

# Development of the Icha Thermo Solar (ITS) Smart Sterilization Device Model Based on Solar Panels with Sensor Automation for Changes in Bacterial Colonies

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**Abstract:** Cross-infection in dental and oral health services remains a challenge, mainly due to the use of diagnostic tools that do not undergo optimal sterilization processes and dependence on conventional power sources. This study aims to develop a Smart Sterilization Icha Thermo Solar (Its) tool model based on solar panels with an automated sensor system and to test its effectiveness against bacterial colony changes. The research method uses a Research and Development (R&D) approach based on the Four-D model (Define, Design, Development, Disseminate) with a mixed-method design, combining qualitative methods in needs analysis and product design with a pre-experimental approach in product testing (pre-test-post-test without a control group). Validity testing was conducted by three experts using Aiken's V and reliability testing using the Intraclass Correlation Coefficient (ICC). Effectiveness testing was conducted using the Total Plate Count (TPC) test on Plate Count Agar (PCA) media before and after sterilization with variations in time of 5, 10, and 15 minutes. The validation results showed an average Aiken's V value of 0.88 (highly valid) and an ICC of 0.958 (highly reliable). The effectiveness test results showed a decrease in bacterial colonies from  $2.2-5 \times 10^3$  CFU to 0 CFU at 5 and 10 minutes, and 1 CFU at 15 minutes. It was concluded that ITS is effective, valid, and reliable as a renewable energy-based sterilization innovation to support the prevention of cross-infection in dental health services.

**Keywords:** Smart Sterilization; Solar Panels; Sensor Automation; Bacterial Colonies; Diagnostics; Cross-Infection.

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## I. INTRODUCTION

Cross-infection is one of the main problems in health care, especially in dental and oral health care facilities, which have a high risk of transmission of pathogenic microorganisms due to direct and indirect contact between health workers, patients, and medical equipment and materials that are used repeatedly[1].

Preventing cross-infection from unsterilized equipment is a serious problem, and sterilization is an important solution to this challenge by eliminating microorganisms, both pathogenic and non-pathogenic, from media, equipment, and

other medical devices. Proper sterilization can reduce the risk of cross-infection, which can endanger the safety and success of medical procedures in efforts to maintain health and prevent outbreaks of disease. Healthcare workers are at risk of exposure to cross-infection and infectious diseases. Cross-infection requires a source of infection, an intermediary, and a means of transmission.[2].

Sterilization is a process that aims to destroy microorganisms, spores, and viruses, which can be done through various methods including dry heat, chemicals, and steam. The use of steam, chemicals, and dry heat has low bacteriostatic properties, so their use is limited. The autoclave

method has several disadvantages, such as requiring a long time, special skills in operation, and the risk of damage to instruments due to the nature of the material.[3].

The sun is the largest source of alternative energy that is abundant, environmentally friendly, and supports the life of all living things. With the increasing population and technological developments, the demand for energy, especially electricity, is also increasing. Dependence on electrical energy can cause problems when supplies are limited. Conventional energy sources such as fossil fuels have limited supplies and negative impacts on the environment. Renewable energy, such as solar energy, offers a sustainable solution. Solar energy can be harnessed by converting it into electricity through solar cells. Several interconnected solar cells form a solar panel to generate electricity from sunlight. The performance of solar panels with a maximum power output of 20.9V and 8.1A in sunny conditions, a maximum power output of 17.6V and 1A in cloudy conditions, a maximum solar panel power of 163.13 watts and a minimum of 62.08 watts. The temperature of the sterilization machine can reach 170 degrees Celsius, which is necessary for the sterilization process of medical equipment.[4].

Seeing the problem that most sterilization devices still rely on conventional electricity, innovation is needed to reduce dependence on traditional energy sources. The development of solar panel-based devices is one of the more sustainable and efficient alternative solutions to support the sterilization process. This research also reflects a paradigm shift towards the use of renewable energy in healthcare practices. On the other hand, healthcare workers are at high risk of exposure to cross-infection and infectious diseases due to the use of contaminated or unsterilized equipment. This condition has the potential to create an unsafe service environment, both for patients and for healthcare workers themselves.

Thus, the innovative ICHA Thermo Solar (ITS) device offers a sterilization solution that integrates solar panel technology with a sensor automation system, an approach that is still rarely applied to currently available sterilization products. The integration of this technology provides advantages in energy efficiency while also increasing ease of use. In addition to being able to operate without relying on conventional power sources, this device also has the ability to sterilize glass on diagnostic mouth mirrors, which in general practice are often only disinfected by immersion in a 70% alcohol solution. This approach is expected to improve the effectiveness of the sterilization process and minimize the risk of cross-infection in dental and oral health care settings.

## II. RESEARCH METHODS AND SAMPLE

The method used in this study is research and development, which is used to produce a specific product. The development model used in this study is based on Thiagarajan 1974's Four D model (Define, Design, Development, and Disseminate)[5]

The research design used is a mixed method that combines a pre-experimental approach and descriptive analysis with a research design that does not have a control

group and is used to test the effects of an intervention in a limited context focusing on the impact of the intervention. This mixed method is very useful in situations where researchers want to explore the impact of a particular action while presenting data in a concise and informative manner. It provides a more comprehensive picture of the effects of the intervention without requiring a more complex research design.

The initial stage is the definition stage, which is carried out by gathering information through interviews related to the sterilization of oral diagnostic tools during dental examinations, especially in the field with users. The aim is to collect relevant data to develop sterilization tools that are effective, efficient, and in line with user needs.

The information from the data collected is used as the basis for designing an effective, efficient, safe, and easy-to-use Smart Sterilization tool. The technical specifications of the device (dimensions, materials, capacity, temperature, time, energy source, features), conceptual design (sketches/drawings considering ergonomics, aesthetics, and portability), and selection of appropriate components (solar panels, temperature sensors, heat sensors, heating elements, thermal insulation, control systems) are compiled. The completed model design was then coordinated with a third-party team to create a design for the smart sterilization device.

The next step is to develop a prototype and conduct expert assessment or validation and revisions to test the quality and safety of the tool to determine whether or not it is suitable for a product. In assessing content validity, researchers do not conduct statistical tests, but use a qualitative approach by assessing the measurement tool carried out by several experts. A measurement tool is considered to have good content validity if the items in the measurement tool are able to measure all aspects related to the construct to be measured.[6]

This stage begins with selecting experts who are competent in the fields of electromedicine, renewable energy, and medical device design. Validity testing is carried out by three experts, namely an electromedical expert to test the validity of the use of panels in the device design system, sensor technology and device automation, a microbiologist to evaluate the effectiveness of the device in reducing bacterial colonization, and a competent dental and oral therapist with proven scientific knowledge and work results and educational background that meets the qualifications.

The validation instrument in the form of a questionnaire was used for questions containing personal assessments of the informants to evaluate the feasibility of the design to be made, from the design, functionality, effectiveness, safety, and ease of use of the device[7]. The modified tool was evaluated as the basis for revising the tool to meet established quality and safety standards and provide optimal benefits for users. Expert validity testing used the Aiken-V scale, and model reliability testing used the Interclass Correlation Coefficient (ICC).

After validation, the effectiveness of the product is tested. Test preparation (tools, materials, testing protocol) is carried out. This study conducted tests using a pre-

experimental design (pretest-posttest without control group). The effectiveness of the tool was measured by calculating the number of bacterial colonies before and after use using Plate Count Agar (PCA) media. The bactericidal test will be conducted in the laboratory of the analyst using diagnostic swabs from the Swadana Poltekkes Kemenkes Jambi Clinic. If the product trial results are not satisfactory, revisions will be made to the Icha Thermo Solar (ITS) smart sterilization device. If the trial results are satisfactory, they will be immediately taken as product test results due to sample limitations. The sample for the sterilization device product trial stage is a dental examination diagnostic device (mouth mirror) that has the most contact with the oral mucosa, with an irradiation time of 5 minutes, 10 minutes, and 15 minutes. Samples were collected using random sampling techniques from patients visiting the Primary Clinic of the Dental Health Department of the Jambi Ministry of Health Polytechnic, spread on Plate Count Agar (PCA), and then incubated for 2x24 hours. Bactericidal testing was conducted at the Laboratory of the Analysis Department of Ministry of Health Polytechnic Jambi.

Descriptive analysis was used in the information gathering stage because the data obtained was qualitative, obtained from interviews and observations. Validation tests by experts were conducted using the Interclass Correlation Coefficient (ICC) reliability test to assess the consistency of scores when assessments were made by different experts. In the product testing stage, data analysis also uses descriptive statistics to describe the percentage of data collection results.

### III. RESULTS

#### A. Information Collection Result

The interview results show that the use of sterilization equipment is a very important aspect of dental health services and practices. Effective sterilization not only ensures the cleanliness of diagnostic equipment, but also protects patients and health workers, prevents cross-infection, and maintains safety standards in every clinical procedure.

In addition, the main features required in the development of sterilization equipment include the ability of the system to work automatically and ease of operation, in order to minimize user error and increase work efficiency. Speed and effectiveness in killing microorganisms are crucial factors that must be met. Support for an automatic monitoring system with real-time reports is also considered important to ensure that the sterilization process runs optimally. In addition, an ergonomic design needs to be considered so that the device is comfortable

to use and capable of supporting activities in clinical and educational environments to the maximum extent possible.

#### B. Icha Thermo Solar (ITS) Design

This device is called Icha Thermo Solar (ITS) and is an advancement of the solar panel-based Smart Sterilization device. Solar energy is captured by solar panels and converted into electrical energy through the transfer of positively and negatively charged electrons to operate the device.

ITS combines two sterilization methods, namely type C ultraviolet light (UV-C) and infrared heating. UV-C light with a wavelength of 200–280 nm works by damaging bacterial DNA so that microorganisms cannot grow and eventually die. Infrared heating helps increase the temperature of the sterilization chamber to make the sterilization process more effective.

This device is automatically controlled using light and temperature sensors, and is equipped with a thermostat to maintain a stable and safe temperature. With a power consumption of approximately 385 watts, this device can operate for approximately 2 hours using a 100 Ah LiFePO4 battery. ITS is suitable for use in areas with limited access to electricity, such as remote areas or disaster posts. This device is specifically designed as an active sterilization device, not as a storage unit for instruments, resulting in more efficient battery power usage. If the battery capacity drops below 50% and the weather is cloudy, power supply can be switched to conventional electricity.

#### C. Expert Validation

Three experts conducted testing on the solar-based icha thermo solar (ITS) model with sensor automation for changes in bacterial colonies, namely an electro-medical expert, a materials expert, and a microbiology expert. The validation process was carried out using a questionnaire consisting of 21 questions that had to be assessed by each validator. The data analysis results used the Aiken V test and Interclass Correlation Coefficient (ICC).

#### ➤ Validity Test

The validity test was conducted using Aiken V to test the feasibility of the model so that a model trial could be carried out. The criteria were that if the index was less than or equal to 0.4, the validity was considered low; an index of 0.4-0.8 was considered moderate validity; and if it was greater than 0.8, it was considered highly valid[8]. which can be seen in the following table:

Table 1 Validity Test Using Aiken V

No	Nilai Validitas	Interpretasi	Tindak Lanjut
1	0,91	Highly valid	Accepted/Used
2	0,91	Highly valid	Accepted/Used
3	0,91	Highly valid	Accepted/Used
4	0,91	Highly valid	Accepted/Used
5	0,91	Highly valid	Accepted/Used
6	0,91	Highly valid	Accepted/Used
7	0,83	Highly valid	Accepted/Used
8	0,91	Highly valid	Accepted/Used
9	0,83	Highly valid	Accepted/Used

10	0,83	Highly valid	Accepted/Used
11	0,83	Highly valid	Accepted/Used
12	0,91	Highly valid	Accepted/Used
13	0,83	Highly valid	Accepted/Used
14	1	Highly valid	Accepted/Used
15	0,83	Highly valid	Accepted/Used
16	0,91	Highly valid	Accepted/Used
17	0,91	Highly valid	Accepted/Used
18	0,83	Highly valid	Accepted/Used
19	0,83	Highly valid	Accepted/Used
20	0,83	Highly valid	Accepted/Used
21	0,83	Highly valid	Accepted/Used
Average Total Score = 0.88			

Based on table 1 The results of the assessment by three expert validators showed that the average validity score was 0.88, which is considered highly valid (V hit  $\geq$  0.8).

➤ *Uji Reliabilitas*

The reliability test was conducted using an analysis test with the Interclass Correlation Coefficient (ICC). The

measurement instrument was considered adequate if the ICC value between measurements was  $>0.50$ , and was categorized as having high reliability if the ICC value between measurements reached  $>0.8034$ ., which can be seen in the following table:

Table 2 Reliability Test of Expert Validation Using ICC

<i>Interclass Correlation</i>		<b>Sig</b>
<i>Single Measure</i>	0,520	0,00
<i>Average Measure</i>	0,958	0,00

*\*Interclass Correlation Coefficient (ICC)*

Based on table 2The reliability test results from one expert showed a single measure value of 0.520. Since this value is  $>0.50$ , the reliability has an adequate r. Meanwhile, the overall results from the three experts showed an Interclass Correlation value of 0.958. This value is  $>0.80$ , so it can be concluded that the application has high reliability

D. *Product Result*

The trial of the Icha Thermo Solar (ITS) based on solar panels with sensor automation for changes in bacterial colonies is an alternative model for sterilizing diagnostic tools. In this study, bactericidal testing was conducted at the Bacteriology Laboratory of the Medical Laboratory Technology Department at the Jambi Ministry of Health Polytechnic. This study aimed to test the Icha Thermo Solar (ITS) model based on solar panels with sensor automation for detecting changes in bacterial colonies. The device model was tested as follows:

➤ *Bacterial Identification Test*

Before the study was conducted, samples were tested using the Total Plate Count (TPC) method with Plate Count Agar (PCA) media to identify the presence of bacteria. The principle of the TPC test is to count the number of mesophilic aerobic bacterial colonies that grow after incubation for 2×24 hours at a temperature of 35–37°C. The samples were first homogenized and diluted, then inoculated using the spread plate method on sterilized media. Colonies were counted on plates with 30–300 colonies, and the results were expressed

as colonies per mL or gram of sample after multiplying by the dilution factor. The results of this test were used to determine the effectiveness of the sterilization process based on the presence or absence of bacterial growth.

➤ *Preliminary Tests*

Preliminary tests are conducted to detect the presence of bacteria on diagnostic tools after they have been used in examinations. These tests aim to identify the level of microbial contamination resulting from contact with patients or the environment. The test results form the basis for determining the need for and effectiveness of sterilization processes and serve as a reference in designing infection control measures to ensure the safe use of tools in subsequent examinations.

➤ *Repeat Tests*

Repeat tests were conducted on bacteria for 5 minutes, 10 minutes, and 15 minutes. These repeat tests were conducted using an icha thermo solar (ITS) model based on solar panels with the same sensor automation.

Table 3 Number of Colonies Resulting from Repeat Tests

Total Plate Count			
Before Sterilization		After Sterilization	
X1	2,9 x 10 <sup>3</sup> CFU	POST X1	0 CFU
X2	5 x 10 <sup>3</sup> CFU	POST X2	0 CFU
X3	2,2 x 10 <sup>3</sup> CFU	POST X3	1 CFU

**DESCRIPTION:**

X1 = Total number of flat plates for respondent 1

X2 = Total number of flat plates for respondent 2

X3 = Total number of flat plates for respondent 3

Post X1 = Number of flat plates after sterilization using the ITS device for 5 minutes

Post X2 = Total plate count after sterilization using the ITS device for 10 minutes

Post X3 = Total plate count after sterilization using the ITS device for 15 minutes

The results of the total plate count before and after sterilization are presented in Table 3. Before sterilization, all samples showed bacterial colony growth in varying amounts, namely 2.9 × 10<sup>3</sup> CFU in X1, 5 × 10<sup>3</sup> CFU in X2, and 2.2 × 10<sup>3</sup> CFU in X3. This indicates that the equipment used was still contaminated with microorganisms before the sterilization process. After sterilization using the Smart Sterilization device, there was a significant decrease in the number of bacterial colonies. In treatments using the Smart Sterilization device for 5 minutes (Post X1) and 10 minutes (Post X2), no bacterial colony growth was found (0 CFU). In the 15-minute treatment (Post X3), 1 CFU was still found, but this number showed a very drastic decrease compared to before sterilization.

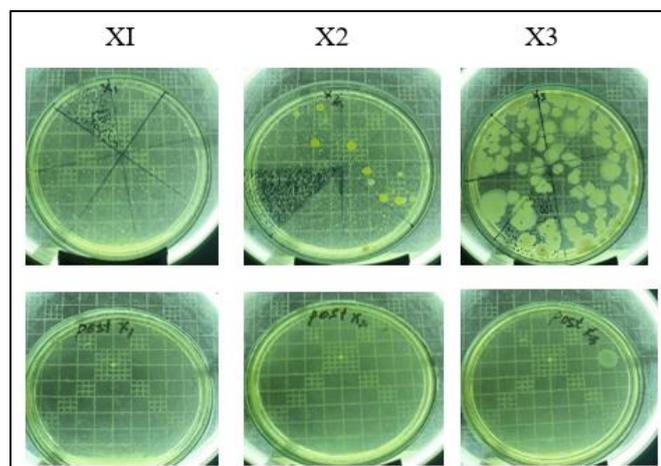


Fig 1. Bacterial Colonies on Plate Count Agar (PCA) Before and After Sterilization.

**E. Produk Icha Thermo Solar (ITS)**

The research product is an innovation called Icha Thermo Solar (ITS), a solar panel-based sterilization device equipped with a sensor automation system. This device is designed to support the sterilization process of diagnostic tools by utilizing solar energy as the main power source. The application of sensor automation enables optimal control and monitoring of sterilization parameters, which is expected to

inhibit and suppress bacterial growth on diagnostic tools. The results of the ITS model development show the potential for utilizing environmentally friendly technology as an effective, efficient, and applicable sterilization solution in supporting the safe use of diagnostic tools.



Fig 2. The Developed Icha Thermo Solar (ITS) Model.

**IV. DISCUSSION**

➤ *The Icha Thermo Solar (ITS) Model is Based on Solar Panels with Sensor Automation for Detecting Changes in Bacterial Colonies.*

• *Results of Information Gathering*

The results of the study show that sterilization is a crucial aspect of dental services, education, and practice because it plays a role in preventing cross-infection and maintaining safety and service quality standards. Effective sterilization not only ensures the cleanliness of diagnostic tools but also protects patients, health workers, and students.

Based on the interview results, the development of sterilization equipment needs to emphasize an automated system that is easy to operate in order to minimize user error and increase efficiency. In addition, the effectiveness and speed of the process in killing microorganisms, a monitoring system with real-time reports, and an ergonomic and practical design are important factors in supporting optimal use in clinical and educational environments.

• *Expert Validation Results*

Expert validation results for the Icha Thermo Solar (ITS) model based on solar panels with sensor automation show Aiken's V and Interclass Correlation Coefficient (ICC) values that meet the criteria for validity and reliability. These results indicate that the model is suitable for use in reducing the number of bacterial colonies on diagnostic tools. The validation process is an important step prior to wider

implementation to ensure the effectiveness and usefulness of the tool in supporting the sterilization process optimally.

#### ➤ Model Trial Observation

Sterilization of medical devices is an important process to ensure that equipment used in medical procedures is free from microorganisms, including bacteria, fungi, viruses, and spores that can potentially cause nosocomial infections. The success of an effective sterilization process is key to preventing infections related to contaminated medical devices, which can increase patient morbidity and mortality.[9].

The results of the study show that prior to sterilization, all diagnostic device samples had fairly high total plate counts, ranging from  $2.2 \times 10^3$  CFU to  $5 \times 10^3$  CFU. These values indicate the presence of microorganism contamination that could potentially cause cross-infection if the devices are reused without adequate sterilization. According to infection control theory, non-disposable medical devices that come into direct contact with body tissues or fluids must undergo decontamination and sterilization processes to prevent the transmission of pathogenic microorganisms.[10]

After sterilization using the Smart Sterilization device, there was a significant decrease in the total plate count across all treatment times. At sterilization times of 5 minutes and 10 minutes, no bacterial colony growth was detected (0 CFU). These findings indicate that the Smart Sterilization device is highly effective in eliminating microorganisms in a relatively short time. Theoretically, an effective sterilization process must be able to damage the structure of microbial cells, either through protein denaturation, cell membrane damage, or disruption of the metabolic system[11].

Interestingly, even after 15 minutes of sterilization, 1 CFU was still found. Critically, this finding does not necessarily indicate a decrease in the effectiveness of the device, but rather needs to be analyzed from a methodological perspective. The presence of a single bacterial colony could be caused by secondary contamination, either during sample collection, the inoculation process into Plate Count Agar (PCA) media, or laboratory environmental factors such as air and work surfaces. Several microbiology studies have noted that total plate count test results are highly sensitive to aseptic procedures, so technical bias remains a possibility even when sterilization equipment is functioning optimally[12].

These findings are reinforced by research conducted by Rahmah et al. (2024), which proves that the use of ultraviolet-C-based sterilization devices can significantly reduce the number of bacterial colonies. Sterilization research using ultraviolet-C light on *Streptococcus mutans* showed a 74% reduction in colonies (5 minutes), 86% (10 minutes), and 100% (15 minutes), confirming that exposure duration affects bactericidal effectiveness. The mechanism works by damaging the DNA of microorganisms, thereby inhibiting replication and causing cell death.

The results of this study indicate that the Smart Sterilization device can reduce the number of colonies to 0 CFU even at durations of 5–10 minutes. Differences in effectiveness time may be influenced by the type of device and

testing conditions. In general, ultraviolet-C and infrared-based technology has proven to be effective and has the potential to be applied as a practical and efficient sterilization method in healthcare services.

## V. CONCLUSION

Based on the results of the study, it can be concluded that the development of the Icha Thermo Solar Smart Sterilization Device (ITS) is effective in reducing bacterial colonization. In addition to being able to be used without conventional electricity, this device has the advantage of being able to sterilize glass on dental examination diagnostic tools (mouth mirrors), which are usually only soaked in a 70% alcohol solution. This solar panel-based device with an automated sensor system has been proven to significantly reduce the number of bacterial colonies within 5–10 minutes, even reaching 0 CFU. Expert validation results show a very high level of feasibility (value >0.8), so the model is declared valid and reliable for application in clinical practice. Furthermore, this study confirms that the use of solar energy as an environmentally friendly technology can be an effective and efficient sterilization alternative in dental health services.

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