person drinking two liters of treated water per day (a total intake of about 2 mg of niclosamide), ingests a thousand times less niclosamide than someone taking the therapeutic dose routinely used to treat tapeworm infections in people. Swimming in treated water is also of negligible concern because of

low acute cutaneous toxicity and because the low concentrations required to kill snails (<1mg/l) do not cause eye irritations.

The same general considerations apply to livestock, which, based on available data, are no more affected by niclosamide than laboratory mammals or humans. There is no compelling evidence to indicate that niclosamide is harmful to economically-significant vascular plants at molluscicidal concentrations (Gonnert, 1961), including all major aquatic or terrestrial crop plants, or that it is accumulated in any substantial way by such plants. Rice can be stunted by long-term (2 months and longer) exposure to concentrations ten times the molluscicidal dose (Strufe, 1968); as rice is not grown in the project area and because it would be almost impossible to maintain such high concentrations long enough to affect rice plants, there is no perceived danger to rice cultivation. Some small aquatic plants such as *Lemna*, *Salvinia*, and *Azolla* can be affected to some degree by Bayluscide, but it can be concluded that any set back in their growth would be temporary and would have no significant lasting environmental effect (Andrews et al, 1983).

The primary concern about the use of niclosamide is its toxic effect on fish, frogs and selected invertebrates. Molluscicidal contrations of Bayluscide will almost certainly kill fish and amphibians, so the potential impact on pisciculture must be carefully assessed. Selective removal of fish also could have unforseen effects on other parasites of public health significance. For example, the removal of fish that exert some measure of natural control of mosquito larvae could have a major detrimental impact on malaria control operations.

After discussing this issue with Cameroonian officials and villagers, and after personally visiting some of the proposed treatment sites, I am convinced that the use of Bayluscide poses no substantial environmental risk in this particular project. Because the waterbodies to be treated are ephemeral, they are inhabited by relatively few species of animals of no commercial value. Most fish of commercial value in Africa can not tolerate total drying of the habitat. One exception that should be considered is the African lungfish (*Propterius*), which is present in the habitats to be treated. However, because the size of these habitats is so small, they simply do not support large numbers of fish. Dried fish are available for sale in the local markets but I was told they came from the Logone River or Lake Tchad, not from small local waterbodies. Therefore, it

is concluded that there is essentially no pisciculture in the proposed treatment areas.

Regarding other potential environmental effects, although some invertebrates such as microcrustaceans are affected, the result is usually short-lived and their populations quickly rebuild to pre-application levels (e.g. Schiff and Garnett, 1961). In fact, there may be some beneficial impact of niclosamide treatment on guinea worm transmission because of its transient effects on copepod populations. Amphibians are also likely to be affected. Insofar as they are common in the sites to be treated and serve as important predators of insects, the removal of amphibians may have a measureable effect on medically-significant insects. This is by no means certain, however, and should be investigated during this pilot project (see Recommendations).

It should be appreciated that because the sites to be treated are ephemeral, they are inhabited by relatively simple organisms adapted to cope with unfavorable conditions that exist for much of the year. Important characteristics of such organisms are their good colonizing ability, ability to withstand harsh conditions in a dormant condition, and ability to increase rapidly in numbers. The organisms found in such environments are adapted to cope with disturbances; the use of molluscicides simply represents a somewhat different type of disturbance and should be well-tolerated. It should also be appreciated that Sahelian Africa contains innumerable habitats of this description, which will provide a vast source of biological material to repopulate treated areas. For these reasons, any unforseen adverse effects on nontarget organisms resulting from the use of Bayluscide are not likely to persist for more than a year or two. However, this same set of biological circumstances also dictates that snails will rapidly recolonize and proliferate in such habitats. Yearly applications of molluscicides may therefore have to continue for long periods, depending on the rate at which schistosome populations are diminished as a result of the overall control effort.

Finally, it is possible that the use of molluscicides near villages will provoke local people to change their water use patterns out of an erroneous concern that their source of drinking water has been poisoned. It is conceivable that this could pose a problem if, for example, water use is suddenly switched to waterbodies that are further away or more polluted.

5.6 Measures available to minimize hazards

The following measures are available to minimize any hazards associated with the use of Bayluscide, and are listed in the proposal:

1. Use in accordance with instructions supplied by the manufacturer (see Appendix 3). Note in particular the guidelines provided regarding safe storage and disposal conditions, and steps to be taken for treatment following accidental contact with eyes or skin, or if accidentally swallowed or inhaled.

2. Appropriate technical staff should instruct both division-level and subdivision-level handlers in the basic properties, methods of storage and disposal, handling and application, possible hazards, and known environmental consequences of the use of Bayluscide. The effectiveness of this training should be evaluated, preferably by direct observation by technical staff of application of the chemical to the environments to be treated.

3. Store major stocks of Bayluscide in a dry, ventilated, secure facility away from frequented areas, out of direct sunlight and out of the reach of children.

4. Disposable face masks and gloves should be provided to the individuals charged with dispensing and mixing Bayluscide. Special uniforms are not required but handlers should be encouraged to minimize skin contact.

5. Bags used to hold pre-weighed aliquots of Bayluscide powder should be filled in open, but wind-free locations, and the bags should be sturdy so they are not broken during handling or transport. The proposed method of dispensing pre-weighed packages of Bayluscide is appropriate because a significant portion of the required handling can be carried out in a centralized facility, resulting in no extra, unnecessary handling.

6. Mixing of the powder with water should take place in open, but sheltered and wind-free sites.

7. Normal precautions, such as wearing knee-high rubber boots and gloves, should be taken to prevent exposure to schistosome infection during application of Bayluscide to target sites. Applicators should submit fecal and urine samples annually to monitor possible schistosome exposure.

8. Secure prior approval from, and provide information to, appropriate local authorities (i.e. local chiefs) so they do not become alarmed for their safety if they notice dead fish or amphibians subsequent to molluscicidng. This will be worked into the general public education campaign, which is an important component of this project.

9. Maintain sensitivity to safety issues throughout all levels of the project through an annual review by the appropriate technical staff of the standard precautions taken in handling this compound.

10. Require the handlers of this compound to submit to annual general physical exams to monitor any unforseen or novel problems resulting from the handling of Bayluscide.

5.7 Effectiveness of the required pesticide for the proposed use

After its initial development in the late fifties, Bayluscide has been used for many years as a molluscicide for schistosomiasis control operations (see reviews by Cheng, 1974; Mott, 1987; Klumpp and Chu, 1987). In area-wide snail control programs, such as the Egypt 49 project (Gilles et al. 1979) or the Fayoum, Egypt project (Mobarak, 1982), its effect on reducing transmission can be considered equivocal. Area-wide use cannot be condoned simply because of the expense. Klumpp and Chu (1987) estimated that the cost of Bayluscide in area-wide control programs could exceed by a factor of greater than ten the total cost of chemotherapeutic agents such as praziquantel or metrifonate.

Any cost-effective use of Bayluscide will therefore require focal seasonal application, particularly in arid regions where water volumes are small (McCullough et al., 1980). Several studies indicate that this approach can be successful in controlling transmission (see that review by Klumpp and Chu, 1987).

Transmission in northern Cameroon is compatible with focal seasonal application of Bayluscide. Given that the number of water contact sites proposed to be treated in this pilot project is small (approximately 80), the prognosis for successful snail control using Bayluscide at these sites is good.

There is a large body of data to suggest that bulinid snails are relatively uniformly susceptible to the manufacturer's recommended dose of 0.5 ppm in standing water (Andrews et al., 1983). Some preliminary work with this compound has been undertaken with Cameroon specimens of *Bulinus* and it has been shown to be effective in killing snails at recommended levels (Greer, personal communications).

Conditions existing in the habitats to be treated should not preclude molluscicidal concentrations of Bayluscide from being readily attained. For example, the pH in these ephemeral habitats is typically 6.5-7.0, a range that is compatible with full activity of Bayluscide. The water in the habitats to be treated is moderately hard (approximately 100-200 mg CaCO^Y3^Y/l). Because the molluscicidal activity of Bayluscide decreases in hard water, it may be necessary to increase the dose. This will probably require empirical testing in the field. The presence of varying amounts of submerged and emergent vegetation in the treatment sites may also require some adjustment of concentration of the molluscicide. Habitats densely choked with vegetation will require higher doses, both because of impeded distribution of the chemical and absorption of the active ingredient by plants. Because niclosamide is adsorbed by suspended particles, to the extent possible, the molluscicide should be applied at times when the turbidity of the water is low. Applications should not follow heavy rains nor should they immediately precede use of the habitats by domestic animals, which are likely to muddy the water.

As a final comment regarding the efficacy of Bayluscide, one possibility that must be considered in the application of any pesticide is the development of resistance by the target species. There is no definitive answer to this question regarding the use of Bayluscide to control snails. However, results in Iran (Mansoori et al., 1976) and in St. Lucia (Barnish and Prentice, 1981) did not indicate the development of any significant degree of resistance over periods of five to nine years of continuous use. In the author's opinion, it is unlikely that the snails to be treated will develop a significant degree of resistance over the three year project period. Longer per-

iods of continuous use obviously increase the risk of development of resistance.

5.8 Compatibility of the proposed pesticide with target and non-target ecosystems

As previously stated, the molluscicidal ingredient in Bayluscide, niclosamide, is biodegradeable and photolabile. Effective concentrations of this compound are expected to reach very low levels within a few days after application. Also, because any affected organisms are likely to recolonize the treated habitats from other sources no later than the following rainy season, it seems unlikely there would be any permanent effect of Bayluscide in the target environment. It should be appreciated that many of the target habitats are highly modified by human activities. In particular, they may be used for washing vehicles, watering livestock, or depositing raw sewage. The target habitats are often polluted by large quantities of organic wastes, so it seems unlikely that addition of Bayluscide could have any measureable effect except on fish and amphibians, a topic that has been discussed at length in section 5.5.

Any danger to non-target habitats would probably occur either in the central location where stocks of Bayluscide are stored, or at the periphery of the habitats to be treated. Regarding the central storage area, any spills of the powder from large storage drums should be swept up immediately, and disposed in such a way that water, food, or feed can not be contaminated. Disposal in a sanitary landfill would be preferable because the material is biodegradeable in soil. When the original storage container is empty, it should not be reused in connection with food, animal feed, or drinking water. It should be completely emptied, then disposed of in a sanitary landfill or, if permitted, by burning.

At the periphery of habitats to be treated, the amounts to be handled would be small (less than 1 kg at any one habitat). Any spilled material should be recovered as best as possible, mixed as appropriate, and applied to the habitat. Any remaining material on the soil will degrade naturally and is not anticipated to pose a serious contamination problem. Probably the most important consideration is that emptied packets of molluscicide should be retained, traded in for full packets, and eventually disposed of by burning or by burial in a sanitary landfill.

Again, it seems unlikely that the proposed use of Bayluscide would cause any significant damage to non-target environments. The proposal includes a detailed statement on the appropriate steps to minimize danger to the environment.

5.9 Conditions under which the pesticide is used, including climate, flora, fauna, geography, hydrology and soils

Bayluscide is used in both tropical and temperate freshwater aquatic environments, ideally in a pH range of 6-9. Its molluscicidal activity increases with temperature, and temperatures existing within the treated habitats (20-30^Xo^XC) are compatible with activity. Its activity is diminished in hard water (Meyling et al., 1962). Thick aquatic vegetation can impede its effectiveness by preventing adequate mixing in the water and by either adsorbing or absorbing activity from the water; however, the latter effects are not believed to significantly reduce the effective concentration. Bayluscide is also adsorbed from the water by suspended soil particles and bacteria. The latter may degrade niclosamide as a source of nitrogen.

Additional details may be found in Andrews et al. (1983). Additional information about the habitats to be treated is found in sections 4, 5.5, and 5.7 of this report.

Bayluscide is used most effectively either in small water bodies, in which the entire water volume is treated, or at specific water contact points in larger water bodies, such that snails likely to be be involved in transmission of schistosomiasis are selectively eliminated.

5.10 Availability and effectiveness of other pesticides or non-chemical control measures

As stated previously, Bayluscide is virtually the only commercially available molluscicide. Other methods of snail control are either not yet feasible or inappropriate for the habitats to be treated. One option is to encourage research on plant molluscicides, preferably originating from plants indigenous to Cameroon, that might eventually be used in place of imported synthetic compounds. This process is likely to take several years, as appropriate toxicity testing would have to be carried out. Research into biological methods of control is also to be encouraged at the local level. If possible, attempts should be made to identify indigenous freshwater predators or

competitors able to control snails in the shortlived environments in which transmission occurs. Again, it is likely to be several years before this approach becomes operational.

In the case of urinary schistosomiasis transmission in northern Cameroon, the best non-chemical control methods are public education to minimize contamination of habitats, and aggressive chemotherapy. Both of these methods are incorporated into the present proposal design. Another method, which is probably beyond the means of the country, is to provide additional sources of safe drinking water.

5.11 Requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide

Responsibility for regulation of the use of Bayluscide in the Republic of Cameroon lies with the Ministry of Health (MOH). To the author's knowledge, this compound has not been used previously by the MOH, so it is difficult to assess the ministry's ability to effectively regulate its use. The MOH is charged with the responsibility of handling other pesticides used in public health programs, so it is not without experience in this realm. Because there is no precedent for use of this compound in Cameroon, it is recommended that the technical staff associated with this project work closely with the MOH to develop guidelines for storage, handling, application and disposal of Bayluscide. Such collaboration is also encouraged in the proposal. It is appropriate because MOH personnel are to be intimately involved in all aspects of the project. Many of the key members of the MOH team have recently received higher degrees from Tulane University, which has provided, and probably will contine to provide, technical staff. Certain components of this report can be used in creation of such guidelines.

5.12 Provisions made for training users and applicators

Because Bayluscide has not been used previously in Cameroon, it is necessary to document the provisions used to train users and applicators. This topic is addressed in the proposal. Recommendations provided as part of this assessment should be considered in developing training protocols.

5.13 Provisions made for monitoring the use and effectiveness of the pesticide

The proposal provides details on how Bayluscide use will be monitored and how its efficacy will be assessed. The recommendations at the end of this assessment should be consulted as these protocols are developed.

5.14 Will the pesticide affect endangered or threshold species?

In the author's opinion, the answer to this question is no. First of all, the number of habitats to be treated is small. They are representative of a vast number of comparable rain-filled ephemeral pools that exist in this region in Africa. Indeed, from the air, one is impressed by the large numbers and high density of these pools that form in the Kaele area. As previously indicated, such habitats typically contain depauperate assemblages of species.

The habitat types to be treated are certainly not rare, ancient, or far-removed from other waterbodies. That is, they do not conform to conditions expected to result in the evolution of potentially rare endemic species. Furthermore, these habitats are often highly disturbed by activities of humans and domestic livestock, which collectively pose a far greater danger to the original or natural composition of species than does Bayluscide. All water bodies to be treated are situated at least 100 km from Waza National Park, which, because it represents a habitat relatively unspoiled by humans, would be a far more likely place to encounter endangered species.

Unfortunately, lists of rare or endangered species for the Kaele region are not available so a more specific analysis of this point is not possible at present. For the reasons specified above, however, the risk of endangering rare components of the flora and fauna of the Kaele district through the use of Bayluscide is considered to be insignificant.

Annex 1. Itinerary

July 5	Departed Albuquerque for Washington, D.C.
July 6	Briefing at VBC in Washington, departure for Cameroon.
July 7	Arrival in Yaounde.
July 8	Met with George Greer.
July 9	Met with USAID/Yaounde officials.
July 10	Met with Ministry of Health officials, began preparing report.
July 11	Met with Ministry of Health officials, visited IMPM schistosomiasis laboratory, continued writing report.
July 12	Met with George Greer, traveled with him to Maroua, Extreme Northern Province, proposed project site.
July 13	Visited project sites, including town of Kaele and village of Guereme, with George Greer, collected snails, observed habitats, met with Helen Regis, talked to local villagers.
July 14	Visited additional possible study sites near Maroua and Mora, visited guinea worm transmission site.
July 15	Returned to Yaounde.
July 16	Visited USAID, continued writing report.
July 17	Continued writing report.
July 18	Visited USAID to turn in draft of report, visited additional snail habitats near Sangmelima.
July 19	Wrote appendices and prepared recommendations for report.

July 20	Met with USAID officials (Songer, Washington, Bennett, Olson) to discuss draft of EA, began revisions of draft, printed a copy for USAID.
July 21	Met with George Greer to discuss revisions of his proposal, met with James Washington to discuss final version of my report, departed Yaounde.
July 22	In transit to Washington, D.C.
July 23	Debriefing at VBC, return to Albuquerque.

Annex 2. People and Places Visited

Dr. Ndeso Atanga	Coordinator, Cameroon National Schistosomiasis Control Program, MOH
Dr. Owona Essomba	Director of Preventive Medicine, MOH
Dr. Remy Mimpfoundi	Cameroon Schistosomiasis Project, Institute for Medical Research and Medicinal Plants, and Faculty of Science, General Biology Laboratory, University of Yaounde
Dr. George Greer	Malacologist, Cameroon Schistosomiasis Project, Tulane Technical Assistance Team
Ms. Helen Regis	Anthropologist, Cameroon Schistosomiasis Project, Tulane Technical Assistance Team, stationed in Kaele, Extreme Northern Province
Mr. George Vishio	USAID/Cameroon, Health Officer
Mr. Robert Shoemaker	USAID/Cameroon, Project Design and Evaluation Officer
Mr. James Washington	USAID/Cameroon, Health Officer
Mr. Carlton Bennett	USAID/Cameroon, Contracting Officer
Mr. Norman Olson	USAID/Cameroon, Project Officer
Mr. David Songer	USAID/Cameroon, Agricultural and Rural Development Officer
Unidentified Villagers	Guereme Village, within the proposed project site

Places

USAID/Yaounde

Ministry of Health, Department of Preventive Medicine, Yaounde

Schistosomiasis, Institute for Medical Research and Laboratory Medicinal Plants, Yaounde

Proposed study site, Guereme Village, Extreme Northern Province

Typical snail habitats in and around towns of Maroua and Mora, Extreme Northern Province

Typical snail habitats in and around town of Sangmelima, southern Cameroon