THE IMPORTANCE OF CONTAINER MATERIAL IN STORED WATER QUALITY

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Major Advisor　　　　　　　　Second Reader

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ABSTRACT

Water is one of the primary resources to sustain human life. The quality of good water and air are important factors to protect human health and the environment. The impact of container material on stored water quality is investigated in this study. The objective of this research is to compare the performance of a polyethylene (plastic) container to that of a bioplastic container over a period of 32 days. Water quality parameters analyzed were temperature, acidity (pH), turbidity and dissolved oxygen (DO). Both container types met the water quality requirements for safe drinking water, but the bioplastic container performed better over polyethylene. Bioplastic materials have the added sustainable benefit of being made from natural components that result in less harm to the environment both in production and degradability.

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1. INTRODUCTION

Water is, without question, one of the main resources to sustain human life. The quality of good water and air is an important factor to protect human health and the environment. Only 2.5% of the earth's water is considered freshwater suitable for human consumption. Nevertheless, human activities have substantially caused water contamination, decreasing the amount of water available for humans to consume. This thesis aims to delve deeper into aspects of drinking water storage, best materials for storing water, and the changes that take place over time in water quality. Irrespective of the container material and other contributing factors, the quality of water tends to be affected while it is in storage. But the impact can be reduced if several factors are taken into consideration.

The World Health Organization (WHO) has laid down a set of rules with which drinking water quality is analyzed, including microbial, chemical, radiological and acceptability aspects (WHO, 2011). Not everyone in the world enjoys the privilege of having access to fresh drinking water all the time. This is definitely not the sole reason to store water, but one of the many important reasons. Water storage becomes a vital concept, especially when the constant supply of freshwater is a difficult option for most of the world's people. However, as great as it sounds, the idea of water storage brings an array of questions with respect to the quality of water preserved in the containers over time. The objective of this research is to determine the changes in the quality of water with two container materials, polyethylene (plastic) and bioplastic, over a period of 32 days.

Plant-based materials such as bioplastics are advocated as ecologically beneficial alternatives to petroleum-based plastics. Polyethylene plastic containers best preserve water quality, if the water is stored only for a period of 3 weeks (Ogbozige, 2018). Plastics are made up of a complex mix of known and unknown substances, some of which are potentially hazardous (Zimmermann et al., 2020). However, bioplastics are materials that are created from renewable feedstocks and are meant to naturally disintegrate (Lambert and Wagner, 2017). Furthermore, bioplastics have the added benefit of being created from natural components, which do less harm to the environment in terms of both manufacturing and degradability. They are eco-friendlier and more long-lasting than polyethylene polymers (Zimmermann et al., 2020).

The research described by this thesis is an experimental study. The outcome is to make a recommendation towards an environmentally responsible choice by considering the possibility of substituting polyethylene with bioplastics in water storage containers. The hypothesis is that bioplastics can maintain better water quality over polyethylene during a period of 32 days. Bioplastics may be crucial in resolving global issues concerning the over-production of plastics, which has led to exacerbated carbon emission and other environmental crises.

2. LITERATURE REVIEW

2.1. WATER QUALITY REQUIREMENTS

It is impossible to survive and to carry on with our daily chores without clean water. Controlling water contamination has become a top priority in both developed and developing countries (Enderlein and Peter, 1997). With the rise in the population and global pollution, there is a drastic rise in water contamination worldwide. The World Health Organization (WHO) has particular guidelines published for safe drinking water quality. These guidelines list conditions that have to be followed by all nations and are known as water quality standards (Renwick, 2013). The WHO has set standards to ensure the water quality management foundation for safe drinking water, allowing for a preventive water contamination risk (WHO, 2011). Analysis of water samples is supplementary to water quality study, and when both types of data are provided, the power of future analysis increases (Robertson et al., 2006).

The three main factors of a water safety plan are (1) health outcome targets and (2) water quality targets, and (3) surveillance and control. The water supplier must meet the water quality, performance, or technological targets as part of the water supply strategy. The water quality targets may be used to assess and monitor whether water safety measures have been successful in reducing the danger of pollutants in drinking water. Surveillance and control ensure that all the water safety plans and targets are being met for humans for safe drinking water quality (WHO, 1997). All of these requirements are vital for the quality of water that is healthy for drinking, aquatic life and other irrigational purposes. There are certain physical and chemical parameters required for safe drinking water.

2.1.1. Temperature

Water temperature is one of the most fundamental qualities, but it does not determine whether the water is drinkable or not. A higher water temperature would mean lower oxygen solubility when it comes to natural water systems. Higher water temperature increases the chance of aquatic microbial growth (Karki, 2018). The microorganisms consume the dissolved oxygen rapidly, thus causing a reduction in the availability of dissolved oxygen.

2.1.2 Acidity (pH)

The measurement of acidity/basicity of a solution is called its pH. A pH value of 7 indicates that the water is neutral. A value below 7 indicates acidity, and a value above 7 indicates alkalinity. In surface water systems, the range of pH would vary between 6.5 and 8.5. The U.S. Environment Protection Agency (EPA) has indicated that excessive consumption of acidic or basic water could have harmful effects (Gorde and Jadhav, 2013). To satisfy EPA standards, the pH value of drinking water should fall between 6.5 to 8.5. Changes in pH could be aesthetically unappealing because the water could taste like baking soda when pH is high or have a metallic taste when pH is low. In addition, variation in pH in stored water can damage pipelines and storage container material, resulting in serious health issues.

2.1.3 Particulate matter (turbidity)

The measurement of how much light is obstructed as it passes through water is considered its turbidity. Water portability is not harmed by turbidity unless its source includes disease-causing microorganisms (Trevettet al., 2005). From the analysis made by Helmer (1996), the majority of turbidity in surface waterways is caused by soil erosion of colloidal elements such as silt, clay, fragmentation of rocks, and oxidization of metals. Soaps, detergents, and emulsifying agents form stable colloids (Peavy,1998). These chemicals may cause a change in the odour and taste of water with the resulting turbidity. Less than 5 Naphthalometric turbidity units (NTU) is ideal for drinking water (Karki, 2018).

2.1.4 Dissolved oxygen

Dissolved oxygen is the amount of oxygen that is available for consumption by aquatic life. It is an indicator of water's ability to help aquatic life thrive. Hence, that makes it a crucial parameter for measuring water quality. In all the pollution studies that are conducted, measurement of dissolved oxygen is considered (Pradeep, 2012). Several factors could deplete the amount of dissolved oxygen available, including high temperature, sewage or other waster materials and increased microbial activities. Potable water suitable for drinking must contain dissolved oxygen concentration above 6.5-8 mg/L.

2.1.5 Pesticides and chemicals

Pesticides and other chemicals are commonly found in drinking water today as they are used globally to manage pests in agriculture and other facilities (Younes and Galal, 2000). These pesticides and chemicals have a long-term effect on humans (Maroni and Fait, 1993). Due to the immense use of these pesticides and chemicals on land, they leach into groundwater through rain and cause serious health issues. Some hard chemicals and pesticides are being banned due to their severe effect on the environment (WHO European Centre for Environment Health, 1995).

2.2 WATER STORAGE CONTAINER MATERIALS

People consider water storage as a prime and non-negotiable factor. All over the world, water is being stored in tanks or containers. The stored water can be used for different purposes like cooking, drinking, or on a bigger scale like for maintaining livestock, irrigation, and agriculture. Below are some properties of stored container materials available nowadays. However, with the adverse effect on different physical and chemical conditions, and changes in the properties of stored water over time, storage will always have a negative impact on the quality of water.

2.2.1 Polyethylene

Plastic tanks are considered the safest option for water storage due to their unique properties. Polyethylene is considered one of the food-grade plastics. Polyethylene tanks can withstand bacteriological activities over time better compared to other materials but need proper treatment to maintain the water quality (Ogbozige et al., 2018). Plastic is the best material to preserve water quality standards among all the water storage containers in use. Polyethylene is a useful and cost-effective plastic polymer (Dhakal & Ismail, 2020). This is a kind of thermoplastic that was created in 1941 by John Rex Winfield, who combined ethylene glycol and terephthalic acid (Ogbozige et al., 2018). Polyethylene tanks are lightweight and can withstand rust and sunlight impacts. However, plastics from fossil fuels are made of a complicated combination of known and unknown compounds, some of which can be harmful.

2.2.2 Bioplastics

Bioplastics are plant-based materials promoted as environmentally friendly alternatives over petroleum-based plastics (Zimmermann et al., 2020). Bioplastics are materials made from renewable feedstocks and are designed to decompose naturally (Lambert and Wagner, 2017). Bioplastics share many of the same advantages as polyethylene plastics. They are lightweight, flexible, and easy to repair, but with the added sustainable benefit of being made from natural components that result in less harm to the environment both in production and degradability (Zimmermann et al., 2020). They are more environmentally friendly and sustainable than polyethylene plastics.

2.3 Colour of stored containers

The colour of a storage container is an essential factor because water contains light-sensitive microorganisms like bacteria and algae (Hemanth & Rajiv, 2016). The activity of these microorganisms can be reduced by use of dark-coloured containers, as they reduce the amount of light that passes through the container (Admin, 2019). When an internal solution is exposed to sunshine, the growth rate in microbes can be increased significantly. Furthermore, dark-coloured tanks are more resistant to UV rays and have a longer lifespan due to their inherent strength. According to Ogbozige (2018), it has been found that water stored in black polyethylene containers persevered water quality better than any other coloured containers.

2.4 Quality of water over time

Studies have shown that water quality changes over time regardless of the container used. Initially, large suspended flocculated particles and other pollutants larger than water molecules drop to the bottom of the reservoir during storage, maintaining its physical clarity. Over six months, the quality of stored water in-home and public galvanized steel tanks changes, and bacterial contamination begins to increase. (Obianyo, 2020). However, when clean water is stored under sanitary circumstances, the quality should not decrease as particles in the stored water settle at the bottom of the storage container (Ogbozige, 2018).

2.5 Chemical toxicity that leaches from plastics

Chemical complexity is one of the main factors to assess the safety of plastics when it comes to food-grade materials. Humankind has generated 8300 million metric tonnes of plastics to date, with output increasing exponentially. Plastics are inexpensive and adaptable materials, making them an indispensable component of our daily lives. Plastic products are complex mixtures of chemical additives such as fillers, polymers, stabilizers, antioxidants, flame retardants, plasticizers, and pigments (Zimmermann et al., 2019). The chemical analysis from research bioassays only partly describes the chemical toxicity that leaches from plastics. When bioassays are combined with chemical analysis, the compounds that cause toxicity can be determined. While data on exposure, hazard, and epidemiology for a few well-known plastic-associated chemicals, such as bisphenol A (BPA), is abundant, assessing the chemical safety of plastics remains difficult because (1) they are made up of a diverse and heterogeneous group of polymers, and (2) each product has a unique and complex chemical composition, which

(3) frequently includes unknown compounds. More than 5300 polymer compositions are commercially accessible today, and plastic packaging alone is linked to almost 4000 pollutants (Zimmermann et al., 2019).

2.6 Price and Market of Bioplastics

Bioplastics are well known for its environment-friendly property. They are highly degradable packaging material, and the production of the bioplastic is an energy efficient practice. Apart from these positive traits, bioplastics are non-toxic even during the time of degradation. For these reasons, bioplastics are considered better packaging material than synthetic plastics (Biodegradable plastic products, 2022).

Even though bioplastic probably is the answer to many of our environmentally pressing problems, it is not cheaper than conventional plastics. The low cost of manufacturing and higher quality of synthetic plastic poses a competition for bioplastic since the cost of its production and the biomass extraction aren't a match for the low prices associated with synthetic plastics. Corn and sugarcane are the two renewable source of biomass associated with the production of bioplastics (Biodegradable plastic products, 2022). The extraction of biomass to produce bioplastics is not a concern in places like US where they have developed genetic variants of corn to yield them in higher amounts. These variations in the availability of raw materials, the pressure on the manufacturers to produce bioplastics cheaper yet at a higher quality, and other associated factors make it difficult to get bioplastics a higher global market share where conventional plastics still control the lion share. The price of the conventional fossil fuel-derived plastic dominates the market since the price of the raw material like crude oil is cheaper. Bioplastics could only compete with these production prices if the oil prices escalate (Biodegradable plastic products, 2022).

Obtaining bioplastics for the purpose of this research was a herculean task given the unavailability of them in the Canadian market and the high price associated with it. The bioplastic used for the purpose of this research was purchased from an online store called The Plastic Bottles CO. from the UK and was priced at £0.87 per piece, including tax. The major hindrance in obtaining bioplastic for the purpose of this experiment will also be considered one of the major limitations of this research.

3. MATERIALS AND METHODS

3.1 QUALITY ANALYSIS AND COLLECTION OF WATER

Cold tap water, after letting the tap run for a full minute, was stored in two replicates each of polyethylene and bioplastic containers, alongside one glass container as a reference for 32 days indoors in sunlight in the Wood Science Lab at Lakehead University (Figure 1). The maximum retention period for water in each container corresponds to the shortest time necessary for any of these human health factors (parameters) to exceed the WHO acceptable level (Ogbozige et al., 2018). The water quality parameters of interest, temperature, acidity (pH), particulate matter (turbidity), dissolved oxygen, and pH, were analyzed with the help of Lakehead University Environmental Laboratory (LUEL). Temperature measures were taken using a temperature logging Thermochron iButton, and the readings were recorded every half-hour interval during the storage period.

3.2 DATA ANALYSIS

Day one data and day 32 data were compared across container types and to the WHO acceptable levels.

Figure 1: A picture containing Base control (Glass), White container (Bioplastic) and Translucent container (High-density Polyethylene), including replicates

4. RESULTS

4.1. Safe Drinking Water Quality Parameters During Storage

The data obtained before and after the storage period of 32 days are presented in Tables 1 and 2 for each of the water quality parameters and the changes that happened during storage are addressed accordingly.

4.1.1 Temperature

While there were changes from initial readings of turbidity, pH and DO (Table 1) in the expected directions (higher, lower and higher respectively), comparing the values after 32 days, differences in the polyethylene and bioplastic containers were not substantial after storage (Table 2). Water temperature was also similar in the containers. However, there were high temperatures in the afternoon of most days when the sun was striking in the afternoon (Figure 2). Even small differences in warming of the water may change the properties of the water. A difference of 0.4 ºC cooler in the bioplastic container replicates compared to polyethylene (Table 2) is a good indicator that bioplastic can retain cooler night-time and morning temperatures better.

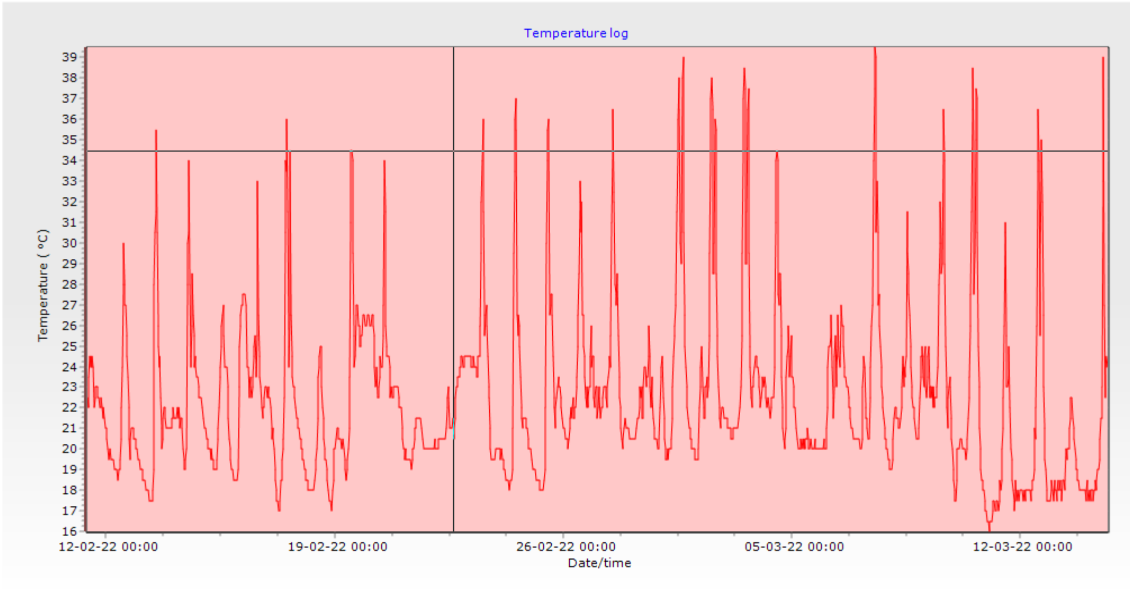

Figure 2. Temperature log data from February 11th, 09:41:00 to March 14th, 16:11:00, the span of 32 days of storage.

Table 1: Analytical Laboratory Report before storage for Turbidity, pH and DO

Parameter	Unit	Base Control	Bioplastic Time 0:0	HDPE Time 0:0
Turbidity	NTU	0.03	0.03	0.05
pH	pH unit	7.56	7.59	7.63
Dissolved Oxygen	Mg/L	10.00	9.03	9.04

Table 2: Final Analytical Laboratory Report for Temperature, Turbidity, pH and DO

Parameter	Units	Base Control	Bioplastic 1	Replicate 2	HDPE 1	Replicate 2
Temperature	°C	20.06	20.04	20.04	20.08	20.08
Turbidity	NTU	0.18	0.12	0.12	0.19	0.14
pH	pH unit	6.56	6.77	6.84	5.91	6.37
Dissolved Oxygen	Mg/L	9.06	8.97	9.02	8.98	8.99

4.1.2 Turbidity

Bioplastic containers had lower turbidity compared to polyethylene containers (Table 2). The liquid was more transparent in the bioplastic containers, even though both container types were well below the 1.0 NTU considered safe for drinking.

4.1.3 Acidity (pH)

Only the pH level of water stored in the bioplastic containers and the glass reference remained between 6.5 and 8.5, which falls within the suggested pH range by WHO for drinking water quality (Table 2). The polyethylene containers become more acidic than 6.5 after the 32 days of storage. Initially, the reference and both bioplastic and polyethylene containers had pH values between 7 and 8 (Table 1), suggesting that storage container material lowered pH over 32 days.

4.1.4 Dissolved Oxygen (DO)

There was no effect of container type on dissolved oxygen after storage (Table 2), which dropped similarly among the glass, bioplastic and polyethylene containers from initial conditions (Table 1). All replicates met the WHO standard for this parameter.

5. DISCUSSION

Bioplastics make suitable storage reservoirs that apparently retain the quality of water during storage or have minimal effect on the stored water. In this study conducted under extreme afternoon warming conditions, both bioplastic containers and polyethylene containers were able to meet W.H.O. criteria after 32 days. But the results suggested that bioplastics pose the lesser changes to temperature, turbidity and pH in stored water, even while they offer less harm to the environment both in production and degradability According to U.S. EPA standards, the pH value of drinking water should fall between 6.5 and 8.5. Water stored only in bioplastic containers in this experiment met these standards.

From the product purchase experience of bioplastics for this study, it was clear that the market, availability and purchase option for bioplastics and other plant-based products are lower in Canada compared to the U.S. and Europe. The experiment was supposed to include tests to analyze the concentration of PLA (HPLC) that can determine the changes in the chemical toxicity that leaches from plastics container material, both bioplastics and polyethylene, after the storage period. Nevertheless, the inaccessibility of base control of PLA and pH specifications in the equipment resulted in not conducting the tests, which was a major limitation in this research.

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