OPERATIONAL AND SCIENTIFIC NOTES

AN IMPROVED CONSTANT FLOW DEVICE FOR DISPENSING LIQUID MOSQUITO LARVICIDES TO FLOWING WATER[1]

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Recent research employing liquid formulation of *Bacillus thuringiensis* serotype H-14, (*B.t.i.*), for control of *Psorophora columbiae* (Dyar and Knab) larvae in rice fields has brought about a need for automatic delivery of the formulation at a constant rate. Years ago various devices were utilized for dispensing non-phytotoxic oils or emulsifiable DDT solutions (Dunham 1940, Geib and Smith 1949, Knowles and Fisk 1945, Wisecup et al. 1946). Gahan et al. (1955) devised a system that created a static head of liquid independent of the quantity in the main container. This system produced uniform flow rates. Oils and insecticidal chemicals are no longer used on rice fields. A need to improve and alter the device of Gahan et al. (1955) arose because the diluted *B.t.i.* formulation would not reliably flow through a metal orifice at rates of 50–80 ml/min (reason undetermined) and because of costs of metal valves, nozzle tips and pipe which have greatly increased since 1955. Use of this method by a mosquito abatement district would require large numbers of dispensing containers and low cost is essential. The purpose of this paper is to present an economical and reliable constant flow device to use with flowable concentrate *B.t.i.* formulations.

DESCRIPTION OF THE OPERATING PRINCIPLE AND THE DEVICE. The basic principle utilizes a nearly constant height of liquid column to the outlet orifice; gravity creates the pressure for the flow through the orifice. The flow is a function of viscosity, orifice size and height of the liquid column. The constant height of the liquid column over the orifice (or "static head") is created in a 1″ (2.5 cm) diameter vertical reservoir of pipe outside the main container connected horizontally to it by a supply pipe. Liquid flows from the main container through the horizontal pipe into the vertical tube which is open to the atmosphere. The flow of liquid from the container to the outside reservoir creates a partial vacuum inside the sealed main container, resulting in a cessation of flow. Liquid flows out the bottom of the vertical tube through the hole in the stopcock, or the hole drilled in the solid cap (Fig. 1). As the level of liquid in the vertical reservoir drops below the liquid level in the horizontal connecting tube, air is momentarily allowed to return to the main container. The partial vacuum created inside the main container by removal of some of the liquid is therefore reduced, allowing more liquid to flow out the tube to the vertical reservoir. As more liquid flows into the vertical reservoir tube the horizontal tube is filled, closing off the air return into the main container. The process results in a "bubbling" of air back into the main container at regular intervals, a small fluctuation in the height of the static head (3 to 5 mm) and uniform flow from the orifice until no more liquid is available.

The basic device is constructed from polyvinylchloride (PVC) tubing. (Fig. 1). A 1″ (2.5 cm) hole is cut in the container cap (B). A 1″ (2.5 cm) PVC male threaded adapter (A) with a 1″ (2.5 cm) O-ring (C) is inserted through the hole, with the threads projecting outside the cap. Then a 1″ (2.5 cm) PVC female threaded adapter 2″ (5. cm) long (D) is tightened onto the threads, sealing the cap to prevent leakage. The vertical static head reservoir is formed by connecting a 1″ (2.5 cm) PVC tee (F) to (D) by a short (¾″) (1.9 cm) piece of 1″ (2.5 cm) PVC pipe (E).

Construction of the variable flow rate device is shown in Fig. 1. The 1″ (2.5 cm) tee reservoir (F) is reduced by two PVC reducers (G and H), stepping from 1 to ¾″ (2.5 to 1.9 cm) (G); then from ¾ to ½″ (1.9 to 1.3 cm) (H); finally a ½ to ⅜″ (1.3 to 0.9 cm) threaded reducer is inserted (I). A short piece of ⅜″ (0.9 cm) plastic tubing (J) is used to connect to a 4 mm orifice Teflon® stopcock (K). The rate of flow can be adjusted by opening or closing the stopcock.

The fixed flow rate device is shown by the insert in Fig. 1. This device is much simpler and more economical than the variable flow rate device. A piece of 1″ (2.5 cm) PVC pipe (E) is fitted into the 1″ (2.5 cm) PVC tee (F) serving as the vertical reservoir. A 3½ to 4″ (8.3 to 10.2 cm) length will suffice. A hole is drilled into a 1″ (2.5 cm) PVC diam. cap (L) which is fitted onto the end of the pipe. All the fittings are pressure fitted by hand. No leakage occurred in any of the tests.

[1] Mention of a trademark, proprietary product or vendor does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

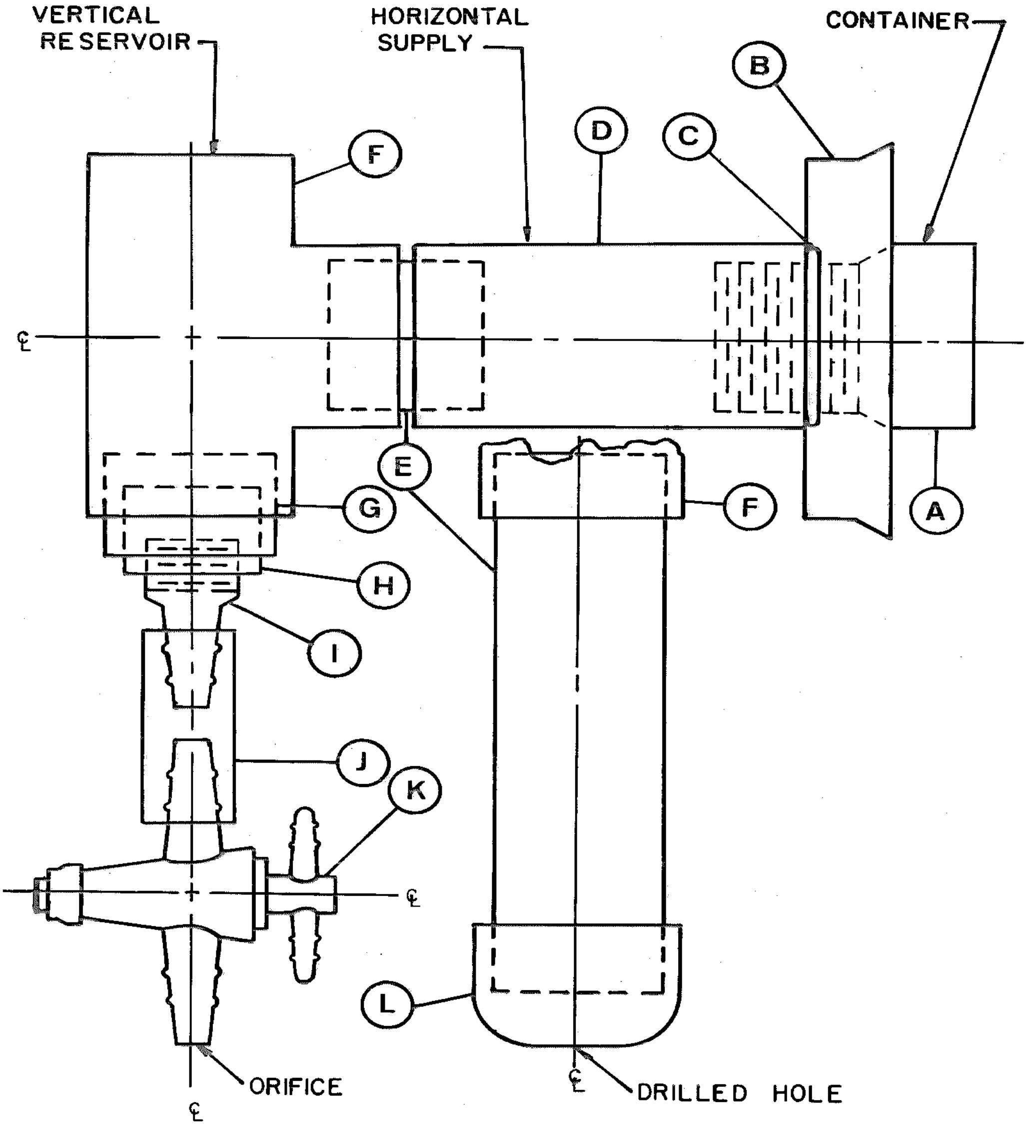

Fig. 1. Constant flow device with variable orifice or fixed orifice (insert). A. 1″ (2.5 cm) PVC male-threaded adapter; B. Cap from 5 gallon plastic container; C. 1″ (2.5 cm) "O" Ring; D. 1″ (2.5 cm) PVC female threaded adapter; E. 1″ (2.5 cm) PVC pipe; F. 1″ (2.5 cm) PVC TEE; G. 1″ to ¾″ (2.5 to 1.9 cm) PVC Reducer; H. ¾″ to ½″ (1.9 to 1.3 cm) PVC Reducer; I. ½″ to ⅜″ (1.3 to 0.9 cm) PVC Threaded Reducer; J. ⅜″ (0.9 cm) plastic tubing; K. 4 mm Teflon stopcock; L. 1″ (2.5 cm) PVC Cap.

The orifice in the cap (L) is drilled with various size bits, depending upon the flow rate desired and the formulation used. The caps can be easily interchanged. Small adjustments in flow rate between that obtained by a different drill bit diameter can be attained by lengthening or shortening the 1″ (2.5 cm) PVC pipe connecting the cap to the tee.

The cost of materials purchased on the open market in January 1982 at Lake Charles, LA, was $11.03 for the variable flow stopcock device and $2.23 for the fixed flow model using the cap with a drilled hole.

RESULTS OF FLOW RATE TESTS. A 3.8 liter (5 gallon) capacity plastic container was used for dispensing formulated *B.t.i.* in rice fields for control of *Ps. columbiae* larvae. The cap was located on the top at the periphery. The container was laid on its side for dispensing a diluted formulation. When the container was level, about 1.4 liters (3 pints) remained after the flow stopped. A slight tilt towards the cap allowed all but ca. 0.5 liter (1 pint) to flow out of the jug. The actual time required to empty the container was observed in eight tests using the stopcock device. The expected vs actual times averaged 266 ± 21.7 min vs. 274 ± 23.4 min. In 3 tests using the drilled cap the expected vs actual times were 260 ± 0.0 vs. 259 ± 4.0 min.

A test was conducted in the laboratory to determine the relative importance of three variables to the flow rate. The variables were the diameter of the orifice, the height of the static head and the dilution ratio of the formulation. The flow rate in ml/min was determined for each test condition. All combinations of the levels of each variable were tested. The orifice sizes were 0.04″ (1.016 mm), 0.041″ (1.041 mm), 0.042″ (1.072 mm), and 0.046″ (1.168 mm). Heights of the static head in the test were 10.0, 11.5, 13.5, 15.5 and 18.5 cm. Concentrations of formulation were 0.0 (water only), 3%, 10%, and 30%. Multivariate analysis by stepwise regression correlation was performed using the model: Flow rate = X (orifice size) + x_2 (height of static head) + x_3 (formulation) + a. Analysis of the data for the correlation coefficient (R^2 value) of each variable independent of the others to the flow rate showed the orifice diameter to have the greatest effect ($R^2 = 0.71$), the static head of next lesser importance ($R^2 = 0.13$) and the concentration of the formulation the least important ($R^2 = 0.09$), for a total of 93% of the variance accounted for by these three variables. The best equation values were: $10{,}734.94\ X + 3.45\ X_2 + 74.84\ X_3 - 493.54$. Therefore, the size of the orifice should be selected first in construction of the flow device to attain the general flow rate desired. Next, the appropriately diluted formulation should be placed in the container and final calibration achieved by adjustment of the height of the static head.

A sample calibration table is presented as Table 1. Flow rates (ml/min) of a 30% TEKNAR[2] suspension in water are presented for 4 orifice sizes, each with 5 static head heights. These data provide guidelines for initial selection of an appropriate combination of orifice size and column height for a desired flow rate. The combination of orifice and column height must be calibrated with the specific formulation and dilution to be dispensed to obtain the desired flow rate.

ACKNOWLEDGMENT. The author recognizes the assistance of Mr. O. R. Willis of the Gulf Coast Mosquito Research Laboratory and the assistance of Alan Inman and Chris Polk of the Jefferson Davis Parish Mosquito Control District in testing the device.

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Table 1. Flow rates (ml/min) of a 30% concentration of TEKNAR[2] in water for 4 orifice sizes and 5 heights of liquid column.

Column ht (cm)	Orifice size 0.040″ (1.016 mm)	0.041″ (1.041 mm)	0.042″ (1.072 mm)	0.046″ (1.168 mm)
10.0	32	36	40	80
11.5	38	38	40	90
13.5	66	48	48	100
15.5	50	56	60	120
18.5	54	60	62	132

[2] A flowable concentrate formulation of *B.t.i.* produced by Sandoz, Inc., 480 Camino Del Rio South, San Diego, CA 92108.

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DO MOSQUITOES FEED ON TROUT?[1]

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In searching unfamiliar literature for documented occurrences that may have led the public to the conviction that effective mosquito control was possible, this reviewer encountered a number of highly interesting items that he believes should be made easily available to current mosquito research and control workers. One such, Mrs. C. B. Aaron writing in the Lamborn Prize Essays (Lamborn 1890), discusses harmful effects of mosquitoes on page 37, as follows: "Perhaps the most surprising charge made against them (Mosquitoes) is that of Murray, who states that he has observed the imago of *Culex* light upon baby trout which come to the surface of the water, and literally pump out their unsuspecting little brains before they could escape."

Fortunately, Mrs. Aaron gave a reference (Murray 1885), and after some difficulty the long out-of-print paper by C. H. Murray was located in an old bulletin. The paper is reprinted here in full, in the belief that this lead should be followed up, and either confirmed, or if it should be that C. H. Murray misinterpreted what he saw, then any evidence so indicating should be interpreted and published.

Further credibility is given the Murray report by Dr. L. O. Howard, who stated on page 35 of his book (1901) as follows: "Moreover, there are several instances on record in which mosquitoes have been seen puncturing the heads of young fish." Unfortunately, he did not cite references, so it is impossible to determine if he was referring only to the same reports of Mrs. Aaron and C. H. Murray (Mrs. Aaron was an entomologist, and Mr. Murray evidently was a prospector and amateur naturalist, but I have been unable to determine if he had any specific training in biological observation, although his statement is indeed detailed and appears to represent keen observation).

(From page 243,
Bulletin of the United States Fish Commission,
Vol. 5, for 1885:)

"60 YOUNG TROUT DESTROYED BY MOSQUITOES."

By C. H. Murray.
(From a letter to Prof. S. F. Baird)

"In the middle or latter part of June, 1882, I was prospecting on the headwaters of the Tumichie Creek, in the Gunnison Valley, Colorado. About 9 o'clock in the morning I sat down in the shade of some willows that skirted a clear but shallow place in the creek. In a quiet part of the water where their movements were readily discernible, were some fresh-hatched brook or mountain trout, and circling about over the water was a small swarm of mosquitoes. The trout were very young, still having the pellucid sack puffing out from the region of the gills, with the rest of the body almost transparent when they would swim into a portion of the water that was lighted up by direct sunshine. Every few minutes these baby trout—for what purpose I do no know, unless to get the benefit of more air—would come to the surface of the water, so that the top of the head was level with the surface of the water. When this was the case a mosquito would light down and immediately transfix the trout by inserting its proboscis, or bill, into the brain of the fish, which seemed incapable of escaping. The mosquito would hold its victim steady until it had extracted all the life juices, and when this was accomplished, and it would fly away, the dead trout would turn over on its back and float down the stream. I was so interested in this before unheard-of destruction of fish and I watched the depredations of these mosquitoes for more than half an hour, and in that time over twenty trout were sucked dry and their lifeless bodies sent floating away with the current. It was the only occasion when I was ever witness to the fact, and I have been unable by inquiry to ascertain if others have observed a similar destruction of fish. I am sure the fish were trout, as the locality was quite near the snow line, and the water was very cold, and no other fish were in the stream at that altitude. From this observation I am satisfied that great numbers of trout, and perhaps infant fish of other varieties in clear waters, must come to their death in this way; and if the fact has not

[1] This item has been taken from a portion of the paper presented at the 1980 Annual Meeting of the AMCA, at Salt Lake City, April 13–17, 1980.