The 2024 World Congress on
Advances in Civil, Environmental, & Materials Research (ACEM24)
19-22, August, 2024, The K hotel, Seoul, Korea

Development of Water Evaporation Suppressant for Reservoir Utilizing Fern as an Antimicrobial Agent

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ABSTRACT

This study focused on developing a water evaporation suppressant for reservoirs using fern as an antimicrobial agent. Employing an experimental design with quantitative methodology, the research introduced the ecolayer, comprising Calcium Hydroxide, Cetostearyl Alcohol, and Fern. If applied to water storages, particularly dams, the ecolayer aimed to mitigate evaporation on surfaces exposed to solar heat, addressing water scarcity cost-effectively and eco-consciously. Amidst escalating global evaporation rates due to climate change, the study aimed to innovate tools mitigating effects on open reservoirs to prevent substantial water losses. The research included experiments to identify optimum component ratios, assess water quality with the ecolayer, and evaluate changes in water specimen evaporation rates. Following rigorous experiments, the ecolayer, with the appropriate component proportions, proved effective in reducing water sample evaporation rates. This research, culminating in a practical and sustainable approach to water scarcity mitigation, stands as a valuable contribution to global water conservation endeavors.

1. INTRODUCTION

Natural phenomena, such as biological processes, tidal flow, natural disasters, and physical processes, complete daily cycles to maintain balance among living organisms. These occurrences cannot be initiated or stopped, making them difficult to influence for prolonged benefits or to prevent damage. Evaporation, a natural event where liquid turns into gas, might seem less destructive than a thunderstorm, but it can still significantly

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impact water reservoirs. A 400 sq. ft. reservoir can lose up to 10,000 gallons of water annually due to evaporation (Wanamaker, 2019). This suggests that large structures like dams can lose vast amounts of water over time.

Human ingenuity has always found ways to use natural resources effectively, but not all resources are renewable. Some take years or even centuries to replenish, with consumable water resources being a prime example. Dams are among humanity's greatest constructions, but they also contribute to water scarcity, partly due to inevitable water evaporation. Despite advancements, building dams remains complicated, and evaporation continues to be a challenge.

Given water scarcity's significant global impact, it is crucial to innovate and find alternatives for water preservation. One proposed solution is the use of a monolayer lipid cover, a thin surface of fatty substances like Cetostearyl alcohol, to block sun heat and reduce evaporation in dams. Researchers have also identified Diplazium Esculentum plant roots for their antibacterial properties to enhance the durability of this ecological layer (Umaili-Stuart, 2016). This innovative approach aims to address the growing issue of water scarcity by reducing evaporation in water reservoirs.

The main objective of this study was to develop a water evaporation suppressant for reservoir utilizing fern as an anti-microbial agent. More specifically, this study aimed to:

1. Determine the effects of the ecolayer on the evaporation rate of water;
2. Obtain the best ratio among the proposed mixtures of ecolayer; and
3. Evaluate the effects of the ecolayer in the quality of water.

2. METHODS

Experiments on evaporation were conducted in compliance to the guidelines given by Department of Science and Technology. Samples with different ratio were prepared for an evaporation testing in order to determine the best ratio. The best ratio were chosen by observing the highest water level between the specimens. The water levels of the sample with the ecolayer and the pure water sample were observed for comparison. The results from this tests were then used to determine whether the proposed compound is an effective solution to the stated problem or not. Finally, the researchers acquired the toxic level of the water samples through microbiological testing via a trusted laboratory. (Manalo, Ferdous, & Aravinthan, 2014)

2.1 Materials and Properties

2.1.1 Fern

Fern, also known as Diplazium Escukentum and locally known as Pako, is a plant that is widely available in the Philippines and is common in gravel bars and banks of streams. Several studies are made to determine the components of the fern and, it exhibited an anitimicrobial and antibacterial property. (Umaili-Stuart, 2016). It has a characteristic that is capable of storing water which would be very vital for this study since, instead of having water losses due to evaporation, water would be stored instead. (Ballesteros & Walters, 2007)

2.1.2 Cetostearyl Alcohol

Cetostearyl alcohol ($C_{16}H_{34}O$) is a white and waxy solid material in the form of flakes which, is insoluble in water but soluble in oil (IBM Watson Micromedex, 2018). It has a molar mass of 242.44 g/mol and a density of 0.82 g/cm^3. The said alcohol is a mixture of fatty alcohols, mainly cetyl and stearyl alcohol that can come from vegetable sources, such as coconut alcohol (Kimberlite Softwares Pvt., n.d.).

2.2 Specimen Details

There were three different mix ratio designs that were prepared. The list below shows the ratio of each ingredient required for every mix.

- Mix 1: 25% Dried Fern Roots, 75% Cetostearyl Alcohol
- Mix 2: 50% Dried Fern Roots, 50% Cetostearyl Alcohol
- Mix 3: 75% Dried Fern Roots, 25% Cetostearyl Alcohol

For the appropriate amount of the Ecolayer Powder, the researchers used the ratio of 10 grams per 100 square meters surface area coverage (Lapp, 1968).

2.3 Specimen Preparation

2.3.1 Weight and Density Measurements for the Ingredients

The first step of preparation was to calculate the amount of each component required for the Ecolayer. This were completed by finding the ratio that exhibited the best result for the specimen to be tested.

2.3.2 Fern Drying

Fern, as one of the vital part of the ecolayer, was dried to optimize its phytochemical properties that helps in antibacterial, anti-glucosidase, and bioactive constituents which might prolong the life expectancy of the ecolayer. (Chai et al., 2013).

2.3.3 Material Grinding

The materials in this study were finely granulated in order for each to react quickly and respond to the formation of the ecolayer. All the components were powdered and sieved using a No.100 mesh (Kumawat, 2013).

2.3.4 Powder Mixing

This process provides the easiest way to utilize the research's product. After the grinding of materials, all the powdered components were measured based on the studied ratios and mixed together in a mixing container. (Kumawat, 2013).

2.4 Projecting Testing and Validation

2.4.1 Evaporation Test

Different liquid evaporates at different rates. Temperature, humidity, air flow and surface area of the liquids exposed to the air, are just some of the factors that has an impact on the evaporation rate (Banas, 2018). In order to conduct the experimental study, the beakers were placed next to one another on a flat surface so that each of them would experience the same conditions. After placing the beakers, a fixed volume of water was filled for every container, composed of different concentrations of the ecolayer.

2.4.2 Water Toxicity Test

Toxicity can be defined as the negative effect of a substance in the biological system of an organism over a designated time period. It can be in identified in three types: chemical, biological and physical. To monitor the hazardous compounds in water and their effect, many methods for toxicity testing is available such as chemical toxicity testing, direct toxicity assessment, water effluent toxicity, and water quality index (Gunjan & Gargi, 2015). The toxicity test can thoroughly show the whole adverse biological effects of multiple chemical in the body of water, which is necessity for the conventional water quality assessment method (Xue, 2014).

2.4.3 Project Validation / Evaluation

The evaporation test were performed by the researchers by monitoring each changes in the water level that would be validated using measuring instrument. It were recorded and compared to the sample without ecolayer in order to determine the changes of evaporation due to the presence of the said substance.

The toxicity test was conducted by The First Analytical Services and Technical Cooperative or also known as F.A.S.T Laboratories. It is a testing center that provides services such as water testing, environmental testing, and analytic instrumentation (F.A.S.T. Laboratories, n.d.).

A cost benefit analysis was also provided by the researchers to show the evaluation on the total cost of the project compared to its overall benefits. It would show whether the project is worthwhile of the cost or not (Plowman, 2009).

3. RESULTS AND DISCUSSION

3.1 Toxicity Tests

As shown in Table 1, the following samples from ratio 1 possess an alkalinity within the scope of 20-200 $\frac{\text{mg}}{\text{L}}$ which, is the typical level of the aforementioned mineral in a drinking water. Since the pH level of the samples are inside the range between 6.5 and 8.5, the tested water can be regarded as a nonacidic liquid and, considering that the drinking water standard for iron is less than 0.3 $\frac{\text{mg}}{\text{L}}$ while, the samples under ratio 1 presented values less than 0.1 $\frac{\text{mg}}{\text{L}}$, the water samples are deemed safe from iron overload. Noticeably, the samples in this ratio has the most number of pH values that are equal to 7.0 among the other ratios which, indicates that these specific samples have the most balanced acid and alkalinity.

Same with the first ratio and all other samples, the iron content of the specimens under ratio 2 passed the standards for drinking water, making the water free from the negative effects brought by excessive iron in liquids that are being consumed. Though the pH and alkalinity level of all the ratio differ from each other, the values under ratio 2 are still within the standard range and can still be considered as safe for usage.

Even though the pH levels of the specimens under ratio 3 could not have been way different from the samples under the second ratio, the degree of alkalinity is remarkably higher in the third ratio compared to the ratio 2. It should also be address that among the other ratios, ratio 3 has the sample with the highest alkalinity among the others meaning, sample 1 with 121$\frac{mg}{L}$ of alkalinity has the biggest capacity to resist changes in pH which would prevent making an amount of water more acidic. In terms of iron content, based on the test results, ratio 3 is still safe for consumption.

Moreover, with the pure water sample having an iron content of less than 0.10$\frac{mg}{L}$, a pH level of 7.1 at 23.3°C, and an amount of alkalinity of 116$\frac{mg}{L}$, it is to be accounted that the following specimen had passed the standards of consumable water which, can be compared to the quality of water in dams.

Table 1. Toxicity Level

Ratio	**Sample**	**Parameters**		
		Iron ($\frac{mg}{L}$)	**pH**	**Alkalinity° as $CaCO_3$ ($\frac{mg}{L}$)**
Pure Water	1	Less than 0.10**	7.1 @ 23.3°C	116
1	1	Less than 0.10**	7.0 @ 23.5°C	119
	2	Less than 0.10**	7.0 @ 23.2°C	120
	3	Less than 0.10**	7.1 @ 23.2°C	118
2	1	Less than 0.10**	7.1 @ 23.3°C	119
	2	Less than 0.10**	7.1 @ 23.3°C	119
	3	Less than 0.10**	7.1 @ 22.7°C	118
3	1	Less than 0.10**	7.1 @ 22.8°C	121
	2	Less than 0.10**	7.3 @ 22.7°C	117
	3	Less than 0.10**	7.1 @ 23.1°C	116

3.2 Evaporation Tests

Table 2 shows the average changes in water level for each water sample. Based on the results, Ratio 1 and Ratio 2 conserved an average of 8.67 mm of water per day. Ratio 3, on the other hand, saved an average of 6 mm of water per day. From this data, it shows that both Ratio 1 and Ratio 2 has conserved a large amount of water while Ratio 3 has the least amount.

Table 2. Average Water Level Change per Day (Uncontrolled Environment)

Figure 1 presents average changes of water level from four different water sample which are pure water sample, water samples containing ratio 1, ratio 2, and ratio 3. With the blue line acting as the reference and the representation of the pure water sample, it is to be deduced that the farther the distance between the lines with respect to the blue line, the better the result is. Such distances show the effectiveness of the ecolayer in reducing the evaporation rate among the specimens. The effectivity of water sample containing ratio 1 and ratio 2 are 37.52 to 43.71%, respectively. While, the effectivity of water sample containing ratio 3 is 24.95 to 37.52%. Also, the positive slope of the lines representing water samples subjected to Ratio 1, 2 and 3, means the degradation of the ecolayer with respect to time.

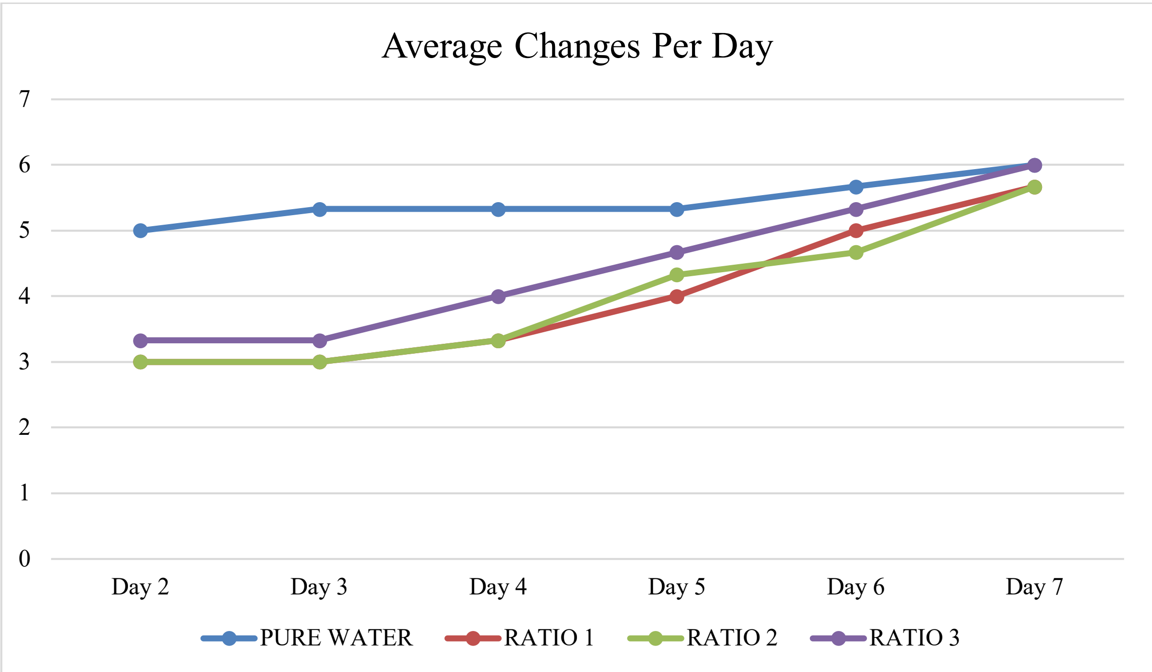

Fig. 1 Comparison of the Averages Changes in Water Levels

	AVERAGE WATER LEVEL (mm)			
DATE	**PURE WATER**	**RATIO 1**	**RATIO 2**	**RATIO 3**
Day 1	56.00	56.00	56.00	56.00
Day 2	51.00	53.00	53.00	52.67
Day 3	45.67	50.00	50.00	49.33
Day 4	40.33	46.67	46.67	45.33
Day 5	35.00	42.67	42.33	40.67
Day 6	29.33	37.67	37.67	35.33
Day 7	23.33	32.00	32.00	29.33

3.3 Water Budget and Cost Analysis

3.3.1 Evaporation Estimation

The Penman equation is used to estimate evaporation from a water surface by considering the following conditions: average temperature of the surface, T_o = 306.55 K; average air temperature, T_a = 302.95 K; relative humidity, r.h. = 73.8%; wind speed, u_2 = 4.39 m/s; surface pressure, p = 100000 Pa; roughness length, z_o = 0.0001; net available energy, Q_n = 180 W/m^2:

$$E = \frac{\Delta}{\Delta+\gamma}\left(\frac{Qn}{Lv}\right)+\frac{\gamma}{\gamma+\Delta}E_A \qquad (1)$$

The aforementioned equation shows a result of 6 mm/day which is similar to the result of the proponents' evaporation test. Using this value as a basis for loss of water due to evaporation in Angat Dam which do have a surface area of 11.42 km^2, an estimated value of 68,520 m^3 per day of water will be loss due to the said process. The change in water level can be said to be very minimal, but considering the total area of a dam, the total loss of water is such huge amount.

3.3.2 Cost-Benefit Analysis

Using Ratio 2, for the sample location at Angat Dam, with an area of 11.42 km² and a daily evaporation loss of 68,520 m³/day, the calculation for the grams needed per area is based on an ecolayer covering 100 m² per 30 grams of the mixture. The total requirement is 3,426 kg of ecolayer. This results in 1,713 kg of Cetostearyl Alcohol and 1,713 kg of Dried Fern Roots for the 50:50 mixture.

Table 3 Sample Computation of a Project applying the ecolayer

	(Per 3 Days estimation)	Price per unit	Calculation	Total
	COST			
A	Fern	P0.00	0*1713	P0.00
B	Cetostearyl Alcohol	P355.00/500g	355*1713 *2	P1,216,230.00
C	Labor for Manual Sifting	P537/day/pax	537*7	P3,759.00
D	Hand Sifter	P136.0/piece	136 * 7	P952.00
	TOTAL COST		A+B+C+D	**P1,220,941.00 (1,220,941.00 USD)**
	BENEFIT			

E	Evaporation Loss Prevention		68,520 m^3/day	
F	Water (as per FCDA)	P25.50/m^3		
	TOTAL BENEFIT		68,520 *3*F	**P5,241,480.00 (89,400 USD)**

If only 35.77% of the evaporation loss is suppressed, the cost-benefit ratio is 1.536, approximately 2. According to Table 4.3.2.2, this benefit ratio means that for every expenditure on the proposed project, there will be a generated benefit of twice the amount spent. An estimated cost of P1,220,941.00 can save up to 73,528.812 m³ of water per application over three days.

4. CONCLUSIONS

After the samples have undergone testing and experiments, the study's objectives are met and its significance have been proven through the results of the systematic processes set by the researchers. The application of the ecolayer among the water specimens was deduced to be effectual since the desired results have been produced during the experiments. Having an effectivity of 27.83 to 43.71 percent compared to the pure water sample, Ratio 2 have been considered as the best ratio of the study since the reduction of evaporation rate in this specific condition have been considered and picked as the best outcome among the others, meeting the first and second objective of the study which is to determine the effect of the ecolayer to the evaporation rate and choose the best ratio among the samples, respectively. Although there have been other samples that appeared to be having higher effectivity, ratio 2 was selected as the best ratio since, when it comes to its level of toxicity, it is regarded as the safest ratio for consumption.

Since climate change had intensified evaporation, having an innovation, such as the ecolayer, will extensively contribute in managing and preventing huge water losses in dams without totally disrupting the natural processes of water cycle. Having an example, such as Angat dam which, is losing an estimated of 68,520 cu.m of water due to evaporation, suppressing this specific occurrence could actually help saving as much water as possible that could be used for consumption and can lead to a convenient depreciation to the price of water for the citizens of Metro Manila. The study is also essential in terms of expanding the scope of the engineers' and future researchers' innovation capacity.

ACKNOWLEDGMENTS

This research paper was funded by the Lyceum of the Philippines University – Cavite Research Grant. Heartfelt gratitude is also given to Prof. Arnel Avelino, Dean of the College of Engineering, Computer Studies and Architecture for his utmost support.

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