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Rain Water Treatment by Ultraviolet Radiation Using Photovoltaic Energy

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HIGHLIGHTS

- A self-sufficient system is presented
- Energy is generated by photovoltaic panels
- Rainwater is captured and treated with ultraviolet lighting.
- This water is used in toilets, pulping the use of drinking water

Abstract: Shortages, deterioration in the quality of water sources and increased demand for water have been a problem for both developing and developed countries. In view of this scenario, the use of alternative sources such as the capture and use of rainwater proves to be a feasible solution. In remote places, without water and electricity supply, the use of a rainwater capture system, with ultraviolet disinfection and powered by an isolated photovoltaic panel can be the solution for the water and energy supply. Thus, this work evaluates the efficiency of the isolated photovoltaic system and the quality of rainwater after passing through the ultraviolet germicidal (UV) lamp. To measure water quality, laboratory analyzes were performed. Analyzes of water from the cistern were performed and after passing through the UV disinfection system using different flow rates to determine which would be more viable for the system. The rainfall and solar irradiation data are collected to determine whether the system powered by photovoltaic energy is viable in the city of Curitiba in the state of Paraná. The results for water analysis showed that the UV disinfection system is efficient, and in the medium and minimum flow rates, there were 100% improvements in the water quality for coliforms. The isolated photovoltaic system proved to be effective, as the irradiation rates were satisfactory even in the winter period, when solar irradiation is generally lower.

Keywords: water disinfection; ultraviolet lamp; photovoltaic.

INTRODUCTION

Water is a primary resource for the life of the planet, being necessary in all sectors of the economy. In recent years, water demand has been increasing due to population growth, pollution of water resources and urbanization. The global demand for water is expected to continue to increase by 20% and 30% in relation to the current level of use of the resource, reaching 33% in a scenario of rivalry until 2050 [1].

According to the [2], more than 2 billion people live in countries that suffer from water stress. Still, according to the report, more than 22 countries have water stress above 70% and are therefore in a serious situation.

Unsustainable water resource management causes damage to the economy and society. Scarcity promotes negative impacts on the development of the population, of cities, making it the main factor in the progress of a society [3].

In the last decades, researchers have studied more ecological techniques for the preservation of water in the urban area, looking for alternatives to reduce the consumption of drinking water destined for adverse purposes to human consumption, in order to reduce the pressure on the available water resources.

A first step towards more sustainable water consumption would be to include current and future climate variability in water-related management to help adapt to the long-term impacts of climate change [4]. Second, it is important to evaluate new technologies and solutions for water conservation from an environmental, economic and social perspective [5].

In addition to the scarcity of water, the world population has other adversities such as the lack of basic sanitation, mainly in developing countries, such as Brazil. The use of untreated water generates diseases that affect the population, such as viruses, hepatitis and cholera.

Another problem in Brazil is the inconsistent distribution of its water resources. The report on water resources, [6] pointed to the distribution of surface water resources in the Brazilian territory: while in the basins next to the Atlantic Ocean, which concentrate 45.5% of the total population, only 2.7% of the water resources of the country, in the North region, where only about 5% of the Brazilian population live, these resources are abundant at approximately 81%.

One technique that has been widespread in urban areas is the capture of rainwater, which can decrease and, in some cases, solve problems related to water scarcity.

The capture of rainwater in buildings is the cleanest alternative water source available, requiring little treatment before being suitable for a wide variety of uses [7]. The alternatives of water reuse and use of rainwater undoubtedly promote the minimization of the environmental load on the springs.

In view of this scenario of poor distribution of water resources, lack of water and basic sanitation in Brazil, the use of rainwater recovery techniques is necessary for the conservation of drinking water, which is essential for human consumption. Through rainwater collection systems, it is possible to reduce the consumption of drinking water for human consumption, such as, for example, in toilets, garden irrigation, external taps, laundry, and even minimize flooding and flooding.

For rainwater to be used, it is necessary to apply appropriate treatments, even if its use is for non-potable purposes, aiming at an improvement in its quality, in order to guarantee safety to those who use it. Disinfection of water using an ultraviolet (UV) lamp is a simple, low-cost method that acts according to the source of the water and can achieve a quality that is harmful to human health, with the advantage of avoiding the use of products chemicals in its purification.

UV irradiation inhibits the proliferation of microorganisms, since the rays cause a rupture in the DNA, killing them or preventing their reproduction, and yet, the water will be free of residual odor and taste.

The geographic distribution of cities and towns without treated water and normally without electricity makes the use of solar photovoltaic conversion an appropriate option for UV disinfection systems, as they are reliable, have a useful life of more than thirty years and their energy source is abundant around the globe [8].

The combination of rainwater harvesting, UV lamps and photovoltaic energy is justified by the construction of a self-sufficient, sustainable system, with little maintenance and favoring isolated places and low-income communities. However, the number of studies involving water disinfection using a UV lamp is numerous, but studies that use the three aspects of rainwater capture, UV lamp and photovoltaic energy are still not widespread.

However, it is possible to find a work carried out at UTFPR in 2011 and an article published in 2012. Both use the germicidal lamp to treat water. However, it was not clear whether the water is river or rainwater, but they use solar energy to power the system.

In order to minimize the adversities of water scarcity and improve its quality, it was decided to conduct a survey at UTFPR's Green Office - GO within the sustainability criteria, to assess the efficiency of rainwater treatment through ultraviolet radiation, connected to a photovoltaic energy system.

MATERIAL AND METHODS

The development of the research work took place in the municipality of Curitiba in the State of Paraná. The activities were carried out, on a full scale, in order to characterize the quality of the rainwater.

The collections were carried out at the Green Office (GO) of the Federal Technological University of Paraná (UTFPR) and laboratory analyzes of rainwater quality parameters in laboratories at UTFPR's Ecoville Head office.

Green Office

The Green Office is located in Curitiba, State of Paraná, at Avenida Silva Jardim nº 807, between Rua Desembargador Westphalen and Avenida Marechal Floriano Peixoto, with latitude -25.44º and longitude -49.26º, as shown in Figure 1.

Figure 1. UTFPR Green Office [9]

The GO is a building based on sustainability, distinguishing itself from traditional architecture in Brazil. The construction was done in wood-frame and its execution lasted seven days. The project was conceived following the concept of bioclimatic architecture, allowing cross ventilation, use of the north facade to capture solar energy, the use of a green roof, which favors the environmental comfort of the building [10], in addition to the system for capturing rain water.

The GO aims to develop and implement programs that reduce the environmental impact on the lives of the population, through research carried out at Campus Curitiba.

Green Office rainwater collection system

The system starts with rainwater that seeps through the building's roof and reaches the gutters. Then, the water goes to a 1500 liter cistern, however, on the way to the cistern the water passes through a descent filter. This filter is used to discard the first rainwater, in order to remove impurities such as moss, leaves, insects and other debris that may have joined the water during its flow through the roof.

Next to the cistern there is a valve that controls the flow of water that reaches the disinfection system, so it is possible to check its performance with different flow. In addition, there is a photovoltaic pump of the brand Shurflo, model 8000-443-136 of 12V (volts) that pumps water from the cistern to the disinfection system.

The water flow enters one end of the disinfection system, is subject to ultraviolet radiation, and exits through the other end of the tube.

The ultraviolet disinfection system was developed using a PVC tube 100 mm in diameter and a T8 30 W germicidal tubular lamp, G-Light brand, 89.5 cm long, which emits waves of 254 nanometers, powered by a panel photovoltaic.

Finally, this treated water is distributed to the toilets and an external tap. The complete system is shown in Figure 2.

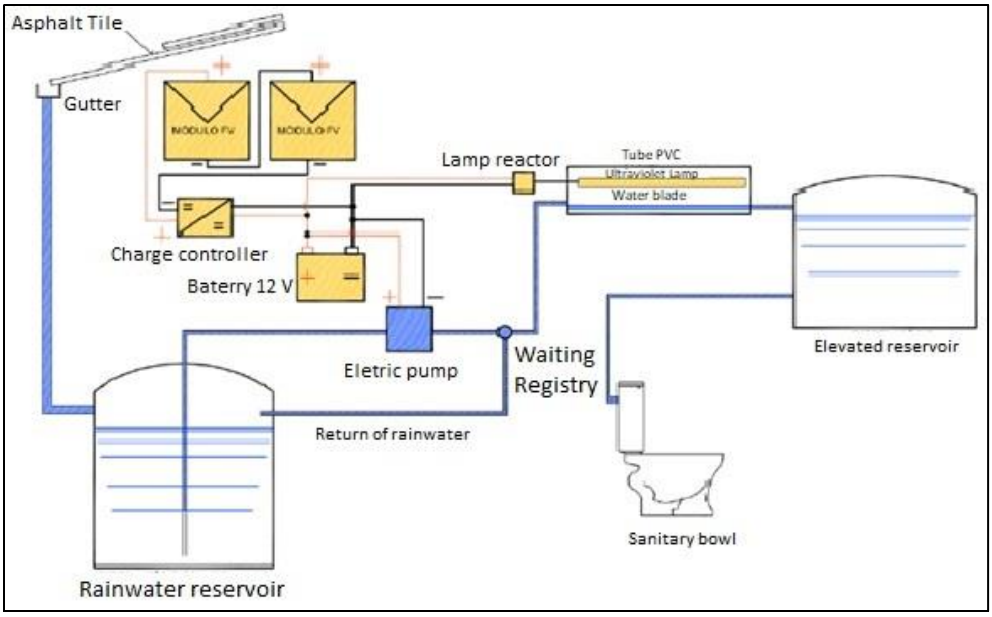

Figure 2. Rainwater disinfection system powered by photovoltaic modules

In Figure 2 you can see the electrical system formed by two photovoltaic modules that add up to a total of 174 Wp, connected to a charge controller, to a 12 V battery that send energy to a photovoltaic pump and the UV germicidal lamp.

This system comes into operation when the water level of the elevated reservoir is low, being activated through a float installed inside it. Then, the photovoltaic pump starts operating and the UV lamp is activated, starting the disinfection of rainwater.

Qualitative parameters of analysis

Physico-chemical and microbiological parameters were selected to analyze the water quality of the cistern and after passing through the disinfection system, and with that, present representative data in different months of the year.

The analyzes were carried out at the UTFPR Water Treatment and Potabilization Laboratory, Ecoville headquarters in Curitiba.

The methods and equipment used for each analysis are described in Table 1.

Table 1. Analyzed Parameters

Parameters	Unity	Method	Equipment
Total coliforms	NMP/100 Ml	plating	hothouse
Thermotolerant Coliforms	NMP/100 Ml	plating	hothouse
Total Suspended Solids	mg/L	Vacuum pump	hothouse
Turbidity	NTU	direct measure	turbidimeter
Color	uH	direct measure	spectrophotometer
pH	-	direct measure	pHmeter

Water collections were made over a period of six months, totaling 13 analyzes at UTFPR and an analysis of total and thermotolerant coliforms carried out in a laboratory of the Companhia de Saneamento do Paraná (SANEPAR). The analysis carried out at SANEPAR had the use of colilert as a method, a different procedure from those performed at UTFPR. However, the result was used to compare whether there was consistency in the values found in the University's laboratories.

Data of pluviometry and solar irradiation

The rainfall and solar irradiation data were obtained from the National Institute of Meteorology (INMET), which since 1961 has collected information from meteorological stations throughout Brazil.

The rainfall data will be used to calculate the real values that can be disinfected according to the monthly rainfall.

The irradiation data used to estimate the electrical energy produced by the Isolated Photovoltaic System that feeds the Ultraviolet Disinfection System, were obtained from the INMET website, consulting the data from the A-807 station, located in the Jardim das Américas neighborhood in Curitiba, on the Campus from the Federal University of Paraná (UFPR), at the Centro Politécnico.

The INMET irradiation data are used to calculate the values in the horizontal plane for each month of the year, this is done through the excel software. With the values of the horizontal plane, another software is used, Radiasol, developed by the Federal University of Rio Grande do Sul. It is used to correct the values of the inclined plane, that is, the inclination in which the panel was installed must be used, in addition to using angulation and azimuth deviation.

RESULTS

The parameters analyzed were rainfall, solar irradiation, temperature, turbidity, color, pH, total suspended solids, total coliforms and thermotolerant coliforms. The choice of these parameters is due to NBR 15527 of 2007, which establishes values for the use of rainwater for non-potable purposes.

Curitiba rainfall data

The rainfall data in the city of Curitiba for the year 2018 to 2020 are described in the Figure 3.

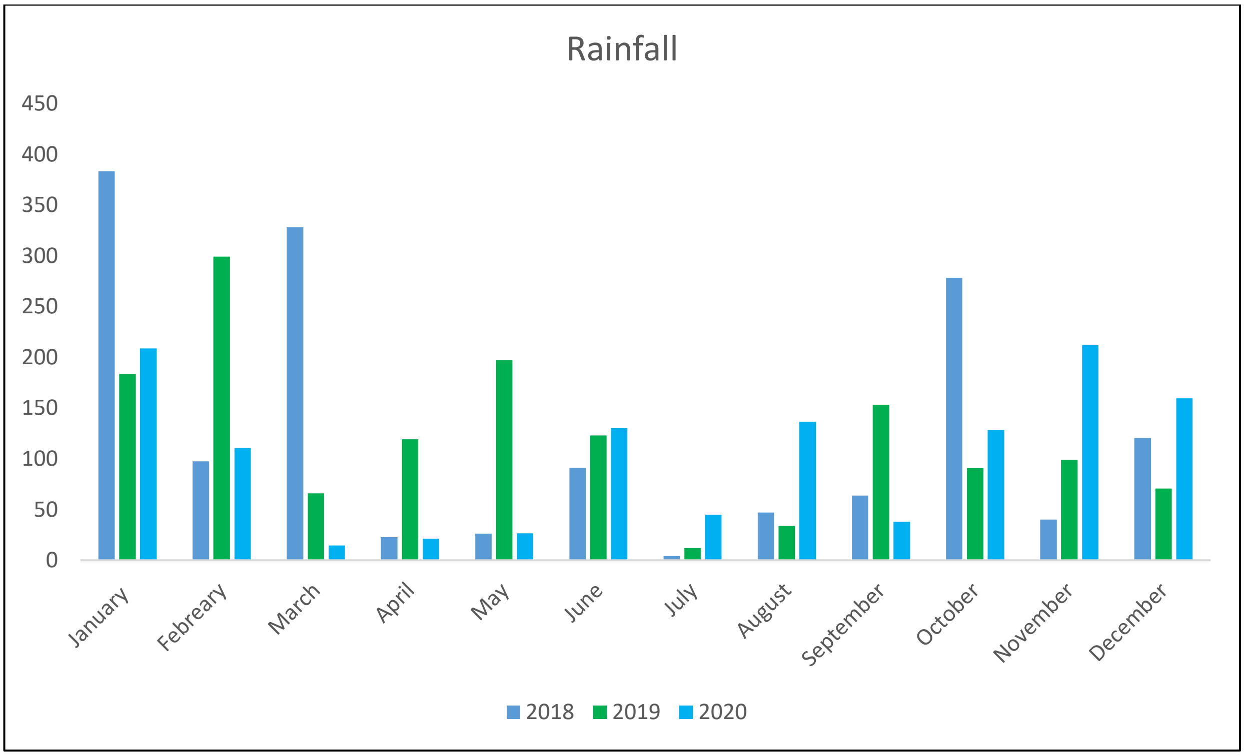

Figure 3. Graph of rainfall data from Curitiba in the year 2018 to 2020 [11]

In the Figure it can be seen that there was a significant variation in the rainfall indexes from one year to the next, demonstrating that in 2018 the precipitation levels were higher than in the following years, with values of 4 and 18% for the year 2019 and 20020 respectively.

With these values it was possible to determine the volume of rainwater that could be disinfected monthly. In addition, listing these data has shown that rainfall in the city of Curitiba is variable, however, there are no periods of drought.

Solar irradiation data on the insulated photovoltaic system panel

The solar irradiation data obtained on the INMET website with the aid of a pyranometer refer to values in the horizontal plane and are contained in Table 2

Table 2. Average daily irradiation in the horizontal plane - INMET (kwh/m².day)

Month	2018	2019	2020
January	4.85	5.85	5.19
February	4.90	4.52	4.53
March	4.20	4.20	5.56
April	4.66	3.67	4.94
May	3.51	2.50	3.85
June	2.43	3.12	2.50
July	3.33	3.29	3.32
August	3.83	3.66	3.80
September	3.78	3.78	4.22
October	3.36	5.35	4.79
November	4.93	5.23	5.74
December	6.39	5.36	5.13

To obtain the irradiation values in the inclined plane, the Radiasol program was used with the conditions of inclination and orientation of the analyzed panel. In the case of the photovoltaic panel of the isolated system on the roof of the UTFPR EV, there is an inclination of 19° and azimuthal deviation of 22° to the west in relation to the north. The graph with the irradiation values for the years 2016 and 2017 are shown in Figure 4.

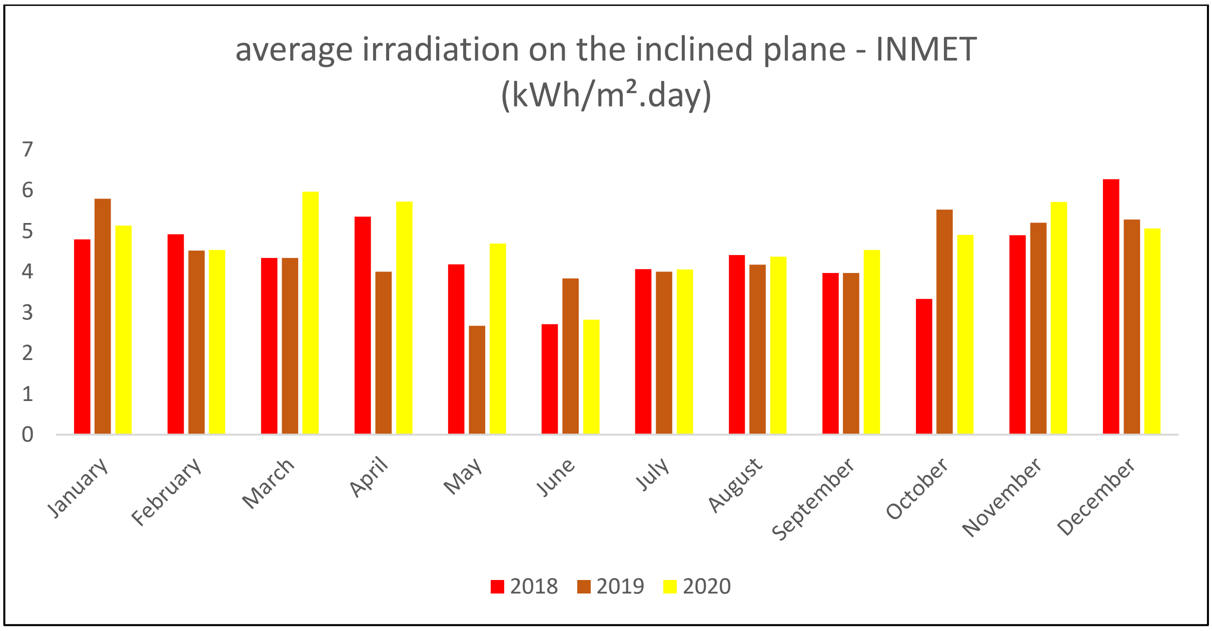

Figure 4. Solar irradiation data on the SFVI panel (kWh/m².day)

The values show a greater irradiation in the summer periods, as expected, and less in the winter months. However, the month of July and August correspond to the winter season and have high irradiation values, as well as the months of September and October (except in 2018), both referring to the spring period. This may be linked to the fact that rainfall was low in these months, and thus, a higher incidence of irradiation.

Listing the indices of the last three years, it can be seen that in the city of Curitiba there are no significant variations in irradiation values. However, the higher the irradiation rates, the greater the number of hours the disinfection system will operate.

Electric energy available in the isolated photovoltaic system and disinfected water volume

To perform the calculation of energy generated daily, the power of each solar module must be added. In this research, two photovoltaic modules with a power of 87 Wp each were used, totaling 174 Wp. In addition, the irradiation values (H_{TOT}) presented in Figure 27 should be used. With these values, it is possible to calculate the energy generated daily for each month of the year, using formula 3. The results are shown in Table 3:

$$P_{FV} = \frac{E.G}{H_{TOT}\,.\,R}\,.F_{loading} \quad (1)$$

Where: E – energy generated daily (Wh/day);
G – irradiance under STC conditions (1,000 W/m²);
H_{TOT} – incident solar irradiation on the PV modules plane (Wh/m².day);
$F_{loading}$ – daily battery charging factor, 1.1 was adopted;
R – performance of the set of devices and system components: charge controller, battery, inverter (if any) and wiring. The adopted value of R was 70%.

Table 3. Energy made available daily by the SFVI (Wh/dia)

Month	2018	2019	2020
January	537,02	647,75	574,67
February	542,56	500,48	501,59
March	465,05	465,05	615,64
April	515,98	406,36	546,99
May	388,65	276,81	426,30
June	269,06	345,46	276,81
July	368,72	364,29	367,61
August	424,08	405,26	420,76
September	418,54	418,54	467,26
October	372,04	592,39	530,38
November	545,88	579,10	635,57
December	707,54	593,49	568,03

Given the values of energy generated daily for each month of the year, it is possible to calculate how many hours a day the system is in operation. For this, the generated energy values (E) must be divided by the pump power (120 W), plus the lamp power (30 W). As a function of the energy generated and the power of the loads (pump and lamp), Table 4 shows the estimated number of hours of system operation per day.

Table 4. Estimation of the number of hours of operation of the disinfection system

Month	2018	2019	2020
January	3.58	4.31	3.83
February	3.61	3.33	3.34
March	3.10	3.10	4.10
April	3.43	2.70	3.64
May	2.59	1.84	2.84
June	1.79	2.30	1.84
July	2.45	2.42	2.45
August	2.82	2.70	2.80
September	2.79	2.79	3.11
October	2.48	3.94	3.53
November	3.63	3.86	4.23
December	4.71	3.95	3.78

Using the values in Table 4, the volume of water disinfected by the ultraviolet germicidal lamp is arrived at. For this, the average values of maximum, average and minimum flow are necessary. Multiplying these values, the volume of water disinfected monthly by the isolated photovoltaic system is found, as shown in Table 5.

Table 5. Estimate of the daily amount of water that can be disinfected (l)

	Maximum Flow			Average Flow			Minimum Flow		
Month	2018	2019	2020	2018	2019	2020	2018	2019	2020
January	526,26	633,57	563,01	307,88	370,66	329,38	75,18	90,51	80,43
February	530,67	489,51	490,98	310,46	286,38	287,24	75,81	69,93	70,14
March	455,70	455,70	602,70	266,60	266,60	352,60	65,10	65,10	86,10
April	504,21	396,90	535,08	294,98	232,20	313,04	72,03	56,70	76,44
May	380,73	270,48	417,48	222,74	158,24	244,24	54,39	38,64	59,64
June	263,13	338,10	270,48	153,94	197,80	158,24	37,59	48,30	38,64
July	360,15	355,74	360,15	210,70	208,12	210,70	51,45	50,82	51,45
August	414,54	396,90	411,60	242,52	232,20	240,80	59,22	56,70	58,80
September	410,13	410,13	457,17	239,94	239,94	267,46	58,59	58,59	65,31
October	364,56	579,18	518,91	213,28	338,84	303,58	52,08	82,74	74,13
November	533,61	567,42	621,81	312,18	331,96	363,78	76,23	81,06	88,83
December	692,37	580,65	555,66	405,06	339,70	325,08	98,91	82,95	79,38

The volume of rainwater that could be disinfected was calculated using the actual values of monthly rainfall throughout the year in the city of Curitiba, available in Figure 3. First, the roof runoff area was calculated, in this case, it was approximately 105 m², and thus multiplied by the monthly rainfall values, described in Figure 3, obtaining the values in liters per month, due to arrive at the result in liters per day. These values are illustrated in Table 6.

Table 6. Rainfall values per day (l)

Month	2018	2019	2020
January	1341,9	641,9	730,1
February	340,9	1047,2	387,8
March	1148,7	231	51,1
April	79,8	417,2	74,2
May	91,7	690,9	93,1
June	319,2	430,5	455,7
July	17,5	42	157,5
August	164,5	118,3	477,4
September	222,6	536,2	132,3
October	974,4	317,8	448,7
November	140,7	346,5	741,3
December	421,4	247,1	557,9

Table 6 shows that the volume of water varies throughout the year. In 2018 and 2019, the month with the lowest rainfall was in July, providing approximately 17.5 and 42 liters of water per day, making it impossible to use the toilets in a residence of up to 4 people, because toilets use an average of 10 liters of water for each flush [12]. However, the month of July can be described as an atypical month compared to the other months of the year, both in 2018 and 2019.

The months with the highest rainfall are usually concentrated in January and February, that is, in the summer period. However, we can observe that the rainfall period varies over the months and from one year to the next. However, summer has the highest solar irradiation months, being the best period of operation of the system.

In 2018, the months of January, February and October obtained values above the daily consumption of a family, since a popular residential house with up to four people consumes an average of 600 liters of water per day, of which about 30 to 40% are related to water. flushing toilets. According to [12] the values can reach 50% depending on the discharge trigger model. However, in 2019 this consumption would only be supplied for the months of January, February and May. In the year 2020, only the months of January and November.

It is worth mentioning that 30 to 50% of the daily values would be used, since the system was designed only for the toilets. Therefore, a family of up to 4 people would need 180 to 300 liters of water daily for the toilets. Therefore, several more months over the three years would supply a residential dwelling.

Comparing Table 5, referring to the daily amount of water subject to disinfection (l), and Table 6 with the rainfall values per day (l), demonstrates that the volume of water available is higher in most months of the year for the maximum and average flows used in the survey. However, the values of water disinfected by the minimum flow would not supply the toilets, which is the purpose of this research.

In remote regions, where there is no access to water, this system would be feasible, especially in some regions of Northern Brazil where rainfall rates are higher, and also, in regions with lower rainfall such as the Northeast of the country, this system could mitigate the adversities caused by the lack of water resources.

For the use of water for human consumption, a secondary treatment using the installation of a filter with sand or activated carbon filter media, before the disinfection system, would retain the solids with greater property, obtaining an improvement in the quality of the water, which may be possible its use for drinking purposes. However, it would be necessary to analyze 93 parameters established by the Consolidation Ordinance Nº. 5 of 2017 of the Ministry of Health.

In Brazil, the use of water for human consumption is only allowed if it meets all the criteria established by the legislation, this normally occurs through the supply companies. However, some regions of the country do not have access to any water distribution network, making this system a viable solution.

This system would also be useful for those isolated regions that do not have access to electricity, as the energy from the isolated photovoltaic system stores solar radiation in a battery bank, making it self-sufficient.

In the city of Curitiba, this water disinfection system would minimize the use of potable water in unnecessary places such as toilets, washing of sidewalks and irrigation of gardens.

As there are electricity transmission lines in the city, the use of a photovoltaic system connected to the grid would be feasible.

Parameters analyzed

The results were analyzed over a period of 3 years. During this period, an analysis of coliforms with input and output values of the disinfection system was carried out by Companhia de Saneamento do Paraná (SANEPAR). The average between the values obtained during the analyzes carried out at the UTFPR laboratory and the analysis carried out at SANEPAR are shown in Table 7 and 8 respectively.

Table 7. Average between the water analyzes performed in the UTFPR laboratory

Parameters	cistern	maximum flow	average flow	minimum flow
Flow (L/s)		0,041	0,024	0,006
Turbidity (UT)	2,24	1,76	1,87	1,93
Color (uH)	19,29	14,71	14,38	10,56
pH	6,60	6,52	6,55	6,49
Temperature (°C)	21,3	21,6	21,4	21,4
Total Suspended Solids ($mg.L^{-1}$)	16,6	9,14	7,15	4,92
Thermotolerant coliforms (NMP/100 mL)	absent	absent	absent	absent
Total coliforms NMP/100 mL	280	54	0	0

Table 8. Analysis of total and thermotolerant coliforms carried out at SANEPAR

Parameters	Cisterna	maximum flow
Total coliforms	308 NMP/100 ML	8 NMP/100 mL
Thermotolerant coliforms	< 1 NMP/100ML	< 1NMP/100 mL

The results carried out in the UTFPR laboratory, express that the flow is directly related to the quality of the water. The lower the amount of water percolating through the disinfection system, the longer the exposure time to the UV lamp and, consequently, the better the efficiency of the system.

However, taking the average between all collections and analyzing all parameters, it can be seen that there were no significant changes in the parameters of turbidity, color, pH and temperature in all flows. Parameters such as pH and temperature do not interfere in the efficiency of UV disinfection [13].

Turbidity is often used to represent the presence of particles in water, being an important parameter of water quality in the treatment of both water for non-potable purposes and for human consumption. These particles can be inorganic solids (silt, sand or clay) and organic matter (algae, bacteria, etc.) [14] The organic matter present in rainwater comes from animal feces, leaves, mosses and lichens that are present at the time of collection. To reduce the turbidity of rainwater, the use of a device to dispose of the first millimeters of rain is essential and in this research a disposal filter was applied, eliminating the most polluting fraction of the water, which possibly improved the turbidity values.

The parameters that obtained changes between the cistern water and the three different flows were total suspended solids, with an improvement of 45%, 57% and 70% for the maximum, average and minimum flows, respectively. Total suspended solids limit the level of disinfection that can be achieved since microorganisms can remain in the “shadow” or be incorporated into these particles, and, in both cases, not be exposed to UV radiation [15].

As for the total coliforms, the system efficiency was 80% for the maximum flow and 100% for the average and minimum flows, referring to raw water (cistern).

In research using UV lamps such as that of [16] the authors used flow rates from 2.0 to 9.9 L/minute, similar to the values of this research, to determine the water quality of an ultraviolet disinfection system, reaching the efficiency of 99%, 98.7% and 98.3% respectively, for total coliforms and Escherichia Coli.

In the work of [17] an ultraviolet disinfection system was used in river water, with turbidity values between 30 and 45 UT and flow rates of 5 to 10 L/min, reaching values of 99% efficiency for coliforms. On the other hand, the research by [18] was performed with rainwater and the efficiency of disinfection of direct precipitation and runoff on the roof by ultraviolet radiation was verified with the inactivation of 100% of total coliforms and thermotolerant coliforms and the non-regrowth of these microorganisms in treated samples. and stored for up to 72 hours.

The analysis of total and thermotolerant coliforms from the cistern and maximum flow performed in the SANEPAR laboratory, obtained values of 97.4% efficiency, a better result than the one performed in the UTFPR laboratory, for the same points. Although the method used in the SANEPAR laboratory is different from that used by the UTFPR, the efficiency of the UV lamp and the performance of the system as a whole are evident.

Comparing the results of the analyzes at the UTFPR laboratory with the rainwater quality parameters established by ABNT in NBR 15.527/2007, arrived at the values described in Table 9.

Table 9. Comparison between the NBR 15.527/2007 quality of rainwater and the average of rainwater analyzed in this research.

	NBR	UTFPR		
Parameter	**15527/2007**	**Max**	**Ave**	**Min**
Turbidity	< 2,0 e < 5,0	1,76	1,87	1,93
pH	6 à 8	6,52	6,55	6,49
Color uH	< 15	14,71	14,38	10,56
To. So. mg/L		9,14	7,15	4,92
To. Col. NMP/100m/L	Absent	54	0	0
Te. Col. NMP/100m/L	Absent	0	0	0

The data observed in Table 9 demonstrate that the average and minimum flow values are in accordance with the standards established by NBR 15527 of 2007. The maximum flow values were not within the standards due to the parameter of total coliforms.

System generated savings in a standard family home

Drinking water consumption in the country is 154.0 liters per inhabitant per day, according to a survey released by the [19].

Of this volume, more than half is spent on toilets, in the shower, to wash the face and brush the teeth. However, the expense can be even greater, if the toilet has a defective valve, with that the expense, which is around 12 liters, could reach 30 liters. When taking a 15-minute bath in an electric shower, 45 liters are spent, reaching 135 liters if the shower is a shower [20].

These values vary by region and family income. Table 10 shows the average volumes of drinking water spent by a typical household (one couple and two children) per day for each activity.

Table 10. Daily water demand for a standard family

Activity	Daily consumption (l)
Drinking and cooking	72
Toilet with actuating valve	240
Toilet with attached box	120
Bath	180
Washing clothes	19
Wash the dishes	60
Wash sidewalk	40

Source: [20]

To arrive at the daily consumption values in Table 10, it was considered that each person flushes the toilet 5 times a day, takes a shower once a day for 15 minutes, and washes clothes and sidewalk is held once a week. Thus, the average monthly consumption would be 14,730 liters for homes that have a toilet with an attached box and 18,330 liters for homes that have a toilet with a trigger valve.

With the UV disinfection system, you would save 4,480 to 7,840 liters of water monthly, a savings of 30 to 42% using just the toilets and sidewalk washing.

Table 10 showed average values for the use of toilets in a residence of up to four people and comparing with the calculations performed in this research, the minimum flow would not meet the objectives of this research, because in months of greater precipitation the values of this flow are around of 80 liters per day, and its use is unfeasible.

CONCLUSION

In Brazil, water collection systems do not have uniform legislation, there are states and municipalities with their own laws and in some places there is no form of law.

The disinfection system installed at the UTFPR Green Office showed better efficiency in water quality for the average and minimum flows, due to the absence of coliforms. This result is due to the exposure time with the UV lamp being slower compared to the maximum flow.

The proposed treatment for rainwater through ultraviolet radiation meets the guidelines of NBR 15517/2007 for non-potable uses of rainwater, for medium and minimum flows. The exception for the maximum flow that does not fit the parameters determined by the resolution and the standard is in the values of total coliforms, which are above the established.

Regarding the availability of liters of water that could be disinfected daily by the isolated photovoltaic system, with the volume of water subject to disinfection according to the flows studied, it can be concluded that the volume of water available is higher in most parts. of the year for the three flows used in the research. However, the values of water disinfected by the minimum flow would not supply the toilets in an environment with up to four people, but would be viable in the medium and maximum flow.

The solar irradiation results showed that the operating hours of the isolated photovoltaic panel in recent years was adequate for the UV disinfection system. However, the number of hours is linked to the daily amount of water that can be disinfected in the EV, and in this case it would be feasible only in the maximum and average flows. These flows would supply the toilets and external faucets in most months throughout the year.

In this way, it is concluded that the proposed system for collecting, storing and disinfecting rainwater connected to photovoltaic energy, is efficient for the mentioned objectives, and can become an important source of water savings in urban areas in addition to a source of supply. mainly in areas without basic sanitation.

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