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Paul M. Cabacungan

Gregory L. Tangonan

Nerissa G. Cabacungan

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Abstract: ***This paper presents the design of the Water-Electricity-Light System (WELS) that is an integration of technologies composed of rain catcher, mechanical filter and UV irradiation, solar panel, charge converter, LED light, inverter and car battery. We traced back its development from a bulky and expensive system that was meant to generate drinking water into a more innovative water cleaning system that integrated lighting and cellphone charging. We tracked the improvements applied to the system to make the design more efficient yet simple enough to be replicated and customized in order to address varied needs. We shared the alterations made to the system components based on installation experiences in different contexts.***

We also explored ways to lower its cost and to make its power storage more durable. Initial results are shared in this paper.

Having seen its usefulness and realized its successful implementation on the ground, we are proposing the pre-positioning of WELS to promote disaster resilience in a community level. We based this assertion on the review of all documentations done and feedback gathered from our ten-year experience of more than 140 WELS installations all over the Philippines.

Keywords: Clean water system, Community level disaster resilience, Potable water during disaster, Technology innovation, Water disinfection, Water filtering.

I. INTRODUCTION

The Philippines is an archipelago that is located along the Ring of Fire where 90% of earthquakes occur. It sits across the Pacific typhoon belt [1] and is visited by an average of 20 typhoons every year [2]. Its exposure to natural disasters is "frequent, varied and severe" [3].

During calamities, infrastructures like communication, power and electricity, and water facilities get damaged. Damage to these structures inhibits emergency response and recovery. Access to clean water is one of the crucial needs emphasized after a disaster [4]. There is a proposal that instead of relying on common lifeline services and relief goods, stocked supplies for daily living can be utilized. However, it was found that many households lack adequate stock of drinking water [5]. This paper hopes to present the innovations of an integrated technology to address the immediate need for potable water and electricity.

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* Correspondence Author

Paul M. Cabacungan, Department of Electronics Engineering, Ateneo de Manila University, Philippines/ BS Electrical Engineering, Mapua Institute of Technology, Philippines.

Gregory Tangonan, Ph.D., Department of Applied Physics/ M.S. Physics, California Institute of Technology, USA/ B.S. Physics, Ateneo de Manila University, Philippines.

Nerissa G. Cabacungan, M.A., Department of Counseling Psychology, Ateneo de Manila University, Philippines.

II. RELATED LITERATURE

The World Health Organization (WHO) projected that water scarcity is going to be prevalent as a result of climate change [6]. In anticipation of this, there are several water treatment methods that are used to provide drinkable water.

A. Water Treatment Technologies

The two treatment methods are chemical and physical.

Chemical Methods include coagulation-flocculation and precipitation, adsorption, ion exchange and chemical disinfection with the use of chlorine [7]. Among those mentioned, chlorine disinfection is probably the most successful mass medication [8], with chlorine seen as the universal water treatment chemical [9]. It kills a variety of pathogenic microorganisms during treatment and is effective in removing faecal streptococci organisms. However, Cryptosporidium parvum oocysts are found resistant to chlorination [9]. The generation of disinfection by-products (DBPs) also poses adverse effects on human health [10]. Chlorine, when mixed with some waters, could lead to the formation of trihalomethanes [11], which the most commonly formed type, chloroform, is a known carcinogen [12]. Several studies cited the health concerns raised in the use of chlorinated water [13].

Physical Water Treatment Methods include boiling water, settling the sediments at the bottom, filtering the impurities and exposing it to UV radiation [7]. UV irradiation inactivates Cryptosporidium and other pathogenic microorganisms, such as viruses and Campylobacter jejuni [10]. Irradiation can also completely remove coliphage organisms, which are used as indicators of viruses. UV has been found to be fairly effective against parasitic cysts and oocysts [8]. There are many pathogenic organisms that are more susceptible to UV than to chlorine [14]. UV light kills bacteria by breaking their DNA bonds and halting their reproduction [15]. It eliminates bacteria without risk of chemical intake nor residual effect. UV irradiation is quickly gaining popularity as a safe, effective, and economical approach to disinfection [16].

However, the effectiveness of UV disinfection depends on the water being irradiated -- its depth, transmissivity and turbidity [17] and bacterial concentration [18]. Exposure to sub-lethal doses of UV opens the possibility of photo-reactivation of organisms [18].

Another physical method is ceramic filtration. Ceramic filtration reduces e-coli up to 99.9%. Use of ceramic water purifier (CWP) reduces MS2, a viral surrogate, by a mean of 90-99% in laboratory testing.

It also reduces diarrheal disease outcomes by approximately 40% in users versus non-users of CWP. In terms of durability, the filter maintains its effectiveness up to 44 months in field use. However, it was noted that there was decline in the use of CWP due to breakage of the ceramic filter coupled with limited availability of replacement parts and susceptibility to recontamination through improper handling [19].

B. Water Treatment During Disaster

Qu, Meng, Yu & You (2016) suggested that an onsite water supply technology that is portable, mobile, or modular is a more suitable and sustainable solution for disaster victims than transporting bottled water [20]. Liu, Zhang, Tang, Huang & Xiong (2010) pointed out that simple methods of water treatment play an important part in disaster rescues [21]. Sobsey, Stauber, Casanova, Brown and Elliot (2008) discussed that point-of-use (POU) water treatment technology empowers people and communities. They concluded that ceramic and biosand water filters are the most effective and have the greatest potential to become widely used and sustainable [22].

We integrated in WELS an off-the-shelf water technology that uses treatment methods found to be effective, based on literature, and a safe off-grid light and power source for use in disaster situation. This is one technology that can be used for community disaster resilience.

III. METHODOLOGY

This paper traces the innovations applied to WELS. We reviewed the reports, interview and personal notes, email exchanges and magazine articles. We recalled feedback given by the communities and innovations borne out of it. We shared lessons learned from the ten-year installation experiences.

We also conducted two experiments on WELS. The first aimed at finding cheaper and more efficient UV lamp alternatives. The other was meant to determine the feasibility of replacing the lead-acid batteries with lithium-ion for longer life span.

IV. PRE-DEPLOYMENT INNOVATION

A. Solar-Powered Atmospheric Water Generation and Purification System

Sources of drinking water are scarce in many remote areas in the Philippines. This reality led to the conceptualization and fabrication of the Solar-Powered Atmospheric Water Generation and Purification System (SAWGAPS).

SAWGAPS harvests atmospheric air, condenses and converts it to potable water. Its initial set-up generated 18.3 liters of water in 24 hours with an average relative humidity of 69.2%. It consumed 25 kilowatt-hour of energy in 24 hours. All water samples collected, after passing through a ceramic filter and ultraviolet (UV) irradiation, were tested and found to conform to the Philippine National Standards for Drinking Water (PNSDW) [23].

The equipment can be powered by solar energy stored in ten 50-ampere-hour batteries with DC-AC converter. The battery system can also provide enough power to light up a bulb and charge cellular phones.

Major hurdles were encountered. The replication of the system proved to be challenging because some components had to be purchased abroad and putting them together was complicated. The converter had to be fabricated manually. It is not energy-efficient and water generation takes time. It is also bulky and heavy.

Despite the issues encountered, SAWGAPS led to the idea of putting together in one stand-alone system a portable water-cleaning device with provision for lighting and cellular phone charging. It gave birth to an integration of technologies in Water-Electricity-Light System (WELS).

B. Water-Electricity-Light System

WELS is composed of off-the-shelf clean water system with provision for lighting and cellular phone charging. A 12-volt battery that is being powered by a 50-watt solar panel runs it. A 10-ampere solar charge controller monitors the solar charging. Its components are available locally.

The rainwater catcher stores water that can be gravity-fed into the system with a computed minimum pressure of 0.39 kilogram-Newtons per square-centimeter. This pressure is obtained when water tank is elevated at 4 meters high using a pipe with 1.27-centimeter-diameter. Another way is to pump the water into the three-stage filtering system. The first stage is the ceramic filtration that removes sediments. The next stage, an ion-exchange filtration, removes sulfates, nitrates and other impurities in water. The last stage -- activated carbon filtration -- improves the taste, color and turbidity and removes suspended elements like chlorine and some heavy metals. After filtering, water passes through an ultraviolet (UV) disinfection lamp where viruses, bacteria and protozoa are eradicated. It can clean and disinfect 4 liters of water per minute.

Lighting is integrated into the system with a 7-watt LED bulb. An outlet is available for emergency charging of one cellphone unit.

The cost of the whole system is reasonably affordable ranging from US$600 to US$700 depending on components included. This system illustrates a concrete way to build disaster resilience in a barangay or community level.

The operation diagram of the system is as follows.

Fig. 1. Operation diagram of Water-Electricity-Light System

V. DEPLOYMENTS OF INNOVATIVE WATER SYSTEM

In ten years, more than 140 WELS have been installed in different parts of the Philippines (National Capital Region or NCR, Luzon, Visayas and Mindanao).

The first installation of WELS in a disaster area was in Cagayan de Oro (CDO) in the aftermath of typhoon Sendong (Washi) in 2011. It was a post-disaster installation meant to clean the municipal water. WELS was attached to a water tank that was being brought around on top of an elf truck to ration drinking water. WELS gave added assurance that the water from the tank passed through further cleaning and disinfection. Water can also be fetched at nighttime with the integration of lighting. An outlet for cellular phone charging was also available.

Fig. 2. Post-disaster WELS installation on an elf truck in Cagayan De Oro

Several days after the calamity hit the area, some Manila-based water companies brought in a Portable Treatment Plant (PTP). The CDO residents initially expressed apprehensions to drink water from it because it sourced water from the river, where locals knew a number of dead bodies were found. They preferred the WELS. When the PTP eventually gained acceptance, the WELS was transferred to Iligan City, the next affected town.

In 2013, the havoc caused by an earthquake in Bohol made drinking water scarce. WELS was connected to damaged water pipes. While aftershocks were still happening, WELS installation was in progress and drinking water was made available immediately after.

The following month, typhoon Yolanda (Haiyan) left Tacloban without potable water and without any elevated water storage facility. This gave birth to the idea of fabricating a PVC pump to push water into the WELS.

The past post-disaster experiences changed the approach to pre-positioning of critical assets -- rain catcher, mechanical filters and UV irradiation, solar panels, charge converters, LED lights, inverter, and car battery. These pre-positioned systems used an elevated storage of 800- to 1200-liter water to eliminate any need for submersible pumps to efficiently flow water through the filters. The system flow was limited to the recommended value of 4 liters per minute to ensure the effectiveness of UV irradiation for disinfection. We did water quality tests before and after filtering using water kits that were brought onsite. Sample water kit was seen in Figure 3 showing excellent results after cleaning and disinfection.

Fig. 3.Water testing kits indicate results of contaminated (upper level) and cleaned water (lower level)

Pre-positioning of solar power for off-grid communities was considered a very expensive proposition, because the solar panels were costly, payback period was considered prohibitive. For communities with these systems, WELS provided a powerful example of creating Disaster Resilient Systems. Post disaster delivering of 100 liters of water to communities in a timely way comes at 100 times or more the pre-disaster costs. After one disaster, being the only Barangay with clean water, LED lights, and battery charging establishes that this is an approach to Understanding Risk and Building Resilience at the community level. The solar powering system, even when there is no rain, continues to deliver LED lights, cooling fans, and everyday cellular phone battery charging. We engineered the design so the system load does not discharge the battery below one half its capacity for improved battery life.

All WELS installations included training in system operation, maintenance, and repair, with complete materials list. A tarpaulin showing the components and maintenance procedures, together with the installer's contact details, was also posted in the installation site for easy reference.

VI. POST-DEPLOYMENT INNOVATIONS

A. Component Adaptations

Deployment experiences in different areas gave rise to more innovations in the components to make the system more adaptable to the community's varied contexts.

Continuous development was applied to WELS to keep abreast with new technologies available in the market. What follows are the processes of improvements done.

Power Source. WELS started with grid electrical powering. Installation in off-grid communities necessitated that the unit run by solar powering with the use of poly-crystalline panel at the start then to a more efficient and cheaper monocrystalline. Transport of solar panel was a concern – it is bulky and its glass cover is prone to breakage. It was realized that the three-ampere solar panel can be replaced with a second-hand pedal-powered alternator. Mechanical charging of batteries using stationary bike and pulley belt with an alternator was found to be more powerful as it generated four to seven amperes by moderate to fast peddling. It can charge and prolong the life of the battery during rainy season.

Energy Storage. The lead-acid car battery used for the first set-up dried up easily and had to be replaced every two years. A maintenance-free battery was better but it was big and heavy. In order to miniaturize the system, a smaller motorcycle battery was used.

DC-AC Converter. The first WELS unit used an imported 300-watt 110-volt DC-AC converter, which was expensive. It was replaced by a 100-watt inverter which was later reduced to a 75-watt. What was found most durable was a recent off-the-shelf 500-watt inverter with built-in 5-volt DC phone charger. It has better heat dissipation because of aluminum body and wider operational power range.

Electrical Wiring. Flat cord was used in the initial set-up. Later, a THHN#14 copper stranded wire proved to be more durable. It has better conductivity and is readily available in the market compared to other materials.

Intelligent Electronic System. Bulky electronic battery monitor consumed too much energy. When it was removed, direct connection to the battery was successful. A charge controller that was more energy-efficient gave the needed monitoring.

LED Light. The light that was initially used was a 10- watt low intensity LED bulb. Then, 10- and 7-watt AC lights were tried out. After some time, the bulb was replaced by a 7-watt DC light so it can be DC-powered and did not have to run through a converter. Another alternative is a more efficient smart 5-watt bulb. Now, a smart light bulb with built-in battery is used because it can also readily serve as flashlight during disaster.

Emergency Cellphone Charging. A duplex power outlet intended for UV lamp and cellphone charging was changed to a single outlet. This prevented “octopus connection” and excessive use of power for non-emergency charging of other devices. This gave priority to use of power for cleaning water. Emergency cellphone charging can be done before and after cleaning water.

Water Storage Facility. The initial design entailed construction of elevated rainwater harvesting facility to gravity-feed water through the WELS filters. Without elevated structure, we used a do-it-yourself PVC pump to suck in water from any water collecting container or source and manually pump it into the system for cleaning without any need for electrical power.

We also suggested the use of a series of 200-liter plastic drums, instead of a concrete or stainless water storage to lower the costs. These drums can be on the ground, positioned under existing downspout or improvised downspout (with the use of use of tarpaulin). Note that only drums that used to contain edible substances, like cooking oil or vinegar, and not toxic chemicals, like paint thinner, were purchased for this purpose. Bottom series connection was used with 5-centimeter height standing pipe inside the drum to prevent the sediments from settling at the bottom of the drum and block the drain. The connection was done in such a way that the drums can be disassembled and isolated from each other for easy maintenance cleaning. It used union fitting and ball valves.

A pre-filtration system was put on the downspout and/or on the roof gutter. The drums were covered properly. The drum cover was cut in the middle and the two half covers were connected with stainless hinges or cable tie for easy opening. Cheesecloth was put on top of the cover to prevent dirt from entering the drum. The cloth was secured by a pull nylon cord lock.

After few installations, it was observed that a stationary clean water system restricted accessibility. Those who did not have their own storage facility encountered problem in transporting the water. Thus, a more portable clean water system was designed. This system can be put in a wheeler or tricycle or back-pack and attached to a pump.

Connections and Fittings. Stored water from elevated structures is usually gravity-fed into the WELS. However, water pressure would be greatly dependent on the height of elevation. At least 3 to 4 meters in height from the water outlet is required. In places where elevation of structure is not high enough, an electric pump, with at least 100-watt power, can be used to push water into the WELS unit. To strengthen water pressure, we avoided plumbing corners because bends in the pipes weaken pressure. PVC pipes can be replaced with water hose for smooth water flow.

Another resourceful solution is the fabrication of PVC pump. This pump has minimal use of angled pipes and the inlet/outlet pipes used are 1.27 centimeter in diameter. To increase suction power of the pump, local technicians of Valenzuela, Metro Manila suggested the use of water pressure gasket instead of O-ring from a PVC union fitting. This change strengthened the pump and brought down the cost of fabrication. With the use of this pump, rainwater and tap water can be cleaned and transferred to 20-liter containers.

Filter and Disinfectant. The basic system started with an off-the-shelf water cleaning kit composed of three stages of filtration. Each stage is enclosed in a canister. Later on, a single canister for the 3-stage filtration is made available in the market. The new model is cheaper and easier to assemble. Before, we were using washable ceramic filters that could last long but very fragile; now, non-fragile disposable particulate filters are also available in the market.

This basic filtration system is attached to a UV lamp for ultraviolet disinfection. This UV lamp is enclosed in a stainless canister, consumes 6 watts of power and has 254 nanometer peak wavelength, which is needed in order to optimally kill microorganisms.

The system put together filtration and disinfection. Fittings to connect the different components of the system are also improved from galvanized iron to stainless fittings. The PVC pipe and goose neck outlet have been replaced with translucent continuous hose to easily detect dirt and provide flexibility without sacrificing flow rate.

Water Sensor System. Water sensor system was added to the installation done in a parochial school in Marikina. The sensors detected water level in the rainwater harvesting facility and measured the acidity (pH), electric conductivity (EC), turbidity or total dissolved solids in water. Once acceptable parameters are not met, an electronic gate valve opens to release water outside the harvesting facility. These helped maintain water quality in conformance with the PNSDW. They were remotely monitored using an Arduino micro-controller and a GSM module. The module sent data in a website designed to indicate monitoring parameters.

Water Testing Kit. Water testing kit was made available during installation. Bringing water sample to a microbiology laboratory was costly and could cause delay. Portable test kits can immediately detect presence of coliform, e-coli, chlorine and pesticide in water. Use of water testing kit identifies contaminated water sources and verifies water quality before and after passing through WELS.

Quick Response (QR) Coding. QR code is reflected in the tarpaulin and in the manual of operations. Scanning this QR code allows access to a repository of data about WELS components, operation, maintenance and troubleshooting methods. Updates on the technology and records of past deployments and feedback can also be found.

B. Component Experimentation

Energy Storage. The use of lithium-ion battery, to replace the motorcycle battery, is currently being studied. These batteries are smaller and lighter but if several of these are connected and arranged to match the needed ampacity and voltage, which is 12 voltage, the battery system has almost the same cost, 25% less volume and a little more than half the weight of a motorcycle battery.

Twenty-four lithium-ion batteries were configured in two ways. The first one was arranged with three groups of 8 cells in parallel that were connected in series. This was labeled as 'Not Configured'. We observed that the first group of batteries connected closest to the LED bulb drained the fastest, so the batteries were reconfigured. This time, the first group was composed of 9 batteries in parallel, the second group with 8 and the last with 7. These three groups were put in series. This was the 'Configured' set-up.

Fig. 4. Lithium-ion battery system and Lead-acid motorcycle battery

Initial results showed that the lithium-ion battery system's actual ampacity is greater than that of the motorcycle battery. With the same loading, lithium-ion lasted longer than the motorcycle battery. Upon improving its configuration, it lasted a little more than 3 hours longer. Both batteries have the same charging time. These batteries have low maintenance demand due to ease in battery cell replacement. The comparative table follows.

Table- I: Comparison between lead-acid and lithium-ion batteries

	Motorcycle Lead-acid Battery	**Lithium-ion Battery (Not configured)**	**Lithium-ion Battery (Configured)**
Physical			
Weight	1,768 grams	968 grams	968 grams
Volume	917 sq.cm.	685 sq.cm.	685 sq.cm.
Price (Php)	600 to 1,000	600 to 1,000	600 to 1,000
Performance			
Expected Energy	86 watt-hours	61 watt-hours	61 watt-hours
Measured Energy in Actual Test	10.5 watt-hours	22.75 watt-hours	33.25 watt-hours
% of Actual Measured vs. Expected Energy	Actual energy is 12% of the rated capacity	Actual energy is 37% of the rated capacity	Actual energy is 54% of the rated capacity
Time lasted with 7-watt LED bulb	1.5 hours	3.25 hours	4.75 hours
Actual Ampacity	0.9 ampere-hours	2 ampere-hours	3 ampere-hours

Water Disinfectant. The UV disinfection lamp is the most expensive part of the WELS unit. To lower down the system's cost, the use of fish aquarium UV sterilizer lamp was explored. Three different brands and wattages of aquarium UV sterilizer lamps -- 5, 7 & 11 watts -- with the same killing wavelength of 254 nanometer, were used. The 11-watt-lamp was the one that can fit in the same canister as the conventional UV disinfection lamp so it was the only one subjected to experimentation. It has the same specification in terms of wavelength but is almost 75% cheaper. Its prolonged use revealed almost the same energy consumption, with a spike at the start but leveled off in the long run. Longer experimentation period is required to determine if it also has the same durability. Experimentation to determine durability is beyond the scope of this paper. The two UV lamps are compared below.

Table- II: Comparison between UV disinfection for drinking water and for aquarium

	Time lasted	Price (Php)
6-watt drinking water UV	3 hrs. 30 mins. (lithium) 1 hr. 30mins. (lead-acid)	2,500.00
11-watt aquarium UV	3 hrs. 15 mins. (lithium) 1 hr. 30mins. (lead-acid)	649.00

VII. RESULT AND DISCUSSION

The Water-Electricity-Light System (WELS) is an improved and innovative system that evolved from its original concept prototype SAWGAPS. It is more affordable and easily transportable making it readily deployable in disaster-stricken areas. It offers a water technology design that can immediately address the crucial need for drinking water; proven by its successful installation as a disaster response effort in several provinces in the Philippines.

All its components are available in local hardware stores so onsite pre-disaster fabrication is feasible and replication of the system can be done. Trainings in communities showed that personnel without technical or plumbing skills could easily learn and understand WELS operation and repair. Some trainees even gave suggestions to further improve the system. We can anticipate that future deployments can still open up for further innovation of the system.

Alterations and improvements in some WELS components and changes in the installation procedures were done to adapt to the context of the deployment site. This shows the system's flexibility to suit varied site conditions.

Having gained promising initial results from experimentation on power source and UV lamp, we look forward to a more efficient system that can help strengthen community resilience.

VIII. CONCLUSION AND RECOMMENDATIONS

As recommended by the World Health Organization, hazard mapping can be done to identify areas prone to natural disasters [25]. Once identified, it is recommended that disaster-prone communities be made aware of the value of having WELS as pre-positioned assets for disaster preparedness and community resilience. It can clean water from damaged pipes, disinfect municipal water being rationed in water tanks or fire trucks, and clean rainwater from a storage facility. Do-it-yourself pumps can address lack of elevated water storage facility. Water test kits continue to confirm that water quality after passing through WELS is according to set standards. If WELS were installed in evacuation centers or secured common facilities, it can provide access to drinking water when municipal water system is damaged. It is easily transportable and its components are readily available in local stores. The system can run off-grid. Lighting and cellphone charging are integrated and can prove to be useful in disaster situations. Its flexibility and adaptability for deployment in different contexts proved its appropriateness for disaster response and resilience.

Community-recipients' feedback on past installations led to innovations and customization of the design. Improvements to the system can best be maximized if WELS would be installed before disaster strike. Pre-positioning installation for community resilience would allow better planning to provide appropriate customization.

WELS has gone through an innovative development from a drinking water generation device and has improved its design for more efficient operation. Experimentation conducted to lower the system's cost and to make its power storage more durable revealed promising initial results. This means that WELS can be made more affordable and portable for deployment in barangay level. Power storage can be made more efficient to operate longer off-grid. WELS can serve as a model for water technology that can be easily replicated and pre-positioned to address crucial need for drinking water, especially in time of disaster.

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AUTHORS' PROFILE

Paul M. Cabacungan M.S. Electronics Engineering, Ateneo de Manila University, Philippines/ BS Electrical Engineering, Mapua Institute of Technology, Philippines

PUBLICATIONS

2019 – Aug 19-21, International Symposium on Multi-media and Communication Technology, in Quezon City, Philippines, Presented Paper: "Intelligent Sensors and Monitoring System for Low-cost Phototherapy Light for Jaundice Treatment", Authors: Paul M. Cabacungan, Carlos M. Oppus, Jeremie E. De Guzman, Gregory L. Tangonan, Ivan B. Culaba, Nerissa G. Cabacungan,
2016 – May 23-26, 3rd International Conference on Industrial Engineering, Management Science and Applications, in Jeju-Island, South Korea, Presented Paper: "A feasibility study and design of biogas plant via improvement of waste management and treatment in Ateneo de Manila University" Authors: Salvador Granada, Roberto Preto, Teresita Perez, Carlos Oppus, Gregory Tangonan, Paul Cabacungan
2015 – April 7-9, IEEE Tenth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Singapore, Presented Paper: Towards a Web-based Decision System for Philippine Lakes with UAV Imaging, Water Quality Wireless Network Sensing and Stakeholder Participation" Authors: D. B. Solpico, N. J. C. Libatique, G. L. Tangonan, C. M. Favila, J. L. E. Honrado, M. A. Cua, T. R. Perez, L. C. D. J. Macaraig, and M. Syson, P. M. Cabacungan1, G. Girardot, C. A. F. Ezequiel.

Gregory Tangonan Ph.D. Applied Physics/ M.S. Physics, California Institute of Technology, USA/ B.S. Physics, Ateneo de Manila University, Philippines

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2019 - Intelligent Sensors and Monitoring System for Low-cost Phototherapy Light for Jaundice Treatment, Authors: Paul M Cabacungan, Carlos M Oppus, Jeremie E De Guzman, Gregory L Tangonan, Ivan B Culaba, Nerissa G Cabacungan
2014 - UAV aerial imaging applications for post-disaster assessment, environmental management and infrastructure development, Authors: Carlos Alphonso F Ezequiel, Matthew Cua, Nathaniel C Libatique, Gregory L Tangonan, Raphael Alampay, Rollyn T Labuguen, Chrisandro M Favila, Jaime Luis E Honrado, Vinni Canos, Charles Devaney, Alan B Loreto, Jose Bacusmo, Benny Palma
2012 - A study on ocular and facial muscle artifacts in EEG signals for BCI applications, Authors: Carmina E Reyes, Janine Lizbeth C Rugayan, Carl Jason, G Rullan, Carlos M Oppus, Gregory L Tangonan

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2003 - Two-dimensional beam steering using an electrically tunable impedance surface, Authors: Daniel F Sievenpiper, James H Schaffner, H Jae Song, Robert Y Loo, Gregory Tangonan
1991 - The first demonstration of an optically steered microwave phased array antenna using true-time-delay, Authors: WILLIEW Ng, Andrew A Walston, Gregory L Tangonan, Jar Juch Lee, Irwin L Newberg, Norman Bernstein
1993 - A scalable multiwavelength multihop optical network: A proposal for research on all-optical networks, Authors: Charles A Brackett, Anthony S Acampora, John Sweitzer, Gregory Tangonan, Mark T Smith, William Lennon, K-C Wang, Robert H Hobbs

Nerissa G. Cabacungan M.A. Counseling Psychology, Ateneo de Manila University, Philippines/ AB Interdisciplinary Studies, Ateneo de Manila University, Philippines, Licensed Teacher, Registered Psychologist and Registered Guidance Counselor

SCHOOL RESEARCH PROJECTS
2019 - Reasons for the Choice of Career Option of Grade 5 Students, School Year 2019-2020
2019 - AGS Faculty Needs Analysis in the Area of Personal Effectiveness
2018 - What Makes the Grade 6 Ateneo Grade School Students Happy?
2017 - Case Study on Children with Special Needs
2016 - Survey on the Needs of Parents of Grade 1 to 6 Ateneans for School Year 2016-17
2015 - The Life Satisfaction of Grade 1 to 6 Ateneans for School Year 2015-16
2014 - Survey on the Nature of Student Concerns that the Ateneo Grade School Teachers Can Personally Handle or need to Refer to the Guidance Counselors
2013 - The Quality of Life of Grade 1 to 6 Ateneans for School Year 2013-14

PUBLICATION
2019 - Intelligent Sensors and Monitoring System for Low-cost Phototherapy Light for Jaundice Treatment, Authors: Paul M Cabacungan, Carlos M Oppus, Jeremie E De Guzman, Gregory L Tangonan, Ivan B Culaba, Nerissa G Cabacungan