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Innovation in vector control of dengue hemorrhagic fever using portable devices mechanical electric methods

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ABSTRACT

This innovation was created to control the dengue hemorrhagic fever (DHF) vector population in the larval cycle because several previous control methods were considered less sensitive, effective, and efficient. To test the effectiveness of portable electrical-mechanical methods in controlling *Aedes aegypti* larvae. The research design was posttest only which was tested on 80-liter and 90-liter volume containers in light and dark colors. Statistical analysis used the independent samples t-test, and Pearson correlation (α=5%). Laboratory test results show that the average time needed to suck all the larvae in a light-colored container with a volume of 80 liters is 38 seconds (28-57 seconds) and a volume of 90 liters is 99.6 seconds (80-119 seconds). In a dark-colored container, the 80-liter volume is 50.8 seconds (3-89 seconds) and the 90-liter volume is 106.8 seconds (88-122 seconds). This tool sucks larvae faster in containers with a volume of 80 liters compared to a volume of 90 liters. The greater the volume of water and the higher the water surface, the longer it takes to suck the larvae. This tool is effective and efficient in speeding up the process of monitoring, collecting, and controlling larvae in large containers.

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1. INTRODUCTION

Vector-borne diseases are still a problem in Indonesia, especially dengue hemorrhagic fever (DHF). According to WHO data for 2004-2010, the Asia Pacific region bears 75% of the burden of dengue in the world. Indonesia is reported as the 2nd country with the largest dengue cases among 30 countries in endemic areas [1] because Indonesia is a tropical country that is a place for the main vectors of dengue transmission, namely *Aedes aegypti* and *Ae. albopictus* [2]. In 2021, 73.5 thousand confirmed cases of DHF in Indonesia, and during 2017-2021, the highest number of DHF cases occurred in 2019 with more than 137 thousand confirmed cases [3].

Dengue fever morbidity can be reduced by implementing good outbreak prediction and detection through coordinated epidemiological and entomological surveillance [4]. Epidemiological and entomological surveillance is a tool to comprehensively collect and track vectors based on place and time [5] by monitoring vector densities to predict possible epidemics of mosquito-borne diseases and evaluate vector control [6]. This activity is an important component of any integrated mosquito management (IMM) program because this activity helps professionals determine what, when, and where control activities are needed, especially in managing mosquito populations before they become adult mosquitoes [7], [8]. The survey results show that vector control methods are still not optimal because the larva free rate (LFR) which is often used as an epidemiological measure, never reaches the target of ≥95%, and even in 2018, it only reached 31.2% [9], [10].

Larva control is one of the main programs to control DHF transmission by increasing LFR, including physical control, biological control, and chemical control because the death of the larvae can eliminate all potential mosquitoes to transmit the disease and reproduce [11]. One of the main problems in larval surveillance activities by field technicians is that the survey method for estimating the density of larvae in an area is still less sensitive [12]. One of the main problems in larval surveillance activities by field technicians is that the survey method for estimating larval density in an area is still less sensitive. Using a scoop is the most common method for collecting mosquito larvae, but other techniques and devices are needed that are more useful and effective for collecting larvae in large containers [13]. Chemical larval control techniques still provide good results, but are hampered by the continuous evolution and spread of insecticide resistance [14], [15]. Biological control methods using natural enemies of larvae, such as parasites and predators, are still less effective because some predators cannot survive more than one generation in containers [16], [17].

A study we conducted on several larva-monitoring cadres ("*Jumantik*") to find out weaknesses in determining LFR through larval surveys showed that the monitoring results were not valid because many containers were difficult to reach visually, such as containers with large volumes and dark colors. Cadres also take a long time to conduct surveys. Eradicating larvae by draining water in positive larvae containers is considered inefficient, especially in areas experiencing water scarcity [18]. Many households store water to meet basic needs related to washing, cooking, and drinking because water supplies are limited at certain times. Water that is still used will be stored in containers for a long time so that it can become a potential mosquito breeding site [16], [19]. To control the sources of DHF transmission through vector reduction, a multidisciplinary response is needed that addresses water access, urban planning, behavior change strategies, and methods of larval control at the household and community levels.

To help control *Aedes sp* larvae in the community, an innovation was created in the form of a portable device that sucks *Aedes sp* larvae using an electrical-mechanical method. The working principle of this tool is to overcome the weaknesses of several larval control methods described above. This tool uses a pump motor that can rotate a fan in the water so that water and larvae can enter through the filter tank. The incoming water will be recirculated into the reservoir in a clean condition, while the larvae that are sucked in with the water will be trapped in the filter. Incoming larvae can be destroyed, counted, and identified for research needs. Research objective: to test the effectiveness of portable electrical-mechanical methods in controlling *Aedes aegypti* larvae.

2. METHOD

2.1. Research design, locations, and period of research

This type of research in laboratory tests uses a post-test-only design. The research was conducted in the Entomology Laboratory, Faculty of Medicine, Gadjah Mada University, and Electrical Engineering Laboratory, Faculty of Science and Technology, Respati University Yogyakarta. The tool trial was carried out for 6 months from June to November 2023.

2.2. Research objects

Mechanical energy functions to rotate the pump impeller, fan, or blower, and move the compressor and lift materials [20]. This tool uses a pump motor which is equipped with a direct current (DC) electric motor and is connected to an inverter circuit that can create a vortex so that water enters through the filter tank. The incoming water is recirculated into the container in a clean condition while the *Aedes sp* larvae are trapped in the filter. Trapped larvae can be destroyed, and counted for entomological data and identification for research needs. The way this tool works is very useful for areas experiencing water shortages because it can destroy larvae without having to waste water.

2.3. Research sample

The samples used for applying the larval suction device were 1,500 third and fourth-instar *Aedes aegypti* larvae obtained from colonization in the laboratory. Determination of the number of samples is based on 2 sizes of container volume. i) 80 liters of light and dark color with a ratio of water volume and water surface height of 10 liters/4 cm, 20 liters/8 cm, 30 liters/12.5 cm, 50 liters /20 cm, 70 liters/36 cm. ii) 90 liters of light and dark colors with a ratio of water volume and water surface height of 10 liters/9 cm, 20 liters/15 cm, 30 liters/23 cm, 50 liters/36 cm, 70 liters/49 cm. In each container, 50 *Aedes aegypti* larvae were placed and repeated 3 times. The shape of the container is a tube, with the formula for calculating the volume of water as:

Water volume Formula: Container Circle Base Area x Container Cylinder Height (1)

Area of Circle Base Formula: 3.14 x (Circle Base Radius)^2 (2)

2.4. Research variable

The research variables are: i) Container volume is the contents of the container in liters to accommodate the water used in 80-liter and 90-liter sizes. ii) Water volume is the amount of water in liters provided in containers measuring 10 liters, 20 liters, 30 liters, 50 liters, and 70 liters. iii) Water level is the height of the water surface from the bottom of the container in centimeters. iv) The color of the container is the impression of darkness or light that the eye gets from the light reflected in the container. v) Time is the entire series of times the tool works to suck all the larvae in the container in seconds.

2.5. Validity and reliability

The temperature in the laboratory room is 25 °C which is the controlled thermal condition (25-35 °C) for use during the experiment [21]. Humidity in the laboratory room is 51%-53% because larval habitat will increase when relative humidity is <60% [22]. To ensure tool consistency, each container will be repeated 3 times. The container was filled with 50 tail larvae of *Aedes aegypti* each time it was repeated.

2.6. Data analysis

Data analysis in this study began with a normality test using Shapiro-Wilk. The test results stated that the data was normally distributed (p-value=0.783>0.05). Based on the results of the normality test, the descriptive analysis uses the mean and standard deviation to determine the average number of *Aedes sp* larvae inhaled by the tool based on the container volume, water volume, water surface height, and time. The next analysis is the Pearson correlation test (α:5%) to determine factors related to the tool's ability to suck all the larvae in the container and the independent sample t-test (α:5%) to determine the difference in the number of larvae sucked based on the container characteristics. This research has obtained permission from the Ethics Commission of Respati University Yogyakarta, with number: 0234.4/FIKES/PL/X/2023.

3. RESULTS AND DISCUSSION

3.1. Tool specifications

Figure 1 shows the components contained in the *Aedes sp* larva suction tool along with the shape of the tool. The series of this tool consists of 3 main components, namely the suction part, the filter part, and the mechanical electronic part.

a) Suction component, consisting of a place to store batteries in the tool (1.1). To connect the upper paralon pipe made from ¾" (1.4) long Polyvinyl Chloride (PVC) pipe with the battery compartment, a 1" (1.2) waterproof paralon is used and locked with a 1 to ¼" (1.3) shock clamp. To install and hold the flashlight on the tool, use a holder that can be rotated 360º (1.5). The lower pipe measures ¾" (1.6) and is locked with a shock valve measuring ¾" to 1¼" (1.7). The final part of this component is the suction nozzle in the form of a 1¼" diameter hose made from rubber and does not crack easily (1.8).
b) The filter component consists of a pipe to connect the suction pipe with a rival pipe using a ¾" PVC Paralon T pipe (2.1). The larva filter holder uses a ¾" L Paralon PVC pipe (2.2) and is connected to a water nut to lock and open the container when the larvae are trapped in the container (2.3). Part of the container is made of PVC (2.4) in which a filter in the form of gauze has been placed to filter trapped larvae (2.5). The final part of this component is a 1¼" diameter water drain hose made from rubber to drain the water back into the container in a clean condition without larvae (2.6)
c) Mechanical electrical components consist of:
   - The On/Off switch (3.1) is of the lever (toggle) type. The ON switch consists of two positions called Double Pole Double Throw Switch (DPDT). ON type, 1 is for low suction power if the water level is low and type 2 is for high suction power if the water level is high. This switch has six terminals, two are input contacts and the other four are output contacts, which operate at the same time.
   - The tool battery (3.2) uses size 18650, rechargeable type up to 1,000 times, voltage 3.7V DC, with a capacity of 2,600 mAh. This type of battery can last 6.5 hours, but the battery must not be left empty, so the usage time reaches 4-5 hours.
   - The battery charger section (3.3.) uses a fast-charging type with a capacity of 1,000 mAh or 1 ampare per hour. If the battery capacity is 2,600 mAh, it will take 2.6 hours to charge.
   - The 5A step-down regulator section (3.4) uses input specifications of 4-30 volts and a maximum current of 5A with adjustable output. This regulator functions to cool the tool and reduce the electrical voltage according to needs when the pump motor is running.
   - The water motor water pump (3.5) is submersible, can be stored in water, and uses a USB cable. This pump produces a water pressure of 240 liters per hour, a power consumption is 2.3W, a voltage value is 5V DC, maximum water height is 250 cm/9.8ft with a noise level of less than 35 decibels.

– The flashlight makes it easier to observe larvae in containers (3.6) has waterproof specifications, has a 10-watt white Cree Light-Emitting Diode (LED) lamp with a light intensity of 400 lumens, and a maximum beam distance under water of 25 meters. This flashlight uses a rechargeable 18,650 battery

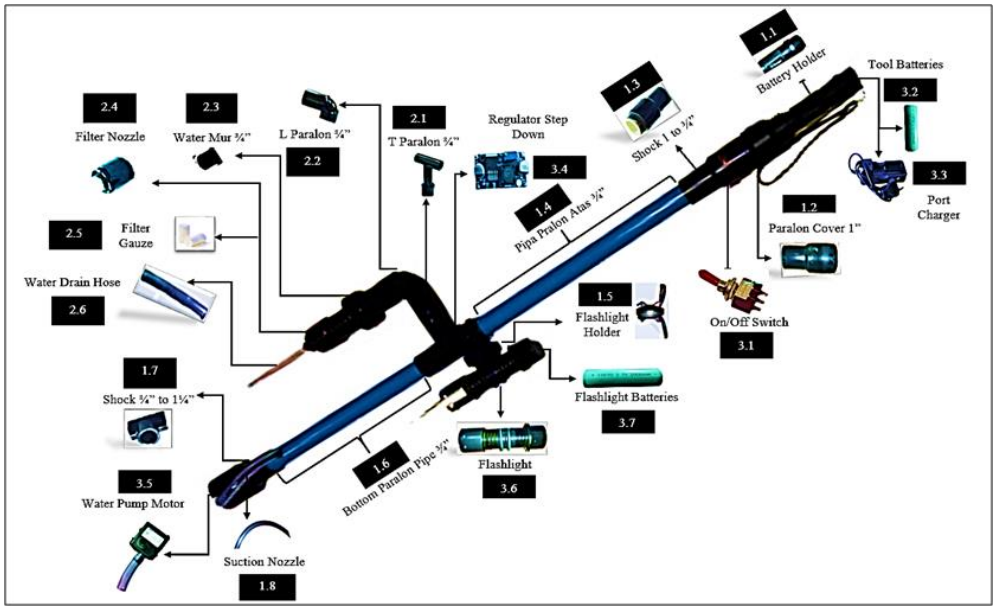

Figure 1. Tools and components for sucking *Aedes sp* larvae using electrical and mechanical methods

3.2. Flow diagram of tool use

The following is a flow diagram for using the electric-mechanical method to suck *Aedes sp* larvae. Figure 2 explains the process of preparing all the components of the tool, assembling the tool, how to use the tool, and even making repairs if there are problems with the tool's working process. If there is a problem with how the tool works, it is necessary to check the installation process of the three main sub-components.

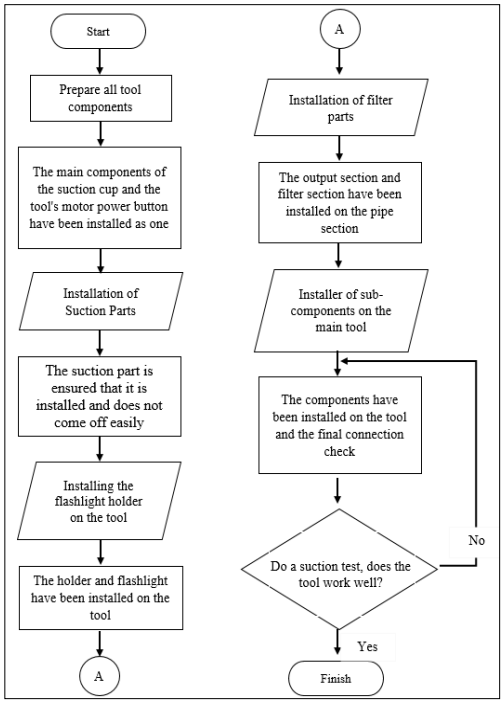

Figure 2. Flow diagram of tool use

3.3. Laboratory test

The first trial was carried out on light-colored 80-liter and 90-liter containers to determine the time required for the device to suck 50 larvae in containers with five types of water volume and different water surface heights. Figure 3 shows that when the tool was tested in a light-colored container measuring 80 liters, with a volume of 10 liters with a water height of 4 cm, it took longer to suck in all the larvae compared to a water volume of 20 liters to 30 liters with a water height of 8 cm to 12.5 cm. However, as the volume and height of the water increases, the time required becomes longer. This means that this tool takes longer when the volume and height of the water are too small and when the volume and height of the water are higher. Tests on a 90-liter container showed a positive linear line, meaning that the larger the water volume and the higher the water surface, the longer it takes to suck in all the larvae with a time range of 80 seconds-119 seconds. The next test was carried out on 80-liter and 90-liter dark-colored containers to determine the time required for the device to suck 50 liters in containers with 5 types of water volumes and different water surface heights.

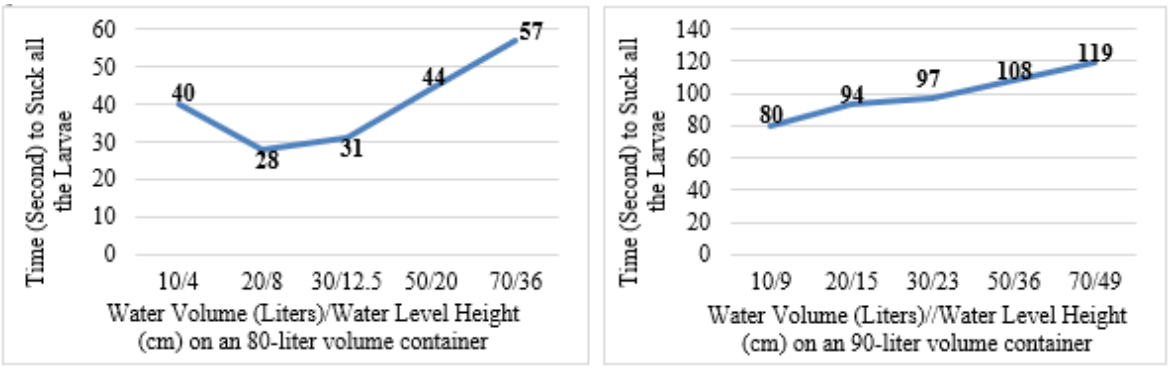

Figure 3. Comparison of the time needed to suck all *Aedes sp* larvae in light-colored 80-liter and 90-liter containers

Figure 4 shows the results of testing the tool on a dark-colored 80-liter container. The test results show the same time trend as a light-colored 80-liter volume container, but the suction time was longer, namely 47 seconds-89 seconds. When the container volume is increased to 90 liters, the suction time for all the larvae increases compared to an 80-liter volume container of the same color and a light-colored 90-liter container, namely 88 seconds-122 seconds.

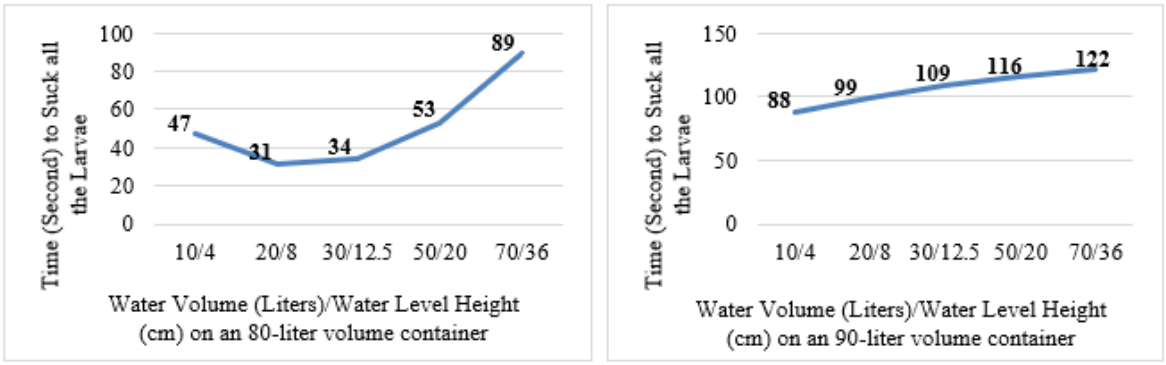

Figure 4. Comparison of the time needed to suck all *Aedes sp* larvae in dark colored 80 liter and 90-liter containers

Table 1 shows that the time required for the tool to suck all the larvae in light and dark-colored containers measuring 80 liters is not influenced by the volume of water (liters) and water height (cm) (p-value>0.05). This is because high power makes the pump rotation in a container that is not too large faster so that more larvae are sucked in in a shorter time. Previous research states that engine speed with high voltage

due to airflow and the use of more batteries will improve tool performance compared to low engine speed [23]. However, when the container size was increased to 90 liters, the larger water volume and higher water surface affected the suction time of all larvae in the container (p-value<0.05). The high water level and dark color of the container create difficulties when monitoring and moving equipment inside the container. Apart from that, the larger the volume of water due to the larger size of the container and the higher the water level, the pressure of the device below becomes greater than the pressure above, so the suction power becomes increasingly reduced. This is to the principle of mechanical energy, namely if an object moves in the opposite direction from the conservative force, then the potential energy increases, and if the object's speed changes, then the kinetic energy also changes [24]. However, this tool is still more effective in controlling and collecting larvae in large containers when compared to physical methods which are carried out visually or using single larvae methods or by taking all the larvae in the container [25].

Table 1. Factors related to the effectiveness of the tool in sucking *Aedes aegypti* larvae in an 80-liter container volume

Variable	Suction time of all larvae			
	Bright color		Dark color	
	p-value	Pearson correlation	p-value	Pearson correlation
Water volume (Liters) 80-Liter	0.109	0.794	0.085	0.826
Water level height (cm)-80 Liter	0.080	0.833	0.056	0.835
Water volume (Liters) 90 -Liter	0.017	0.941*	0.012	0.954*
Water vevel height (cm)-90 Liter	0.018	0.940*	0.010	0.958*

Notes: *Correlation is significant at the 0.05 level (2-tailed)

Table 2 shows that there is no difference (p-value>0.05) in the speed of the tool when sucking larvae in light-colored 80-liter containers (average time 38 seconds) and dark-colored (average 50.8 seconds) and in containers the 90-liter volume is light-colored (average time 99.6 seconds) and dark colored (106.8 seconds). However, there is a difference (p-value<0.05) in the speed of the tool when sucking larvae in light-colored containers with a volume of 80 liters (average time 38 seconds) with containers with a volume of 90 liters (average time 99.6 seconds). In containers dark colored with a volume of 80 liters (average time 50.8 seconds) with a container with a volume of 90 liters (106.8 seconds).

Table 2. The number of *Aedes aegypti* larvae sucked based on the characteristics of the container

Variable		Time to suck all the larvae		p-value
		Mean (Second)	Standard deviation (Second)	
Volume 80 liters	Bright color	38.00	8.22	0.278
	Dark color	50.80	23.19	
Volume 90 liters	Bright color	99.60	14.74	0.445
	Dark color	106.80	13.55	
Light	80 Liter	38.00	8.22	0.000
	90 Liter	99.600	14.74	
Dark	80 Liter	50.80	23.19	0.002
	90 Liter	106.80	13.55	

The test results show that the portable larva suction device using the electrical-mechanical method is effective in speeding up the process of monitoring, collecting, and controlling larvae in large, uncovered containers. The results of the investigation identified that large containers (≥60 L), mainly used in household activities and generally owned by urban residents, were the most productive containers in containing *Aedes aegypti* larvae [26], [27]. Reports from several studies in various countries and regions of Indonesia state that many people are still accustomed to storing clean water in containers for long periods [16], [28]. People also never cover large containers such as bathtubs so that they have the potential to become breeding places for mosquitoes and there is a habit in Asian communities of holding large amounts of water when bathing without using a shower to meet the needs of family members [29]. These results are consistent with research in Venezuela testing innovations in the use of insecticide-treated container covers, which found that only 21.5% of households received the covers, and only 10% were still using them after 22 months. Their main reason is the discontinuation of use that the cover becomes soiled or soiled, damaged, and ineffective every time it is used [19]. This shows that the method of controlling *Aedes sp* larvae through draining containers still has to be carried out at the household level.

This tool is effective for use on dark and light-colored containers because *Aedes sp* larvae can breed in both types of containers. Several research results show that the number of larvae found in dark-colored containers is greater than in light-colored containers. This is related to the behavior of the *Aedes aegypti*

mosquito which prefers dark colors as a resting place [30] and breeds because it provides a sense of security and calm to mosquitoes while laying eggs [31]. Research conducted in Denpasar, Jakarta, and Yogyakarta reported that certain container characteristics such as material, color, texture, and the nature of closed or open containers are very suitable for the breeding of *Aedes* larvae [32]. However, other research also shows that light-colored containers have the potential to become a breeding ground for *Aedes sp* larvae if they are never cleaned or closed tightly [33]. This tool is also effective for use for 4-5 hours, which is by the results of previous research which states that cadres need observation time between 10-15 minutes per house to five hours per day or 20-30 home per day [34]. This tool can suck up 50 larvae in just 38 seconds-106.8 seconds or 0.63 minutes-1.78 minutes, meaning that using this tool can shorten the survey time for cadres in every house or public place that has a large container. This tool can increase the accuracy of monitoring results and eradicate larvae in large, dark-colored containers by Community Health Center Staff and Cadres faster time. Monitoring accuracy can affect the validity of the LFR report which is an indicator of the success of the dengue fever control program through the implementation of the Mosquito Nest Eradication system [35]. The results of previous research explain that not all officers and cadres can plan and monitor larvae well, which has an impact on the accuracy of vector surveillance data [36].

3.4. Study limitations

The scope of this research is still limited to a laboratory scale. The characteristics of the containers used are limited to containers made from plastic and ceramic in the shape of cylinders and have not been tested on containers made from other basic materials. The generalization of the effectiveness of the tool in sucking larvae with the characteristics of containers used in the community still needs to be tested. A manufacturing review is needed to make this tool feasible on an industrial scale.

4. CONCLUSION

The portable tool for sucking *Aedes sp* larvae using the electric-mechanical method effectively reduces the presence and density of larvae quickly. In light-colored 80-liter volume containers, namely 28 seconds-57 seconds (mean: 38 seconds), dark-colored 80-liter volume containers, namely 31 seconds-89 seconds (mean: 50.8 seconds), a light-colored 90-liter volume container is 80 seconds-119 seconds (mean: 99.6 seconds), and a light colored 90-liter volume container is 88 seconds-122 seconds (mean: 106.8 seconds). This tool sucks larvae faster in containers with a volume of 80 liters compared to a volume of 90 liters. The greater the volume of water and the higher the water surface, the longer it takes to suck the larvae. This tool is effective and efficient in speeding up the process of monitoring, collecting, and controlling larvae in large containers without having to drain the water, so it can help increase the accuracy of the larval-free rate. For the next stage, we still need to test the readiness of the equipment for full production, through 4 stages, namely: i) Low-rate initial production (LRIP) test in the community; ii) validate the calculation of estimated equipment production costs (design to cost), iii) Carry out tests and evaluations (DT&E) of the system to meet qualifications.

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