RATIONALE FOR SELECTING MOLLUSCICIDES FOR BILHARZIA CONTROL PROGRAMS

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WITH THE DISCOVERY of many new chemicals which are toxic to aquatic snails, selection of the best molluscicide for bilharzia control programs has become more complicated. In the past relatively simple indices have been used to compare molluscicides.

The simplest index was *CT*, the product obtained by multiplying the applied concentration, in milligrams per liter, which gives complete mortality ($LC_{99.5}$) by the length of time, in hours, this concentration must be applied T_a. The value obtained is directly related to the total amount of chemical needed to kill adult snails and eggs in a given amount of water, and for a specific chemical the *CT* indicates the most efficient application time.

The *CT* was generally considered to be constant for all application times of a specific chemical (*1*, *2*). However, data on *Biomphalaria glabrata* from Puerto Rico show that the *CT* is not constant (table 1).

The *CT* will not serve to compare different chemicals because the price of the chemical is not included. This lack of comparability can be remedied by multiplying the market price of the chemical (*D* in U.S. dollars) by the *CT*, which gives the *CTD* (table 1).

The *CTD* is a better indication of the relative values of chemicals for applications to still-water. However, the toxic stability of each chemical is different. Thus, the *CTD* has little bearing on applications to flowing water because the length of stream treated by one molluscicide application depends on the toxic stability of the chemical.

In addition, the cost of labor for applying the molluscicide is not included in the *CTD*, and this cost may be an important factor. To include all of the factors just discussed in selecting the best chemical for a program to control aquatic snails, it is necessary to go beyond these simple indices.

For flowing water situations, a cost analysis of molluscicidng is proposed, based on a mathematical model for one application. The analysis takes into account the *CTD*, the stability of the chemical, the cost of labor, and flow conditions. From this model the average cost for each kilometer of treated stream can be approximated for a specific molluscicide under given conditions. Thus, the available molluscicides can be compared under local hydrologic conditions and prevailing labor costs.

Model of Molluscicide Application

The three variables in the molluscicide application model are the cost of the chemical *a*, the cost of labor *b*, and the length of stream in which all snails and eggs are killed L_t. Thus the sum of *a* and *b*, divided by L_t gives the average cost per unit length of stream treated.

Experimental data needed for the model are the toxic half-life *A* of the molluscicide in hours for the given water quality and incident sunlight, and the toxic concentration C_t in milligrams per liter for each proposed application time. One must also specify the concentration to be applied C_o in milligrams per liter and the toxic concentration C_t. Other data needed include the cost *D* of the chemical in U.S. dollars

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Table 1. *CT* and *CTD* values for 3 molluscicides used to control *Biomphalaria glabrata*

Chemical	CT* if applied for—			Assumed price per kilogram of active ingredient	CTD** if applied for—		
	1 hour	6 hours	24 hours		1 hour	6 hours	24 hours
NaPCP	170	216	108	$0.86	146	186	93
Bayluscide	3.0	6.0	6.2	13.00	39	78	81
$CuSO_4$	25	60	60	.88	22	53	53

**CT* = Figure obtained by multiplying the concentration, in milligrams per liter, which gives complete mortality (the $LC_{99.5}$) and the time, in hours, that this concentration must be applied. The values used were those necessary to kill both eggs and adult snails of the Puerto Rican strain of *Biomphalaria glabrata*. SOURCE: reference 3.

***CTD* = *CT* x price.

per kilogram of active ingredient and the hourly wage W paid to the laborers. The average stream velocity V in centimeters per second and the discharge Q in liters per second must be specified from a simple hydrologic study of the general area to be treated.

The number of man-hours H of labor required for the average treatment is a rather difficult value to obtain since exact data will not be available for experimental chemicals. However, an estimate can be made on the basis of similar experience with other chemicals. This estimate must include the time spent measuring the discharge of the stream, mixing the chemical concentrate, dispensing the concentrate for the given number of hours, and dismantling and cleaning the equipment. If overtime wages must be paid for nightwork, this also should be included. The estimates used in this study, based on experience in Puerto Rico, are 4, 8, and 15 man-hours for the 1-, 6-, and 24-hour application times, respectively (*3*, *4*).

Analysis

Using the symbols previously described and including the constants necessary to make the units consistent, the cost components for a single application to flowing water are

$$a+b=0.0036DC_oQT_a+HW \text{ (in dollars).} \quad [1]$$

The length of stream treated is calculated from the time necessary for the applied molluscicide to decay below the toxic concentration, assuming a first order equation of detoxification. This decay time multiplied by the velocity of the stream determines the distance over which the applied wave of molluscicide remains lethal, and

$$L_t=0.12AV \log \frac{C_o}{C_t} \text{ (in kilometers).} \quad [2]$$

Combining these components gives the total cost of controlling 1 kilometer of stream. This unit cost is

$$\frac{a+b}{L_t}=\frac{0.0036DC_oQT_a+HW}{0.12AV \log \frac{C_o}{C_t}} \text{ (in dollars per kilometer).} \quad [3]$$

Three currently used molluscicides are analyzed with this model (table 2). Toxicity values for the molluscicides were taken from recent research on *B. glabrata* (*3*). The local conditions for the analysis included $Q=50$ liters per second,

Table 2. Estimated cost of mollusciciding with 3 chemicals used to control *Biomphalaria glabrata* [1]

Value of interest	Molluscicide		
	X	Y	Z
Molluscicide price, dollars per kilogram	0.86	13	0.88
Optimum application,[2] hours	24	1	1
Required labor, hours	15	4	4
Toxic concentration,[3] milligrams per liter	4.5	3.0	25.0
Applied concentration, milligrams per liter	22.5	15.0	125.0
Toxic half-life,[3] hours	5	50	5
Estimated cost, dollars per kilometer	47.00	1.86	11.30

[1] Calculations are for a stream with a discharge of 50 liters per second and an average velocity of 5 centimeters per second. All 3 molluscicides were applied at an arbitrary factor of 5 times the concentration needed for complete mortality. Wages were $1 per hour.

[2] The application time used for each chemical was that which gave the minimum *CT* (table 1).

[3] SOURCE: reference 3.

V=5 centimeters per second, W=$1 per hour, and the ratio of C_o to C_t was arbitrarily fixed at 5:0; thus the cost per unit length was

$$\frac{0.18DC_oT_a+H}{0.42A}=\text{unit cost in dollars per kilometer.} \quad [4]$$

In this instance the cheapest chemical to use is also the chemical with the highest market price. Its low final cost is due to its long half-life and low labor requirements for the short application time. The calculated costs have been checked against field experience in Puerto Rico and have been found to be of the proper order of magnitude. However, the model should not be used for predicting costs but for comparing and selecting molluscicides.

Summary

A mathematical model of a single molluscicide application to flowing water makes it possible to compare chemicals on a rational basis. The model which was used to compare three chemicals considered for use in Puerto Rico incorporates data on the toxicity of a selected compound, its stability in natural waters, labor costs, and hydraulic characteristics of the stream. Results indicated that the chemical with the highest market price would be the cheapest to use in terms of cost per kilometer of stream treated.

REFERENCES

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Rehabilitating Young Cardiac Patients

A comprehensive study of the effect of congenital heart disease on the motivation and capacity of juvenile cardiac patients to prepare themselves for future employment has been approved by the Social and Rehabilitation Service, U.S. Department of Health, Education, and Welfare. The first-year grant of $175,000 has been awarded to the Children's Hospital Medical Center in Boston, Mass.

The 5-year project will involve a representative sample of young patients with congenital heart disease selected from the New England area. Among the aspects to be studied are the psychological and social effects of early-childhood cardiac defect on the adolescent's attitudes and his ability to adjust to and perform in society.

The availability and effective use of existing facilities for successful preparation for employment will also be investigated. In addition, the relationship of the severity of heart disease to intellectual capacity, incidence of neuroses, and effects of attitudes of friends and family on the patient and his work performance will be studied.

New surgical techniques and drugs have resulted in a notably increased survival rate of children with congenital heart disease. Fifteen years ago few such children lived to the age of 12.

The major problems of adjusting to cardiac disability are enormously complicated by the considerable stresses of childhood development. Now there is need to learn about preparing a future for young cardiac patients, whose numbers will continue to grow.