Portable Solar Powered Flood Water Purifier System

Sonido, Mark Darwin T., Balcueva, Blizelda M., Pinpin III, Juanito Carlo A., Mosquera, Rizal M.

ABSTRACT--- During heavy typhoons, an adapted remote community area in Calamba City, Laguna, Philippines suffers from lack of drinking water, for they only rely on low lying deep well that may be contaminated by flood water during heavy storm surge as the community were proximate to Laguna Lake. This study aimed to provide an ideal potable water during heavy drinking water shortage in a calamity scenario at Sitio Runggot, Brgy. Lecheria, Calamba City, Laguna and to stand for the waste reproduction by converting flood water into a safe drinking water. This research established a Solar Powered Portable Water Purifier System that its integrated components can convert flood water into clean drinking water. This water purifier system can purify and eliminate most types of bacteria and microorganisms on a data gathered in a specific location for water purification. The combination of 5 technologized filtration industrial membranes made up this study possible as: Industrial Reverse Osmosis, 7 – pore Ultrafiltration, Sediment Filter (Fine), Carbon Filter and Ultraviolet Sterilizer. The designed portable prototype was modified to its maximum portability state that will allow solar energy to be harnessed and used all throughout its whole process as the source of power. Several tests from different locations were collected and settled within 7, 14, 21, 28 and 35 days for the consideration of flood water stagnancy and possible microbial growth factor within the time span. This allowed the researchers to determine and set a high bar of standard and category that allows the subject for water purification using the flood water purifier system.

The study resulted with a concrete finding of having an acceptable value in terms of pH, Conductivity, Coliform count, Silica and Lead content, Color (Turbidity) and Alkalinity. The physical water quality tests conducted and analyzed by an accredited water laboratory in the Philippines of a maximum allowable flood water stagnancy of 35 days showed safe result to drink the water.

Index Terms— Water purification, Water filtration systems, Antibacterial activity, Reverse Osmosis.

I. INTRODUCTION

The earth's climate has changed throughout history. Over the years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about from years ago marking the beginning of the modern climate era and of human civilization. Average temperatures around the world have risen by 0.75 degree Celsius over the last century and about two thirds of this increase have occurred since 1975, this phenomenon was the so-called global warming. Global warming is damaging the earth's climate as well as the physical environment. One of the most visible effects of global warming can be seen in the arctic as glaciers, sea ice is melting rapidly and unseasonal weather conditions. Here in Philippines, the unseasonal weather changes were experience. Devastating storms and extreme environmental heat can happen in no exact time and scenario.

There are several remote areas in the Philippines that in need of safe drinking water. In Laguna within the first-class city of Calamba, there's a remote area called Sitio Runggot part of Brgy. Lecheria in Calamba City. The sitio is approximately 6 hectares with a vast agricultural land area, small community, and an open field area adjacent to Laguna Lake. One of the major caused of floods in the area was the location of its land which is proximate to Laguna Lake. The residents of Sitio Runggot suffered from flood settlement in a period of time due to lake water splashing out during rainy season.

One of the possible solutions for the potable water shortage was water purification. In today's market, there are several water purifier systems that purifies water according to type and volume of water being purified. This water purifier includes reverse osmosis machineries and other manufactured industrial and household water purifiers.

II. METHODOLOGY

The Research Design

This research established a Solar Powered Portable Water Purifier System that consists of integrated components that convert filthy water into clean drinking water. This study was pursued using descriptive methods and prototyping technique. It showed the specific procedures that was validated to come up with the specific results that was used for further analysis of the study. The researchers also used verbal and non – verbal techniques for data gathering and come up with the results within the supporting data that were gathered.

Research Instrument

1. Interview – this allows the researchers to personally gather information regarding the specific list of questions to be answered.
2. Expert Field Research Data – this allows the researchers to be personally accompanied within the field of expertise of the specific topic to be discussed.

Revised Manuscript Received on June 10, 2019.

Sonido, Mark Darwin T., University of Perpetual Help System Dalta, Philippines (E-mail: markdarwinsonido@gmail.com)
Balcueva, Blizelda M., University of Perpetual Help System Dalta, Philippines (E-mail: blessymaunahan23@gmail.com)
Pinpin III, Juanito Carlo A., University of Perpetual Help System Dalta, Philippines (E-mail: carlopinpin6@gmail.com)
Mosquera, Rizal M., University of Perpetual Help System Dalta, Philippines (E-mail: rizalmosquera6198@gmail.com)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

3. Research Works – this allows the researcher to gather information through books, articles, journals, and webpages.
4. Sampling – this allows the researchers to get the needed physical samples of anything that can be a factor about the water purification.

Data Gathering Procedure

The primary and secondary sources of data were gathered and filtered to get the most suitable information for design considerations. These were used in calculations and testing of the prototype. The testing of the prototype included a comparison to the computation that led the researchers in achieving the preferred functionality.

1. The researchers went to the office of the Local Disaster Risk Reduction and Management Council (LDRRMC) to gather some information in the presence of Mrs. Ampi Velasquez – LDRRMC Secretary about the information on the most flooded area in Calamba City, Laguna.
2. The researchers went to the Community Environment and Natural Resources Office (CENRO) attended by Mr. Michael Limangan – CENRO Representative for the researcher to know what type of organism and bacteria in water of the river Calamba City. The City Health Office representative, through Ms. Nancy Torres assist the researcher to gather some information on what possible bacteria can affect the human body by drinking dirty water.
3. The Sanitary Department of the City Health Office, assisted by Mrs. Carolina Estrella- Sanitary Department Representative help the researcher gather some information and data on the water analysis at different rivers and floods in Calamba City area near the target location.
4. The next destination of the researcher was in Sitio Runggot to conduct interview to residents of the area. The researchers also took in Sitio Runggot samples of tap and flood water.
5. Water samples gathered were collected and subjected to water analysis.
6. A water analysis was subjected at the Alpha Water Laboratories to be able to determine contaminants that were needed to be addressed for water purification.
7. After a week, the researchers got the water analysis data for water analysis examination for the result.
8. The researchers conducted the sampling instrument as elaborated.

To answer the main concern, following methodology was conducted:

2.1. Determine the flood water properties in Sitio Runggot

2.2. Determine the performance of existing water purifier in terms of:

2.2.1. Volume Efficiency

The researchers determine the volume efficiency using research analysis conducted through internet, journals and web pages that showed the volume efficiency of existing water purifiers within a specific volume of purification.

2.2.2. Cost of Machine

To determine the cost of existing water purifiers, the researchers looked for journals and sales brochures for the exact suggested retail price of the existing variety of water purifiers.

2.2.3. Time of Operation

The researchers used internet, journals and web pages for the specific time of operation of the existing water purifier systems for a specified volume of water purified.

2.3. Method of determining the design improvements of existing water purifier system

2.3.1. Volume Efficiency

The researchers determine the actual volume efficiency using graduated container (contains measured volume) as a basis of input and output of water being purified using a five-gallon water container.

2.3.2. Cost of Machine

The researchers used statistical treatment to sum up all cost of materials to determine the total cost of the established flood water purifier system.

2.3.3. Time of Operation

The researchers determined the time of operation with the use of a timer to record actual time taken for the water purification of the flood water purifier system prototype on a five-gallon volume container.

2.4. Method of determining parameters to consider water as potable

The researchers conduct a study to evaluate the scope and limitation for the purpose of the study, a total of 15 local residents were assessed upon giving them the treated water to test. They were given criteria in the evaluation survey form to evaluate their opinion on the flood water purifier system, it also served as a parameter for the acceptance of the study.

III. RESULTS AND DISCUSSION

3.1. Properties of Flood Water in the location at Sitio Runggot in Calamba City.

Table 1. Physical water quality results of flood water sample – front side view of Laguna lake for 35 days

PARAMETERS	METHOD	UNIT	RAW WATER (DEC. 17, 2018)	STANDARD
pH	*Electrometric*	----	10	6.5 – 8.5
Color	*Visual*	----	Brownish	
Conductivity	*Electrometric*	µS/cm	352	0.05 - 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	201.44	< 300
Silica	*Photometric*	mg/L	5.4	< 5
Alkalinity	*Titrimetric*	mg/L	232.41	200
Lead	*Titrimetric*	Ppb	16.8	0 -<15
Coliforms	*Fermentation*	----	> 8.0	0 – 0.9

Table 2. Physical water quality results of flood water sample – near a household deep well for 28 days

PARAMETERS	METHOD	UNIT	RAW WATER (DEC. 24, 2018)	STANDARD
pH	*Electrometric*	----	12	6.5 – 8.5
Color	*Visual*	----	Brownish	
Conductivity	*Electrometric*	µS/cm	343	0.05 - 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	218.87	< 300
Silica	*Photometric*	mg/L	7.4	< 5
Alkalinity	*Titrimetric*	mg/L	202.67	200
Lead	*Titrimetric*	Ppb	18,90	0 -<15
Coliforms	*Fermentation*	----	> 6.0	0 – 0.9

Table 3. Physical water quality results of flood water sample – beside a farm house for 21 days

PARAMETERS	METHOD	UNIT	RAW WATER (DEC. 31, 2018)	STANDARD
pH	*Electrometric*	----	14	6.5 – 8.5
Color	*Visual*	----	Dark Brown	
Conductivity	*Electrometric*	µS/cm	376	0.05 - 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	285.31	< 300
Silica	*Photometric*	mg/L	9.6	< 5
Alkalinity	*Titrimetric*	mg/L	237.51	200
Lead	*Titrimetric*	ppb	21.37	0 -<15
Coliforms	*Multi-Tube Fermentation*	----	> 8.2	0 – 0.9

Table 4. Physical water quality results of flood water sample – along a street road for 14 days

PARAMETERS	METHOD	UNIT	RAW WATER (JAN. 7, 2018)	STANDARD
pH	*Electrometric*	----	11	6.5 – 8.5
Color	*Visual*	----	Brownish	
Conductivity	*Electrometric*	µS/cm	287	0.05 - 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	292.21	< 300
Silica	*Photometric*	mg/L	8.4	< 5
Alkalinity	*Titrimetric*	mg/L	249.15	200
Lead	*Titrimetric*	ppb	17.53	0 -<15
Coliforms	*Multi-Tube Fermentation*	----	> 5.1	0 – 0.9

Table 5. Physical water quality results of flood water sample – middle of rice field irrigation for 7 days

PARAMETERS	METHOD	UNIT	RAW WATER (JAN. 14, 2018)	STANDARD
pH	*Electrometric*	----	14	6.5 – 8.5
Color	*Visual*	----	Brownish	
Conductivity	*Electrometric*	µS/cm	293	0.05 - 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	264	< 300
Silica	*Photometric*	mg/L	7.78	< 5
Alkalinity	*Titrimetric*	mg/L	211.65	200
Lead	*Titrimetric*	ppb	18.34	0 -<15
Coliforms	*Multi-Tube Fermentation*	----	> 7.2	0 – 0.9

Flood water samples on different area from Sitio Runggot were in front side view of Laguna lake, near a household deep well, beside a farm house, along the street road and middle of rice field irrigation. These were bottled each for the consideration of microbial growth, in the same order of 35, 28, 21,14,7 days for each location. The tables 1, 2, 3, 4 and 5 show different laboratory results of physical water qualities that come up with unacceptable water quality, these gave the researchers an idea to what was the highest unacceptable values in terms of these numbers based on the laboratory results. This showed that having flood water beside a farm house had a greater unacceptable values in the standard parameters of drinking water based on Department of Health (DOH).

Table 5 showed that the unacceptable maximum values of filthy water was located beside a farm house that's been stagnant for about 21 days. It showed high acidity of water and a high number of coliforms that was vital for safety drinking water standards based on the DOH and the location stated the maximum bar of flood water filthiness within the whole community. Time was a factor to consider because of the growth of the microorganisms on the flood area. Choosing a maximum unacceptable number of results gave the flood water purifier a high safety factor when purifying flood water in the community.

Table 6. Five flood water laboratory results beside a farm house within a stagnancy up to 35 days

PARAMETERS	UNIT	RAW WATER (DAYS OLD)					STANDARDS
		35	28	21	14	7	
pH	----	14	12	14	11	10	6.5 – 8.5
Color	----	Dark Brown	Brown	Dark	Brown	Brown	---
Conductivity	µS/cm	352	341	326	287	293	0.05 -200
TSS (Total Suspended Solid)	mg/L	324.43	218.87	213.83	292.21	264	< 300
Silica	mg/L	8.21	7.4	3.6	8.4	7.78	< 5
Alkalinity	mg/L	212.21	212.61	217.11	241.15	221.25	200
Lead	Ppb	16.8	11.90	22.37	17.93	13.24	0 < 15
Coliforms	----	> 12.0	> 9.0	< 0.5	>5.1	> 7.2	0 – 0.9

The table 6 showed the five flood water sample results that were collected beside farm house and had been bottled up to 35 days for the consideration of microbial growth. The flood water stagnant for 35 days beside a farm house gives a high maximum value in terms of pH – 14 as its results, color was dark brown, conductivity – $352\frac{\mu S}{cm}$, TSS – $324.43\frac{mg}{L}$, silica – $8.21\ \frac{mg}{L}$, alkalinity – $212.21\ \frac{mg}{L}$, lead – 16.8 Ppb, and coliforms are greater than 12. These numbers will be the set of maximum bars that should be subjected for water purification through the flood water purifier system. Having these kinds of high unacceptable numbers will allow the flood water purifier machine to extend its limit for subjecting water purification.

3.2 Time of Operation

Table 7 showed the time of operation of existing conventional water purifier system. The researcher used the fixed amount of 5 gallons for each purifier. The first column represents the type of water existing conventional water purifier. The second column represents the fixed amount of volume. And the third column represents the time of operation.

Table 7 Time of operation of existing conventional water purifier system.

TYPE OF WATER PURIFIER	VOLUME	TIME OF OPERATION
WENGTONG STAINLESS PURIFIER	5 gallons	1 min & 42 secs
RO WATER PURIFIER MACHINE	5 gallons	11 mins & 26 secs
OZONE STERILIZER MACHINE	5 gallons	2 mins & 48 secs

3.3. Design Improvements of the Established Flood Water Purifier System

3.3.1. Water Purification Efficiency

The table 8 shows the five trials of Flood Water Purifier System in terms of volume purification efficiency. The first column represents the number of trials of the Flood Water Purifier System that the researchers done. The second column represents the fixed volume input raw water. The third column represents the volume of filtered water (output volume of water). The fourth column represents the purification of efficiency.

Table 8. Purification Efficiency trial of Flood Water Purifier System

TRIAL	VOLUME OF RAW WATER	VOLUME OF FILTERED WATER	VOLUME (PURIFICATION) EFFICIENCY
1	5 gallons	4.94 gallons	98.8 %
2	5 gallons	4.88 gallons	97.6 %
3	5 gallons	4.94 gallons	98.8 %
4	5 gallons	4.93 gallons	98.6 %
5	5 gallons	4.89 gallons	97.8 %
AVERAGE	5 gallons	4.92 gallons	98.32 %

The table 9 shows the Flood Water Purifier System purification efficiency. The first row is the different types of water that can be purified. The second row shows the different type filtration process used and the third row represents the purification efficiency.

Table 9. Purification Efficiency of Flood Water Purifier

FLOOD WATER PURIFIER	
TYPE OF WATER	Flood Water
FILTERS USED	Ultra-Filtration Membrane, Reversed Osmosis Membrane, Sediment and Carbon Block Filter, UV Sterilizer
PURIFICATION EFFICIENCY	98.32% Reduce Nano, microorganism, soluble salts, organic matters & bacteria, total suspended solids, alkalinity, lead, coliforms, conductivity, silica

3.4 Time of Operation

The table 10 shows the time of operation of the flood water purifier system. The researchers used a 5-gallon water. The data was then recorded and tabulated on the spreadsheet provided by the researchers. The first column is the number of trials the subject been tested. The second column represents the volume of water to be used. The third column represents the time of operation recorded by the researchers using a stopwatch.

Table 10. Flood Water Purifier System Time of Operation

TRIAL	VOLUME	TIME OF OPERATION
1	5 gallons	2 mins & 7 secs
2	5 gallons	2 mins & 9 secs
3	5 gallons	2 mins & 11 secs
4	5 gallons	2 mins & 8 secs
5	5 gallons	2 mins & 9 secs
AVERAGE		**2 mins & 7 secs**

Table 11 shows the comparison in the time of operation of the four-water purifier being compared. The flood water purifier system is the second most efficient in terms of time operation even if it is smaller in size than the Wengtong Stainless Purifier which has the largest size in area and the largest volume of water to produce.

Table 11. Comparison of Existing Drinking Water Purifier to Advanced Drinking Water Purifier System

TYPE OF WATER PURIFIER	VOLUME	TIME OF OPERATION
WENGTONG STAINLESS PURIFIER	5 gallons	1 min & 42 secs
RO WATER PURIFIER MACHINE	5 gallons	11 mins & 26 secs
OZONE STERILIZER MACHINE	5 gallons	2 mins & 48 secs
FLOOD WATER PURIFIER	**5 gallons**	**2 mins & 7 secs**

3.4. Parameters to consider Water as Potable

There are parameters to consider water as potable, these can represent as passed or failed to standards and in determination for the results.

Table 12. Parameters to consider Water as Potable

PARAMETERS	UNITS	DRINKING WATER ISO: 10500 - 1991	
		DESIRABLE	MAXIMUM
Colour	Hazen	5	25
Odour	-	Unobjectionable	-
Taste	-	Agreeable	-
Turbidity	NTU	5	10
pH value	-	6.5 to 8.5	No relaxation
Total hardness (as CaCO3)	mg/l	300	600
Iron	mg/l	0.3	1.0
Chlorides	mg/l	250	1000
Residual, free Chlorine	mg/l	0.2	-
Manganese	mg/l	0.1	0.3
Sulphate	mg/l	200	400
Nitrate	mg/l	50	No relaxation
Fluoride	mg/l	1.0	1.5
Phenolic compounds	mg/l	0.001	0.002
Mercury	mg/l	0.001	No relaxation
Cyanide	mg/l	0.05	No relaxation
Lead	mg/l	0.05	No relaxation
Zinc	mg/l	5	15
Anionic detergents	mg/l	0.2	1.0
Chromium	mg/l	0.05	No relaxation
Polynuclear aromatic Hydrocarbons	mg/l	-	-
Mineral oil	mg/l	0.01	0.03
Pesticides	mg/l	Absent	0.001
Radioactive materials (a) Alpha emitters (b) Beta emitters	Bq/l Pci/l	- -	0.1 0.037
Alkalinity	mg/l	200	600
Aluminium	mg/l	0.03	0.2
Boron	mg/l	1	5

Table 12 shows the standard parameters for drinking water. This shows each physical water qualities and equivalent standard value. The determination of results relies upon the validated standard value for drinking water and shall be under or above depending on the results

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

provided and to be considered safe for drinking water whenever passed the following standards.

Table 13. Five treated water laboratory results beside a farm house within a stagnancy up to 35 days

PARAMETERS	METHOD	UNIT	TREATED WATER (DAYS OLD)					STANDARD
			35	28	21	14	7	
pH	*Electrometric*	----	7.0	7.0	7.0	6.8	7.1	6.5 – 8.5
Color	*Visual*	----	Clear	Clear	Clear	Clear	Clear	----
Conductivity	*Electrometric*	µS/cm	190	175	158	125	112	0.05 – 200
TSS (Total Suspended Solid)	*Titrimetric*	mg/L	1.58	1.42	1.86	1.18	1.0	< 300
Silica	*Photometric*	mg/L	3.3	3.0	2.9	2.3	1.34	< 5
Alkalinity	*Titrimetric*	mg/L	156.41	138.51	106.8	102.74	198.5	200
Lead	*Titrimetric*	Ppb	0.4	0.5	0.8	0.6	0.3	0 -<15
Coliforms	*Multi-Tube Fermentation*	----	<0.6	<0.4	< 0.5	< 0.46	<0.32	0 – 0.9

The table 13 shows the different physical water analysis of a 7, 14,21,28,35 days old of flood water which includes pH, color, conductivity, total suspended solids, silica, alkalinity, lead content and coliform count. All results were delivered lower than the standards, this shows that flood water (up to 35 days of stagnancy) results to PASSED in DOH standards for drinking water.

IV. CONCLUSIONS

In this study, the researchers introduced a water treatment system that is used to treat water from the flood to become potable water. Because of the findings, the following conclusions were constructed in line with the problem stated:

1. Determination of Flood Water Properties in Sitio Runggot

The location beside a farm house was considered for sampling instrumentation due to its highly unacceptable maximum results within the physical water quality tested and a flood water stagnancy for a microbial growth factor up to 35 days was considered for the safety factor of high-water filthiness that can be subjected to the flood water purifier system.

For the time of operation, it takes a lot of time to purify salt water than tap water. It has an average of 11 mins & 25 secs. While the tap water purifies only for about 2 mins & 48 secs. It was surpassed by the Flood Water Purifier System to only 2 minutes and seven seconds for a five gallon volume.

2. The Design Improvements of the Established Flood Water Purifier System.

Portable Solar Powered Flood Water Purifier has five stages filtration process with a total of 98.32% purification efficiency, the highest among the three existing in terms of purification efficiency than Ozone Sterilizer Machine (purifies tap water).

And for the time of operation, flood water purifier has an average of 2 mins & 7 secs with an initial input of 5 gallons water, a much faster performance than converting salt water and tap water.

3. Parameters to consider Water as Potable

A total of 5 raw water sample that researchers gathered in five different location around Sitio Runggot. All five samples meet the quality and standards of the Philippines national standards for drinking water. For the result, the researchers conducted a survey and test of the taste of purified water output, and out 15 residents that researchers surveyed, 10 had highly accepted to drink the purifier water output.

4. These are the following conclusion that may come up with the objectives of the study:

a. The prototype was designed to produce a clean and safe to drink water out of flood water to give another source of potable water for Sitio Runggot, Brgy. Lecheria, Calamba City during calamities. The treatment process for this problem is biological treatment and filtration process. All Laboratory results passed the National Standards for Drinking Water.

b. Out of 15 local residents surveyed and interviewed, 15 of them were satisfied and highly accepted the designed Flood Water Purifier System.

c. The maximum capacity of the Flood Water Purifier System that it can produce in a single process is 54 liters of potable water.

REFERENCES

1. Botes, Marelize, and Thomas Eugene Cloete. "The potential of nanofibers and nanobiocides in water purification." Critical Reviews in Microbiology 36, no. 1 (2010): 68-81..
2. Magnusson, Jan H., and Kristofer J. Magnusson. "Personal water purification systems." U.S. Patent No. 5,273,649. 28 Dec. 1993.
3. Shannon, Mark A., et al. "Science and technology for water purification in the coming decades." Nanoscience and technology: a collection of reviews from nature Journals. 2010. 337-346.
4. Kuhlmann, K., & Andrews, J. E. (2008). U.S. Patent No. 7,390,417. Washington, DC: U.S. Patent and Trademark Office.
5. Loo, S. L., Fane, A. G., Krantz, W. B., & Lim, T. T. (2012). Emergency water supply: a review of potential technologies and selection criteria. Water research, 46(10), 3125-3151.
6. Diawara, C. K. (2008). Nanofiltration process efficiency in water desalination. Separation & purification reviews, 37(3), 302-324.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication