



ADDIS ABABA UNIVERSITY
COLLEGE OF HEALTH SCIENCES
SCHOOL OF PUBLIC HEALTH

**ASSESSING THE EFFECT OF SUNLIGHT EXPOSURE ON
THE PHYSICO-CHEMICAL PARAMETERS OF BOTTLED
WATER IN ADDIS ABABA, ETHIOPIA**

BY
YIBEYIN MULUALEM

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ADVISORS

ABERA KUMIE (Ph.D.)

YIFOKER TEFERA (Ph.D fellow)

Abstract

Background: It is a common practice for distributors or trader at sales points leaving bottled water to sunlight before being sold. The exposure of bottled water to sunlight facilitates the formation of toxic substances such as chloroform, haloacetic and terephthalic acid; increase concentration of nitrite; reduce concentration of fluoride and increase turbidity level which has a public health importance. The study on the effect of sunlight exposure of bottled water on its quality is limited in Ethiopia.

Objective: To assess the effect of sunlight exposure on physicochemical parameters of bottled water in Addis Ababa, Ethiopia

Methods: Experimental observational study design was employed to assess the effect of sunlight exposure on physico-chemical parameters of the sampled bottled waters from October 3-30/2020 in Addis Ababa, Ethiopia. Randomly selected bottled water were exposed to direct sunlight for 28 days and the physicochemical parameters of exposed and non-exposed groups were analysed in every seven days. A descriptive analysis was carried out to compare the results against the World Health Organization, International Bottled Water Association and our country standards, and the labelled value. Mean values for physicochemical parameters of bottled water before and after exposure to direct sunlight was compared using paired sample t-test and Wilcoxon signed rank test.

Results: The experimental results showed that the values of pH, F^- , Mg^{2+} and NO_3^- were decreased from 7.31 to 7.02; 0.20 to 0.15 mg/L, 0.486 to 0.365 mg/L and 3.95 to 3.52 mg/L respectively as sunlight exposure increased. Whereas the level of NO_2^- , TDS and turbidity were increased with increasing sunlight exposure from 0.00 to 0.02 mg/L, 82.82 to 85.24 mg/L and 0.00 to 0.57 NTU respectively. The rest parameters (EC, Cl^- , Ca^{2+} , and total hardness) were numerically decreased or increased irrespective of sunlight exposure. Statistically significant difference was observed on pH, F^- , NO_2^- , and turbidity levels between exposed and non-exposed group only.

Conclusion: Sunlight exposure has been shown to increase the value of turbidity, NO_2^- , and TDS and decrease the value of pH, F^- , Mg^{2+} and NO_3^- but it has not exceeded the recommended standards except fluoride and turbidity. The increment or decrement of chloride, EC, hardness and Ca^{2+} were not associated with sunlight exposure, instead it may indicate the formation of toxic substances.

Recommendations: Proper handling and storage of bottled water have to be given attention to be on the safest side even if exposure didn't exceed most of the permissible value (limit).

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List of Abbreviations and Acronyms

APHA	American Public Health Association
BW	Bottled Water
BW1, 2, 3, 4	Bottled Water sample One, Two, Three, Four
Conc	Concentration
EC	Electrical Conductivity
ECWQS	Ethiopian Compulsory Water Quality Standards
EIC	Ethiopian Investment Commission
EPHI	Ethiopian Public Health Institute
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
IBWA	International Bottled Water Association
NTU	Nephelometric Turbidity Unit
PET	Polyethylene Terephthalate
PP	Polypropylene
SODIS	Solar Disinfection
TDS	Total Dissolved Solid
UV	Ultra Violet
UVR	Ultraviolet Radiation
WHO	World Health Organization

1. Introduction

1.1. Background

Water is the most essential resource found in the earth crust for the existence of all living organisms. But the availability of water resources is threatened by high population growth, industrial wastes and increasing demands of the population to get quality water (1).

The quality and quantity of water available to humans have been vital factors in determining the well-being of human being. It is also important that the water be attractive and palatable to induce its use; otherwise, consumers may decide to use water of doubtful quality from a nearby unprotected stream, well, or spring or otherwise bottled water (1, 2). Due to lack of safe and accessible drinking water and the taste of chemicals in tap water particularly chlorine, the world bottled water consumption has been significantly increasing for the last thirty years (3).

Bottled water is any potable water that is manufactured, distributed or offered for sale and intended for human consumption. They come from underground sources like spring or bore holes or sometimes it comes from drink water of the distribution system. However they may differ in their chemical composition (4).

Bottled water must be tested and meet regulatory standards before it can be sold. Codex Alimentarius Commission of World Health Organization (WHO) and Food and Agriculture Organization (FAO) have developed a standard for natural mineral waters and packaged drinking-water and an associated Code of Practice. The Standard describes the product and its compositional and quality factors, including limits for certain chemicals, hygiene, packaging and labelling (5).

Bottled water quality are subjected to intensive investigation in many countries worldwide, in order to evaluate its suitability for human consumption. The quality of water may vary from one source to another based on several parameters such as water sources, type of water purification technology, and storage tanks (3, 4). On the top of that direct sunlight exposure is becoming one of the determinant factors for the quality of bottled water (6).

1.2. Statement of the Problem

The consumption of bottled water has been increasing consistently over the last decade, even in countries where tap water quality is considered excellent. It is considered as a health option and confers additional health benefits (7). Bottled water usually tastes better than municipal water. However, the taste does not always indicate safety. At the levels present in drinking water, most harmful substances have no taste (8).

In Addis Ababa, more than 20 different brands of indigenously produced bottled mineral waters are available in local markets and restaurants. There are huge sales of various brands of bottled water in cities and towns especially in major traffic channels. However, the method of storage before it is traded has become of increasing concern (9, 10).

The bottled water sellers and distributors usually expose bottled water to direct sunlight before being sold (11). It is clear that exposing transparent bottles to sunlight at a predetermined time is one of the water treatment mechanisms to make the water safe (12). But the long-time exposure of bottled waters to direct sunlight results in some change of physicochemical parameters of water. This change makes the water parameters increase or decrease within the acceptable range or sometimes beyond the WHO standards of drinking water quality which may result in health effects in an extended period of time. The change of physicochemical parameters due to sunlight exposure is mainly attributed to the leaching of compounds from plastic bottles and results in chemical reactions with bottled water ions (11, 13, 14).

The quality of commercially available bottled water used for human consumption is studied in Gondar town and Addis Ababa city. The results were compared with WHO and compulsory Ethiopian water quality standards as well as the labelled one. (10, 15, 16). However, the studies didn't describe sunlight exposure status, duration of exposure and methods of storage of sampled bottled water.

The effects of sunlight exposure on physicochemical parameters of bottled water in some countries of the world are being investigated. Previous studies in Iraq, Ghana and Nigeria showed that sunlight exposure has an effect on physicochemical parameters of bottled water. Prolonged sunlight exposure results in the formation of toxic by-products such as chloroform, haloacetic acid, etc. which are harmful to human beings. Fluoride also decreases by sunlight exposure because of fluorination reactions which result in inadequate concentrations

of fluoride in bottled water. ([11](#), [16-18](#)). In adequate intake of fluoride (less than 0.5 mg/l) causes dental caries and slow down the mineralization of hard tissues ([19](#)). In addition exposure of nitrate containing bottled water with UV (Ultra violet) light for extended time results the formation of nitrite and the formation increased when UV light dose increased. Nitrite has a health effect especially on children that causes blue baby syndrome when the dose exceeded 3 mg/l. pH also heavily affected by the sunlight exposure due to oxidation reaction inside the bottled water that makes the water to have metallic taste, which interfere the quality of the water and the preference of the consumer ([20](#), [21](#)). That is why nowadays prolonged direct sunlight exposure becomes one of the public health issues.

However, in our country Ethiopia little or no information is available about the effect of sunlight exposure on bottled water since the sunlight intensity and sunshine hour of the country is different from those countries listed above. Thus, an attempt should be going to study the effects of direct sunlight exposure on physico-chemical parameters of selected bottled water in Addis Ababa, Ethiopia.

1.3. Rationale of the Study

The consumption of bottled water for drinking purposes is increasing from time to time. Bottled waters need to be stored in a proper place until reach to end users. Most of bottled water trader (may be kiosks, restaurant, café, supermarket, etc.) stored the bottled water at open space with direct sunlight exposure. It is not clear whether sunlight exposure affects the physicochemical parameters of bottled water or not in Ethiopia, though some studies in other countries shows there is a change of parameters when it exposed. Sunlight exposure not only changes the physicochemical parameters of bottled water but also formation of other chemicals which have public health importance. The sunlight intensity of Ethiopia is different from those countries on which the studies conducted. It is obvious that the bottled water mostly provided for babies, pregnant and lactating mothers, sick and elders peoples which are more susceptible to acquiring disease or health effects. Hence it needs to understand the effect of sunlight exposure on the physicochemical parameters of bottled water.

1.4. Significance of the Study

This research paper was concentrated on the effects of direct sunlight exposure on the physicochemical parameters of bottled water. The findings of the study help the governmental institution especially for Food and Drug Administration (FDA) to set standards on handling and storage of bottled water. In addition, the study gives information to the community (consumer and trader) how to store and handle bottled water. The study may also use as the reference for academic knowledge and for further investigation on the effect of sunlight exposure on bottled water and its health impact on human being.

2. Literature review

2.1. Source of Water Supply

Water is the most essential resource found in the earth crust for the existence of all living organisms. About 97 percent of earth's water found in the oceans, the remaining present as water vapour in the atmosphere, and contained in the solid state as ice snow in snow packs, glaciers and polar ice caps. Only 0.8 percent of water supply present as fresh water for human consumption (2).

The source of water supply mainly classified as: surface water (lake, streams, reservoirs, etc.), ground water (well, spring) and rain water sources. These water sources are not distributed evenly to all regions and countries of the world. Some countries may have excess fresh water whereas the other countries may exist as water scarce condition. The availability of water resources is threatened by high population growth, industrial wastes and increasing demands of the population to get quality water (1).

Due to lack of safe and accessible drinking water and the taste of chemicals in tap water, bottled water becomes one of sources of water for drinking purpose. Bottled water is any potable water that is manufactured distributed or offered for sale and intended for human consumption. They come from underground sources like spring or bore holes or sometimes it comes from drink water of the distribution system. However they may differ in their chemical composition (4).

2.2. Physicochemical Parameters of Water

The quality of water is determined by physical, chemical and microbiological properties of water. There are a number of parameters (physical, chemical and microbiological) to assess the quality of any water supply used for different purpose (5, 22). In the case of bottled water, the physical, chemical and biological parameters that we want to monitor/assess are limited. Alkalinity, turbidity, total dissolved solids (TDS), hardness, cations (K^+ , Na^+ , Mg^{2+} , Ca^{2+}), anions (nitrate, nitrite, chloride, fluoride and ammonium) are the most important parameters for bottled water quality especially assessing the effect of sunlight exposure. In most studies, the biological parameters value and heavy metals concentration is very low or undetectable in bottled water (10, 11, 16, 23).

The physicochemical parameters such as alkalinity, pH, turbidity, TDS, hardness, sodium, potassium, magnesium, calcium, sulphate, and chloride mostly have no direct health effect on human. The variation of the concentration of these chemicals may decrease the palatability and acceptability of water which result inadequate intake of water (5, 22). For example, pH should be in the range of 6.5-8.5 to avoid a bitter taste. Below and above this range makes the water metallic taste and slippery feel (soda taste) which strongly influence palatability of water (24). However the presence of extreme high or low concentration of these chemicals may affect the health of the consumer.

Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Calcium and magnesium are the two main elements responsible for creating hard water. The water bodies' contact with rocks may have high calcium content. Calcium is beneficial element found in water supply. Magnesium is the constituent of hardness as calcium that come from geological formations. It may affect acceptability of water. Most of heavy metals like Cr, Pb, Hg, Co, Zn, Cr, Cu, Mn, etc may present in very small amount in water or nil. But if the water contain these chemicals, most of heavy metals are very toxic and results health effects even in small concentration (5).

The conductivity of water is an expression of its ability to conduct an electric current. It is related to ionic content of the water sample that associated with TDS. TDS describe the inorganic salts (carbonate, sulfate, bicarbonate etc) and small amounts of organic matters (originates from animal or plants waste) present in water that give variety of effects like hardness, taste, odor etc depending on nature of dissolved solid (5).

Excess of the concentration of nitrite, nitrate, fluoride, extreme pH, and heavy metals (even if mostly no found in bottled water) can result a serious health consequences. Fluoride ion is one the physicochemical parameters of water that has public health importance in both extremities. Low concentration of fluoride in water (below 0.5 mg/l) results dental caries especially in children and affect mineralization process of bones and cartilage (22, 25). In contrast, high fluoride concentration in drinking water above (1.5 mg/l) has become a critical health hazard of this century as it induces intense impact on human health including skeletal and dental fluorosis (19, 22, 26).

Nitrate and nitrite are important parameters of water that results methaemoglobinaemia in infants if their concentration exceed the maximum permissible limit of WHO and IBWA

guideline for drinking water (5). In humans, methaemoglobinaemia forms as a consequence of the reaction of nitrite with haemoglobin in the red blood cells to form methaemoglobin, which binds oxygen tightly and does not release it, so blocking oxygen transport. High levels of methaemoglobin formation can give rise to cyanosis, referred to as blue-baby syndrome (21, 27).

Turbidity is not a direct indicator of health risk. Recent studies show that the presence micro plastics ranging from 6.5 µm to greater than 100 µm in bottled water may increase the level of turbidity of water. According to the study conducted on 259 bottled waters, 93 % of sample bottled water showed sign of micro plastics with average concentration of 315mpp/L (micro-plastic particle per liter). Packaging process, caps of the bottles(Propylene), storage conditions and length of time involved for shipping were listed for the reason of micro plastic contamination (28). Micro plastics have a serious health effects and most of health consequences are being under investigation (29). Hence, considering the level of turbidity of bottled water in this aspect may have a paramount advantage to protect the health of the people in addition to the guideline value.

2.3. Water Quality Standards

A number of chemical contaminants have been shown to cause adverse health effects in humans as a consequence of prolonged exposure through drinking-water. In addition, there are chemical contaminants and physical parameters that have potential effect on the acceptability and palatability of drinking water to consumers. The world health organization (WHO) and world's countries have developed their own standards and guidelines to protect the health of the people (5). Ethiopia has established compulsory standards for water quality specification in 2013 (15).

In applying the guidelines to bottled waters, certain chemical constituents may be more readily controlled than in piped distribution systems, and stricter standards may therefore be preferred in order to reduce overall population exposure. Similarly, strict standards of certain naturally occurring substances of health concern, such as arsenic, cadmium, nickel, lead, may be more readily achieved in bottled water better than piped distribution. That is why the international bottled water association (IBWA) has developed its own water quality guideline for bottled water by referring WHO water quality standard (5, 15).

Table 2.1: WHO, IBWA and Ethiopia Compulsory water quality standards

S.No	Physicochemical Parameters	WHO (5)	IBWA (30)	Ethiopian Compulsory water quality standard (ECWQS) (15)
1	Nitrite	3 mg/l	1 mg/l	3 mg/l
2	Nitrate	50 mg/l	10 mg/l	50 mg/l
3	Fluoride	0.5-1.5 mg/l	3 mg/l	1.5 mg/l
4	Chloride	250 mg/l	250 mg/l	250 mg/l
5	Hardness	200 mg/l	NI	300 mg/l
6	Calcium	200 mg/l	NI	75 mg/l
7	Magnesium	150 mg/l	NI	50 mg/l
8	pH	6.5-8.0	6.5-8.5	6.5-8.5
9	Sodium	200 mg/l	NI	200 mg/l
10	Potassium	NI	NI	1.5 mg/l
11	Sulfate	250 mg/l	250 mg/l	250 mg/l
12	Color	150 TCU	5 TCU	15 TCU
13	Total Dissolved Solids	1000 mg/l	500 mg/l	1000 mg/l
14	Turbidity	5 NTU	0.5 NTU	5 NTU

NI: Not indicated on the guideline

2.4. Bottled Water in Ethiopia

Water is packaged for consumption in a range of vessels, including cans, laminated boxes and plastic bags though glass and plastics bottles are the most commonly used vessels throughout the world. Bottled water also comes in various sizes, from single servings to large carboys holding up to 80 litres (5). In Ethiopia, plastic bottles with size ranging from 0.3 liters to 25 liters are available and marketed at commercial places.

The manufacturing and distribution of bottled water has been expanding consistently and the need of the people for bottled water consumption has also been increasing for the last ten year. The tastes of bottled water usually have a good taste when compare with municipal water because of the chlorine in tap water. However, the better taste does not necessary means its safe water. Most of harmful chemical have no taste even if present beyond the standard limit (8).

According to Ethiopian Investment commission (EIA), there are more than one hundred bottled water companies in Ethiopia, of which the majority company found in Amhara and Oromia regions. Some of the literature reported that the number of bottled water companies is more than this number. But there is no tangible reference to cite this information. There are huge sales of various brands of bottled water in cities and towns especially in major traffic channels. Most supermarkets, restaurants and fast food outlets also sell bottled water (9, 10).

Consumers may have various reasons for purchasing packaged drinking-water, such as taste, convenience or fashion; for many consumers, however, safety and potential health benefits are important considerations (5). The consumer may prefer the bottled water based on some own criteria. The study conducted in Addis Ababa on the preference of bottled water showed that 44% and 26% of the respondents preferred Yes and Origin bottled water brands respectively (31).

2.5. Bottled Water Quality

Bottled water quality are subjected to intensive investigation in many countries worldwide, in order to evaluate its suitability for human consumption. The type of water sources, type of water purification, storage tanks and others can be the factors of the variation of water quality (3, 4). The nature of the containers, longer storage duration, exposure to high temperature and sunlight, reuse of bottles without adequate cleaning or disinfection are become important consideration in bottled water (5, 11, 20). Moreover, the IBWA has set maximum and minimum allowable limit of parameters to monitor the quality of bottled water by giving particular attention

The quality of bottled water used for human consumption is studied in Gondar town and Addis Ababa city (9, 10, 23). The study conducted in Addis Ababa (Yilkal et al, 2019) found that all tested parameters of bottled water were within WHO water quality standards and compulsory Ethiopian standards. This shows that the quality of bottled water distributed in Addis Ababa city administration was good (10). However, the studies didn't show the physicochemical parameters variation due to storage condition like sunlight exposure.

Yenus et al assessed the chemical qualities of six brands of bottled water commercially available in Gondar town of Ethiopia and compared with WHO, European Union (EU) and Ethiopian water quality standards. Cations (Ca^{2+} , Mg^{2+} , Na^+ , K^+ and Al^{3+}) didn't show much variation with the labelled value of the bottled waters and found within WHO, EU and

Ethiopian water quality standards. The level of anions in all brands on bottled waters were analysed and found below the WHO/EC maximum acceptable limits for these anions. However the fluoride concentration was found to be less than 0.6 mg/l which may cause dental caries (23).

Both studies conclude that there were a variation with the result and the labelled parameters of bottled water. The sampled bottled waters were taken from commercial places. The variation might be due to not only the purification and packaging process of the company but also the storage practices such as direct sunlight exposure. Since there are evidence on the effect of prolonged sunlight exposure on quality of bottled water, it is necessary to understand the variation due to sunlight exposure and the variation due to purification, labelling and packaging process of the company (11, 16, 17).

2.6. Sunlight Radiation and Exposure

The main source of Ultra Violet radiation (UVR) is the sun. The amount of UVR reaching Earth's surface (ambient UVR) depends on latitudes (near to equator more intense), earth rotation (day to night), season of the year, altitudes (more radiation at higher altitude), presence of clouds and atmospheric conditions of the lower atmosphere (32). Countries near to equator with clear skies particularly during the mid- day in summer are affected with high level UVR (32, 33).

Ethiopia is one of the African countries located to near the equator (3⁰ latitudes). The level of ultraviolet radiation in the country is expected to be high during mid-day and summer season. Exposure to high level ultraviolet radiation (UVR) result human disease in many countries especially those countries located near equator like Ethiopia. Now days the effects of exposure to sunlight radiation is not limited to human disease, but it extends to the physicochemical parameters of bottled waters (33, 34).

The National Metrological Agency (NMA) of Ethiopia is collecting; analysing and studying data of atmospheric air, and provides weather forecast and early warnings on the adverse effects of weather and climate of Ethiopia. Based on the NMA data of 2020, the average sunlight intensity, sunshine hour per day and temperature of Addis Ababa city were 158.9W/M², 5.9hr/day and 18.4⁰C respectively. The highest value of sunlight intensity, sunshine hour and temperature was recorded on March (203. 7 W/M², 10.3 hr/day and 20.5⁰C respectively) (35).

According to Weather Atlas released on website shows that the UV index level of Ethiopia is found between 11 and 12 in all twelve months of the year. Ethiopia is one of African countries with very strong UV radiation that need detail investigation not only human health (skin, eye, gene, etc.) but also beverages like bottled water, plastic juices, any canned food that exposed to sunlight ([34](#), [36](#)).

2.7. Effects of Sunlight Exposure on Bottled Water

It is an usual behaviour that bottled water distributors, kiosks, super market and other establishments are exposing bottled water to direct sunlight due to different reasons ([11](#)). Exposing transparent bottled water to predetermined time is one of the promising technologies for the treatment of water to make it safe for consumption. SODIS (solar disinfection) is low cost technology which has a paramount advantage for developing countries especially countries found in tropical areas ([12](#)). However, the physicochemical parameters of bottled water may change due to prolonged period of direct sunlight exposure. This change makes the water parameters increase or decrease within the acceptable range or sometimes beyond the WHO standards of drinking water quality which may result health effects in extended period ([11](#), [13](#), [14](#)).

The effects of direct sunlight exposure on physicochemical parameters of bottled water were studied in countries like Iraq, Ghana and Nigeria. Most of the studies conducted with experimental study design even if the length of sunlight exposure, frequency of experiment and way of analysis were different among all studies ([11](#), [13](#), [14](#), [16-18](#), [37](#), [38](#)).

Muhamed et al studied the effects of sunlight exposure on physicochemical parameters of bottled for one month and found that the concentration of EC, TDS, COD, NO₃⁻, SO₄²⁻, and NH₄⁻ increased as the sunlight exposure increase which is attributed by the leaching of compounds from the bottle to water content. Whereas the concentration of F⁻, Cl⁻ and pH is decreased as sunlight exposure increase due the fluorination and chlorination reaction in bottled water by UV light ([13](#)).

Obisike et al also investigated the effects of sunlight on some physicochemical constituents of sachet packed water sold in Port Harcourt, reverse state, Nigeria. TDS, pH and turbidity of the bottled water before and after sunlight exposure were measured. The mean value of turbidity, TDS and pH of sachet before and after exposure was found to be 1.62 ± 0.63 and

2.37 ± 0.64 NTU, 361.00 ± 105.19 mg/L and 473.33 ± 123.49 mg/L, and 6.46 ± 0.52 and 5.95 ± 1.32 respectively. There were a significant increase in the level of turbidity and TDS after sunlight exposure at $p < 0.0001$ and $p = 0.000$, whereas there was a significant decrease in the level of pH after exposure to sunlight at $p < 0.05$ (18).

Toma et al conducted a study on the effect of sunlight on physicochemical properties for four bottled water during December-2011 to February-2012 in Erbil city of Iraq and the result compared with World Health Organization (WHO) and International Bottled Water Association (IBWA) standard. The descriptive analysis showed that the increment of the values of EC, TDS, hardness, calcium and magnesium with increasing of sunlight exposure time. While the values of pH, alkalinity, sodium, potassium and nitrate were decreased with increasing of sunlight exposure time. The study revealed that the leaching of ions and metals from plastic bottled to the water probably the reason of the increment of the values of EC, TDS, hardness, calcium and magnesium, whereas the reduction of pH is probability due to oxidation reaction and nitrate is due to the change into nitrite (14).

The study conducted at Benin City, Nigeria (Akhrane et al, 2018) on the effects of sunlight on quality parameters of nine bottled water shows that the value of most physicochemical parameters except alkalinity increased steadily up to 28 days exposure. Before exposure to sunlight, the physicochemical parameters of all bottled waters were analysed and found that except pH level, all parameters were within WHO limit standards. Alkalinity declined consistently with increasing sunlight exposure due to increase in the acidity levels of the water. In all, the varying exposure to sunlight did not result in statistical significant changes ($P < 0.05$) in the water quality (11). Recent study in Nigeria (2020) also showed that pH were decreased as sunlight exposure increase while NO_3^- increased in three of the five bottled sample with sunlight exposure .

Generally the study conducted in most of countries and regions shows the sunlight exposure has an effect on the physicochemical parameters of bottled waters (11, 13, 14, 16-18, 38). However most of the studies didn't show the level of sunlight intensity (UV index) and duration of sunlight exposure of the study area.

2.8. Conceptual Framework

The main purpose of this study is to have a detailed description of the effect of direct sunlight exposure on physicochemical parameters of bottled water in Addis Ababa, Ethiopia. There are limited literatures on sunlight exposure and physic-chemical quality change. However, based on the above few studies and literature, the conceptual framework of this study developed as follows. The quality of bottled water i.e physicochemical parameters is the dependent variable that affected by sunlight exposure. Sunlight exposure can be explicit into sunlight intensity (the amount of incoming solar energy or radiation that reaches the earth surface), frequency of exposure (how many days the bottled water exposed?) and sunshine hour per day (how many hours per day the sun shine?).

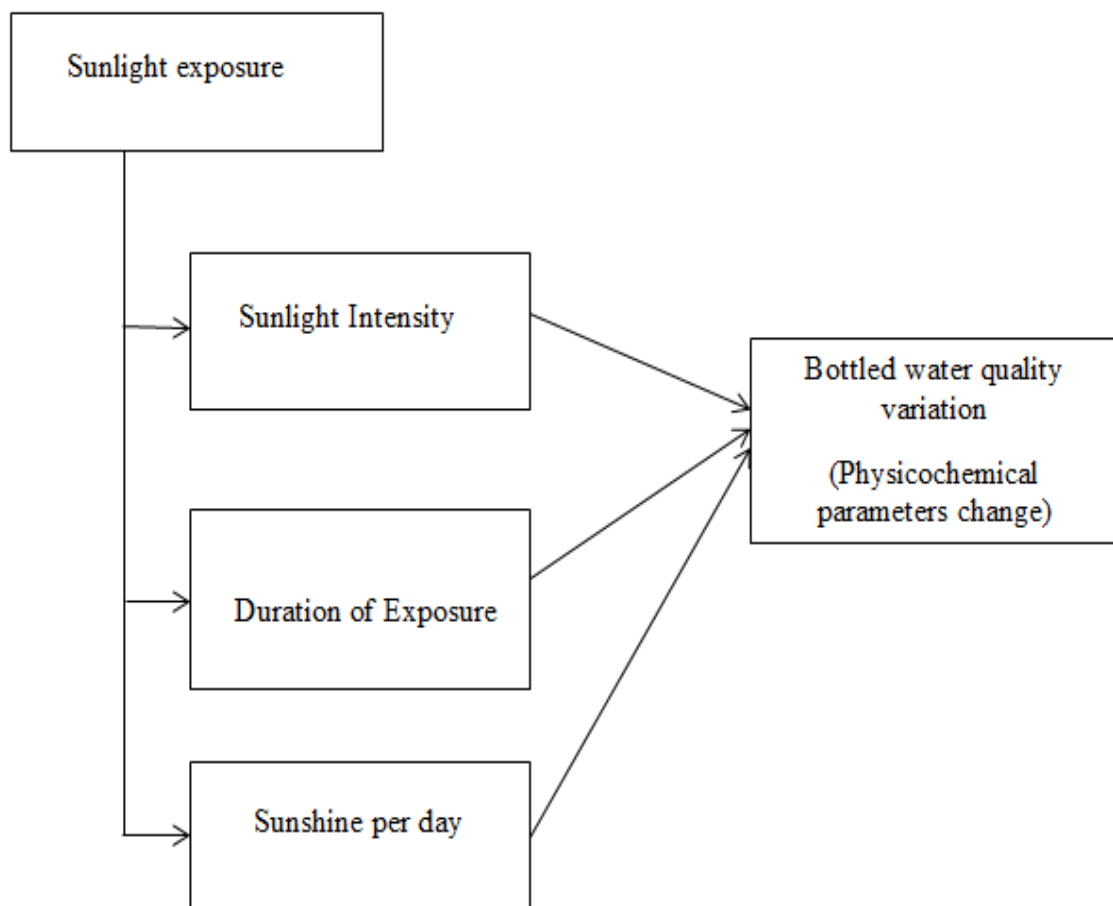


Figure 2.1: Conceptual framework

Source: Own compilation, 2019

3. Objectives

3.1. General Objective

- ✓ To assess the effect of sunlight exposure on physicochemical parameters of bottled water in Addis Ababa, Ethiopia

3.2. Specific Objectives

- ✓ To compare the baseline result against the labelled physicochemical parameters of bottled waters.
- ✓ To investigate the effects of sunlight exposure on physic-chemical parameters of bottled water
- ✓ To compare the result of physicochemical parameters against WHO, IBWA and Ethiopian compulsory water quality standards

4. Materials and Methods

4.1. Study design and Period

Experimental observational study design was employed to assess the effect of sunlight exposure on physico-chemical parameters of bottled waters. The study was conducted from October 3- October 30/ 2020 in Addis Ababa, Ethiopia.

4.2. Study Area

The study was conducted in Addis Ababa city, Ethiopia. Addis Ababa is the capital and the largest city of Ethiopia lies in the geographical coordinate 9.025° N and 38.747° E. The city has an average temperature of 16.8° C and elevation of 2356 meters (7,730 feet) height. There are 1715 hours of sunshine per year with a range between 2:48 for every day in July and 9:42 per day in December (average 6.40 hr/day). According to Ethiopian National Metrological Agency data of 2020, the average sunlight intensity was 158.9 W/M^2 with maximum and minimum value recorded at March and August respectively. The strength of the sun's ultraviolet radiation (solar UV index) of Addis Ababa city lies between 11 and 12 which is categorized as very strong radiation ([34](#), [35](#), [39](#)).

4.3. Materials and Equipment

Chemicals: pH buffers, Indicator, Colour reagent, Silver nitrate (AgNO_3), TISAB solution, EDTA (Ethylenediamine Tetra Acetic acid), Ammonium Oxalate, Sodium Oxalate, ammonium chloride, Ferrous ammonium sulphate, ammonium hydroxide, Magnesium sulphate (MgSO_4), Hydrochloric acid (HCl), Phosphoric acid (H_3PO_4), Sulphuric acid (H_2SO_4), Sulfanilamide, Sodium hydroxide (NaOH), Deionized water, Glacial acetic acid, Sodium chloride (NaCl), Potassium Chloride (KCl), Potassium Manganate (KMnO_4), Eriochrome Black T (EBT), Eriochrome Blue T (EBB), Sodium nitrite (NaNO_2), Potassium nitrate (KNO_3), Trisodium acetate were used during the experiment.

Equipment: These are list of equipment's that were used in the laboratory during the experiment. UV Spectrophotometer, flame photometer, pH meter, Dark Blue bottle, Refrigerator, Ion selective electrode, Turbidity meter, Conductivity meter, volumetric flask, beaker, dropper, Pipette, Filter paper (whatman 42), Erlenmeyer flask, and Cuvette.

4.4. Source and Study Population

All bottled water companies found in Addis Ababa city and Oromia special zone were the source population and the selected brands of bottled water were the study population. The study units were the plastic bottled waters from selected brands.

4.5. Inclusion and Exclusion Criteria

The target population of the study was bottled water company/brands found in Addis Ababa and Oromia special zone. The study included all bottled Water Company exist in Addis Ababa city and Oromia special zone and currently on job. The study excluded those companies outside Oromia special zone because of financial constraints for the collection of bottled water samples and those companies temporarily out of service.

4.6. Sample Size Determination

The sample size was determined based on experimental studies formula for difference in means of exposed and not exposed groups. By taking 95% confidence level, 5% significance level (α), power 80% ($1 - \beta$) and mean of TDS value of exposed and non-exposed groups (42.67 and 37.89mg/L respectively) and effect size of 4.78 (11).

$$\text{Sample size} = \frac{2SD^2(Z_{\alpha/2} + Z_{\beta})^2}{d^2}$$

Where SD= Standard deviation of the previous study

$$Z_{\alpha/2} = 1.96, \quad Z_{\beta} = 0.84$$

D= Effect size= Mean differences between exposed and non-exposed=4.78

$$n = \frac{2 * 2.39^2 (1.96 + 0.84)^2}{4.78^2}$$

$$n = 3.92$$

Hence, four brands of bottled water were selected randomly for this study. Then four brands of bottled waters were allocated for control groups and as the same time those four brands of bottled water were assigned for experimental groups.

4.7. Sampling Method

There are twenty three bottled water company found in Addis Ababa and Oromia special zone (annexed at Annex 5 table 9). The Bottled water brands were classified into two based

on their TDS level to minimize the variation among bottled waters. Then four bottled water brands were selected randomly from the two groups using lottery method. That means two bottled water brands were taken from TDS level less than 50 mg/l and the rest two were taken from TDS level greater than and equal to 50 mg/l. The bottled water make two group when they ranked based on their TDS value. That is why 50 mg/l was used as a cut-off point.

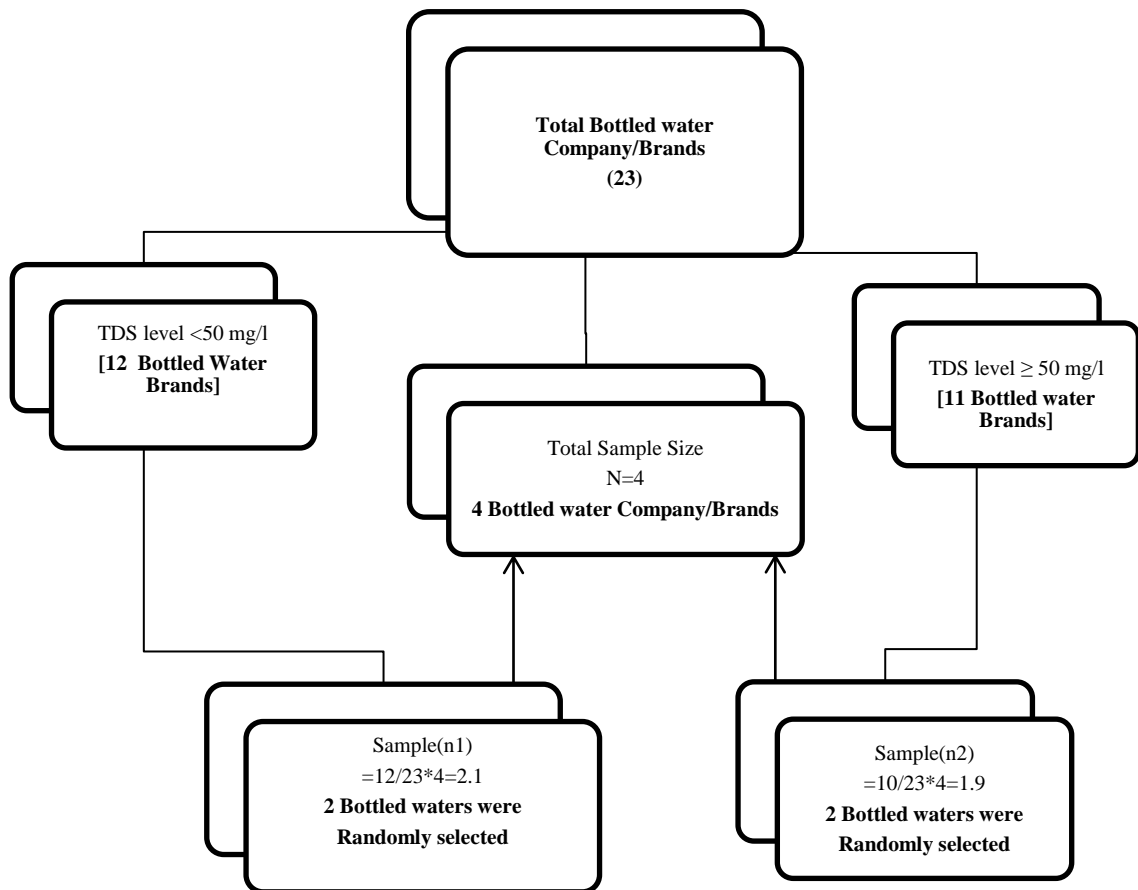


Figure 4.1: Schematic representation of sampling procedure

4.8. Data Collection Procedures

The principal investigator was collected twelve bottled water of 0.6L directly from each factory before exposed to sunlight and transported to the storage place with rental vehicle. The sampled bottled waters were grouped into control and Experimental bottled water. The experimental bottled water sample was subjected to expose to direct sunlight (from 8:00am to 5:00pm in each day) with different length of days while keeping the control bottled water inside the house at normal temperature. The exposed bottled waters were kept at sunlight in a

secured place by preventing the entrance of unauthorized person. One person was assigned to expose bottled water at the morning (8:00 am) and back to home at 5:00 pm with regular monitoring by the principal investigator. The bottled water was exposed up to 28 days (Based on the preliminary assessment conducted on bottled water seller at akaki kaliti sub city woreda 4). In every week (7 days) exposure, the exposed samples were taken to the laboratory. And the physicochemical parameters of both experimental and control bottled water were investigated in every seven days, adopted from Akhrame Mo, et al (2018) (11).



Figure 4.2: Bottled water exposed to direct sunlight

4.9. Physicochemical Parameters Analysis

Most of heavy metals and faecal coliform are nil in bottled water. Hence the main physicochemical parameters such as pH, TDS, EC, turbidity, total hardness, Cl^- , NO_2^- , NO_3^- , F^- , Ca^{2+} , Mg^{2+}) were analysed. All physicochemical tests were conducted in the Environmental health laboratory of Ethiopian Public Health Institute (EPHI) by following standard methods for the examination of water and wastewater of the American Public Health Association (APHA) (40). The chemical analysis of each parameter was done as follows:

The pH of the bottled water was measured using pH meter (model AD111). The pH meter was calibrated with standard buffer solutions before actual measurement is done. Rinse the electrode with distilled water and dry with kimwipes. Then the electrode was immersed to the solution and wait until stable result displayed. Turbidity was measured using turbidity meter (Aqualytic model AL450T). The turbidity meter was calibrated using standard buffer solutions and rinse with distilled water. Take small water sample with its own bottle and insert to conductivity meter, and the result was displayed on turbidity meter screen. TDS and EC was measured using Con/TDS/Sal/Res meter (SX713 model). The instrument was

calibrated and then immerses the electrode to the bottled water sample and takes the measured value.

Hardness was measured using titration techniques called EDTA titrimetric method. Ammonium as buffer solution, EBT as indicator and EDTA as titrant were used to measure the level of hardness of bottled water. Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were measured using EDTA titrimetric method as that of hardness. EDTA as titrant, sodium hydroxide as buffer solution and EBT as indicators were used during the analysis of calcium ion. The final concentrations of calcium and magnesium ions were calculated based on their molecular weight.

Chloride ion was measured by adding potassium chromate indicator to 25 ml of water sample and titrates with silver nitrate until light red appears. Fluoride was analysed using ion-selective electrode method (JENWAY model 3345 ion meter, made in England). The instrument was calibrated using standard fluoride concentrations. Add known amount of TISAB buffer solution (5ml) to 5ml sample water and immerse the electrode to the sample. The value was taken after stable result displayed on the screen. UV-Spectrophotometer (UV-1800, made in Japan) was used to measure the concentration of nitrite and nitrate in bottled water sample. The spectrophotometer was calibrated using standard solutions of respective ions and then the nitrite and nitrate concentration were analysed at 540nm and 220nm absorbance respectively.

The daily sunlight intensity and sunshine hour values were taken from National metrological agency of Ethiopia to correlate the result of the bottled water parameters with sunlight radiation.

4.10. Number of Experiment

A total of 744 (Seven hundred forty-four) single tests were conducted to answer the study objective. That means thirteen parameters and 104 (one hundred four) tests were performed for objective one and 640 (six hundred forty) tests were conducted for objective two and three of the study. The experimental analyses were done by the principal investigator and the laboratory assistance person of EPHI.

Table 4.1: Number of experiment conducted in each specific objective

Objective	No of bottled water tested	No of group (E, C)	No of parameters	No of days	No of Replicati on test	Total test performed
Objective 1	4	1	13	1	2	104
Objective 2 & 3	4	2	10	4	2	640
Total						744

N.B. Number of group: E= Experimental(Exposed), C= Control(Non-exposed)

4.11. Data Management

The experimental data were recorded on paper and then the data were entered into the excel format. The completeness of the values of all physicochemical parameters was checked after conducting each experiment. All the data were cleaned on each day of experiment in order identify unexpected and unclear values. Some of the values of the parameters were taken directly as it is without transforming the results and other parameters were transformed using their own formula to get the exact value. The four consecutive weeks of the physicochemical parameters results of exposed and non-exposed BW were paired. The difference between the mean value of non-exposed and exposed groups were computed using SPSS in order to check the normality assumption. The normality assumption was done using Shapiro-Wilk test. Paired sample T-test were used to compare non exposed and exposed groups for those parameters which fulfilled the assumptions. For those parameters which didn't fulfil the assumptions, we used the non-parametric (Wilcoxon signed rank test) test to know the significant difference among exposed and non-exposed groups of BW.

4.12. Data Analysis

MS excel 2010 and SPSS version 23 was used for data analysis. A descriptive analysis was carried out to compare the labelled physicochemical parameters against this finding. Descriptive analysis was also employed to evaluate the result of the effects of sunlight exposure on physicochemical properties of bottled water against WHO, IBWA and ECWQS. Mean values for physicochemical parameters of bottled water before and after exposure to sunlight was compared using paired sample t-test and Wilcoxon signed rank test with significance level of 0.05.

4.13. Data Quality Management

All equipments used for the experiment were labelled. Replicate samples were taken from each bottled waters that was processed and analysed individually. Average value of the replicate samples result was used. The result of the duplicate experiment was within the acceptable range (10%), otherwise the cause was determined or corrected. Quality control was performed once in a very 10 samples with known standard solution to verify the accuracy of the analysis ([41](#)).

4.14. Ethical Consideration

Ethical clearance was taken from Addis Ababa University. Permission to take sample from the bottled company was obtained from the managers. Letter containing the purpose of the study, name of investigator, outcome of the study was brought from college of health science of Addis Ababa University. The name of company and bottled water were replaced by codes to ensure the confidentiality of the data. The data of laboratory result was entered using MS excel 2010 sheet and kept the confidential and only the researcher accesses the data.

4.15. Dissemination of the Findings

The findings of this study was presented to the school of public health, college of health sciences of Addis Ababa University and it will be disseminated to concerning ministers, bottled water company and non-governmental organizations which are concerned with the study findings. Publication in national and international journals will be considered.

5. Results

5.1. Characteristics of Plastic Bottles and Bottled Water

All four bottled water companies were used white transparent plastics bottled made from Polyethylene Terephthalate (PET) and caps made of Polypropylene (PP). All bottled water companies were packed natural purified water by using a high technology filtration system. The plastics bottles were not exposed to sunlight and high temperature before being filled with purified water. Only one bottled water company wrote the precaution that states "don't expose the bottled water to direct sunlight". No one of the bottled company knows about the thickness of the plastics bottles.

5.2. The Initial physicochemical Parameters of Bottled waters

Four brands of bottled water (two brands from TDS level <50 mg/l and the rest two from TDS level ≥ 50 mg/l) were analysed at the laboratory. The initial physicochemical parameters of bottled water such as pH, TDS, EC, Turbidity, total hardness, Ca^{2+} , Mg^{2+} , Cl^- , NO_2^- , NO_3^- , Na^+ , K^+ and F^- were analysed before exposed to direct sunlight (Table 5.1) and the results of physicochemical properties of this work compared with the reported label values of the bottled water, World Health Organization (WHO) and International Bottled Water Association (IBWA) and Ethiopian compulsory water quality standards (ECWQS).

The laboratory results showed that the concentrations of most of the labelled parameters of bottled waters were not matched with this finding. However, the pH of all bottled water and the value of Cl^- and K^+ of BW1 were matched with the labeled value with 10% of standard deviation (Table 5.1 and 5.2). The value reported on the label of bottled water and the laboratory results of this study were not beyond the standard of WHO, IBWA and ECWQS.

Table 5.1: The baseline physicochemical parameters value of bottled water and the labelled value

S.no	Physicochemical Parameters	BW1		BW2		BW3		BW4	
		Labelled Value	This Result	Labelled Value	This Result	Labelled Value	This Result	Labelled Value	This Result
1	K ⁺	0.50	0.51	0.50	1.23	0.40	0.94	0.80	1.10
2	Na ⁺	0.60	7.91	3.00	13.37	8.11	24.40	1.08	93.40
3	Ca ²⁺	0.50	1.6	1.20	5.61	19.7	29.66	1.95	3.21
4	Mg ²⁺	0.05	0.00	0.50	0.97	3.30	0.97	0.90	0.00
5	Cl ⁻	5.75	6.00	1.10	3.99	7.94	10.00	7.80	9.50
6	NO ₂ ⁻	NA	0.00	NA	0.00	NA	0.00	NA	0.00
7	F ⁻	NA	0.11	0.20	0.10	NA	0.22	NA	0.37
8	NO ₃ ⁻	NA	0.97	0.10	1.56	NA	8.42	NA	4.85
9	TDS	10.00	7.12	20.00	33.15	150.00	107.50	160.00	183.50
10	pH	7.00	7.72	7.20	6.99	7.40	7.15	7.00	7.38
11	Total hardness	NA	4.00	NA	18.00	NA	78.00	NA	8.00
12	E.C	NA	12.51	NA	50.15	NA	149.70	NA	253.00
13	Turbidity	NA	0.00	NA	0.00	NA	0.00	NA	0.00

NA= Not Applicable (The Value of the parameter is not mentioned on the label of BW

Table 5.2: Parameters of Bottled water with ten percent SD matched with the label value

Brands of BW	# of parameters analyzed	# of parameters found on the label of BW	# of parameters matched with this result (within 10% SD)
BW1	13	7	3
BW2	13	9	1
BW3	13	7	1
BW4	13	7	1

5.3. Sunlight Exposure

The daily value of sunlight intensity (W/M²), sunshine hour and temperature (°C) were taken from the National Metrological Agency (NMA). These data were recorded at OBS station (near to stadium, Addis Ababa) which is far from 7.2km from the area on which the bottled water was exposed. The average sunlight intensity and sunshine hour of the study period from October 3 to 30/2020 showed that 197.7±31.8 W/M² and 7.3±2.7 hours respectively. On average, the bottled waters were exposed 6.9 hour in the first week, 4.9 hour in the second

week, 7.5 hour in the third week and 9.9 hour in the last week with a sunlight intensity of 208.9 W/M², 175.7 W/M², 187.6 W/M² and 218.5 W/M² respectively. As shown in Figure 5.1, the sunlight intensity and sunshine hour of the second week (October 11-17/2020) of the experimental period was lower than the rest of the experimental weeks. The average temperature of the study period was 17.8 °C (16.0-19.1°C). The daily value of sunlight intensity, sunshine hour and air temperature of the study period and monthly data of the year 2020 are annexed (Annex VI).

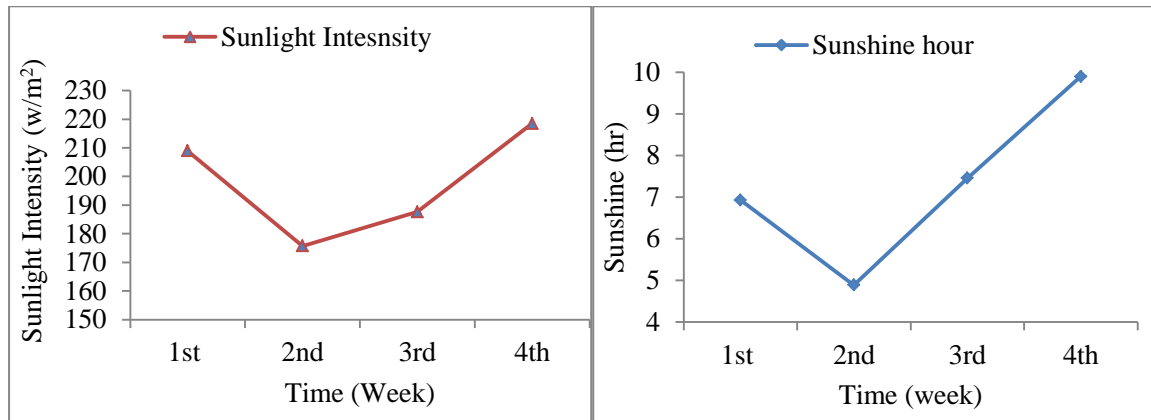


Figure 5.1 : Sunlight intensity and sunshine hour during the study period (October 3-30/2020)

5.4. Effect of Sunlight Exposure on the Physico-chemical Parameters of BW

5.4.1. Electrical Conductivity (EC)

The electrical conductivity of bottled water was measured at zero-day of exposure and every week of direct sunlight exposure. The mean EC value of non-exposed and exposed groups of bottled water was 116.31± 108.73 and 116.06± 108.90 µs/cm at 7 days, 116.18± 108.72 and 117.37± 109.90 µs/cm at 14 days, 116.97± 110.35 and 117.03± 110.26µs/cm at 21 days, and 113.58± 105.96 and 116.38± 108.64 µs/cm at 28 days (Figure 5.2). Nearly similar result was obtained from all exposed BW brands at each consecutive week of observation. Slight decrement (2.3%) was observed in non-exposed groups of BW (Figure 5.2). However, a Wilcoxon signed rank test showed that there was no statistically significant difference between the mean value of EC for exposed and non-exposed groups ($z=-1.863$, $p=0.062$). Hence the effect of sunlight exposure on the electrical conductivity of bottled water was very minimal. The EC values of exposed and non-exposed groups were within the Ethiopian compulsory water quality standards, WHO, and IBWA guideline limit.

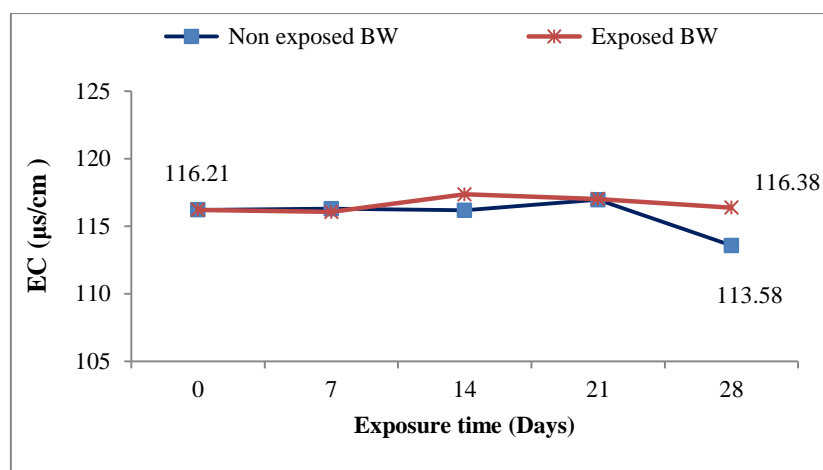


Figure 5.2: Effect of sunlight exposure on EC of exposed and non-exposed groups

5.4.2. Total Dissolved Solids (TDS)

The initial TDS values of sampled bottled water were measured and found to be in the range of 7.12 mg/l to 183.50 mg/l with a mean of 82.82 mg/l. The bottled water samples were exposed to direct sunlight for 28 days and the TDS level was measured each week to compare the results with non-exposed bottled water. The average TDS values of non-exposed groups were 84.37 ± 80.21 , 84.41 ± 79.99 , 86.23 ± 82.43 , 83.86 ± 78.57 mg/L whereas the average TDS value of exposed groups were 85.42 ± 81.38 , 85.90 ± 81.25 , 85.94 ± 81.75 , and 85.24 ± 81.26 mg/L at first, second, third and fourth week of sunlight exposure respectively (Figure 5.3). It was observed that exposed BW increased more TDS value (2.93%) than non-exposed BW (1.25%) from the initial value of TDS which was measured at day zero (Figure 5.3). The results of all bottled water were within the ECWQS, WHO and IBWA standards. The comparison of both mean values of non-exposed and exposed BW using paired sample t-test also showed that there was no statistically significant difference among the two groups of bottled water at $p=0.054$.

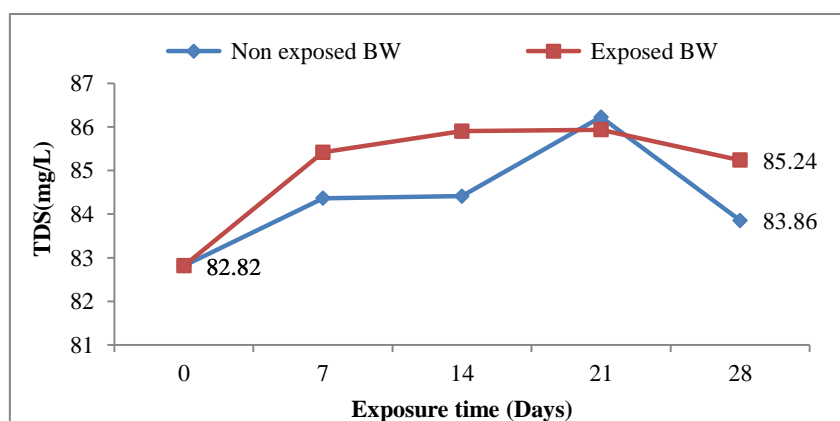


Figure 5.3: Effect of sunlight exposure on TDS value of exposed and non-exposed BW

5.4.3. Fluoride

Fluoride ions were found in all brands of bottled water at concentrations between 0.10 to 0.37 mg/l with a mean value of 0.20 mg/l of F⁻. The bottled water samples were exposed to direct sunlight for 28 days to assess the effect of sunlight exposure on the concentration of fluoride ion. The average concentration of fluoride was found to be 0.20±0.12 and 0.16±0.10 mg/l at 7 days, 0.20±0.12 and 0.16±0.11 at 14 days, 0.18±0.11 and 0.15±0.11 mg/l at 21 days, and 0.20±0.13 and 0.18±0.14 at 28 days for non-exposed and exposed BW respectively. As shown in figure 5.4, the fluoride concentrations of exposed bottled waters (all brands) were decreased with increasing sunlight exposure time and the high reduction was observed in the first week of sunlight exposure. The exposed bottled water F⁻ concentration was decreased by 0.03 mg/l (16.01%) as compared non exposed bottled water due to sunlight exposure. Statistical analysis of paired sample t-test showed that there was a significant difference between the mean value of fluoride for non-exposed and exposed group at $t(15) = 6.666$, $p = 0.000$. This shows that sunlight exposure has affected the concentration of Fluoride ion. The Fluoride concentration of exposed and non-exposed groups of all brands of bottled water was below the recommended value of WHO. However, IBWA and Ethiopian Compulsory water quality guidelines didn't have a lower limit value.

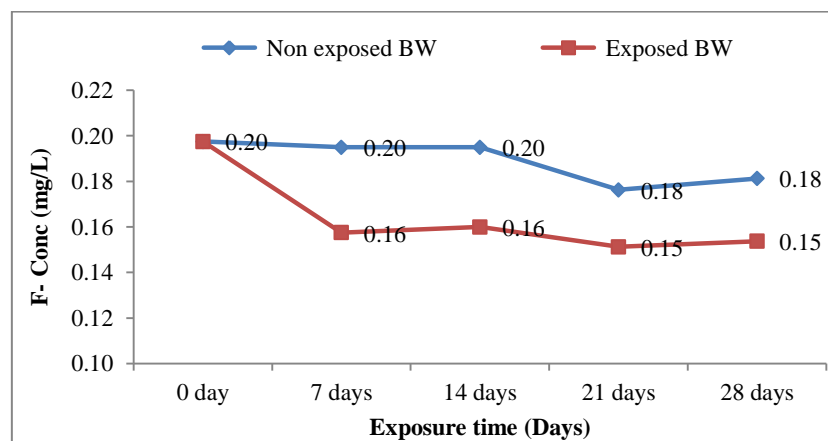


Figure 5.4: Effect of sunlight exposure on Fluoride ion concentration of Bottled waters

5.4.4. Chloride

The initial Cl⁻ values of sampled bottled water were measured and found to be in the range of 4.00 mg/l to 10.00 mg/l with a mean of 7.37±2.87 mg/l. The concentration of chloride ion of the non-exposed and exposed group of bottled water was analyzed at each week of the study period for one month. The concentration of chloride ion was completely absent in both group of BW1 and BW2 whereas, in BW3 and BW4, the value of chloride were decreased by

37.84-60.00% from the initial concentration at 28 days. It was observed that the concentration of chloride for both exposed and non-exposed bottled water was decreased as the sunlight exposure time and room storage increased (Figure 5.5a & 5.5b). That means the concentration chloride decreased irrespective of the storage condition (whether at room or sunlight). A non-parametric Wilcoxon signed rank test was done to check the significance mean difference between non-exposed and exposed BW and found that there was no statistically significant difference between the mean value of chloride concentration for exposed and non-exposed groups ($z=-0.425$, $p=0.703$). The concentration of Cl^- ion for all sampled bottled water was within the ECWQS, WHO and IBWA guideline limit.

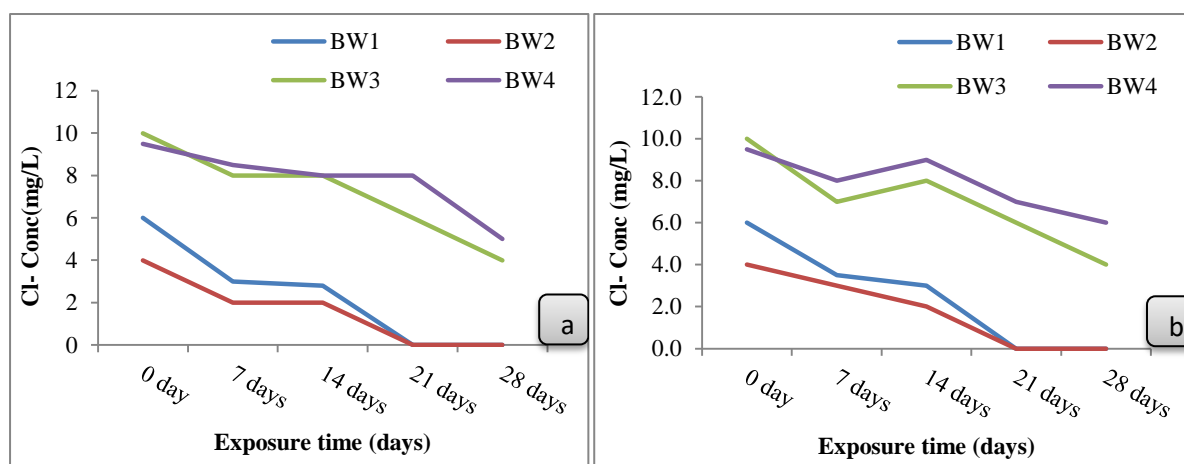


Figure 5.5: Effect of sunlight exposure on Chloride ion concentration of BW (a=Exposed; b=Non-exposed)

5.4.5. pH

The initial pH value of all bottled water brands (BW1, BW2, BW3 and BW4) were in the range 6.99-7.72 with a mean of 7.31 ± 0.32 . The pH of non-exposed bottled water was decreased from 7.31 ± 0.32 to 7.26 ± 0.33 whereas the pH of exposed BW was decreased from 7.31 ± 0.32 to 7.02 ± 0.30 at 28 days. The percent of pH reduction from the initial value was 0.62% and 3.99% for non-exposed and exposed groups respectively (Figure 5.6b). The pH of the exposed group of bottled water was reduced by 0.24 units (3.31%) more when compared to the non-exposed group of BW at 28 days of exposure. As shown in Figure 5.6a & 5.6b, the pH level of the exposed group of BW slightly decreased consecutively from day zero to 28 days whereas the pH level of non-exposed groups fluctuated up and down at each week of observation. The paired samples t-test analysis indicated that there was a statistically significant difference between the mean value of pH for exposed and non-exposed groups at $t(15) = 6.453$, $p=0.000$. But, the effect of sunlight exposure on the pH value of bottled water was very small. All pH values were within the ECWQS, WHO and IBWA guideline limit.

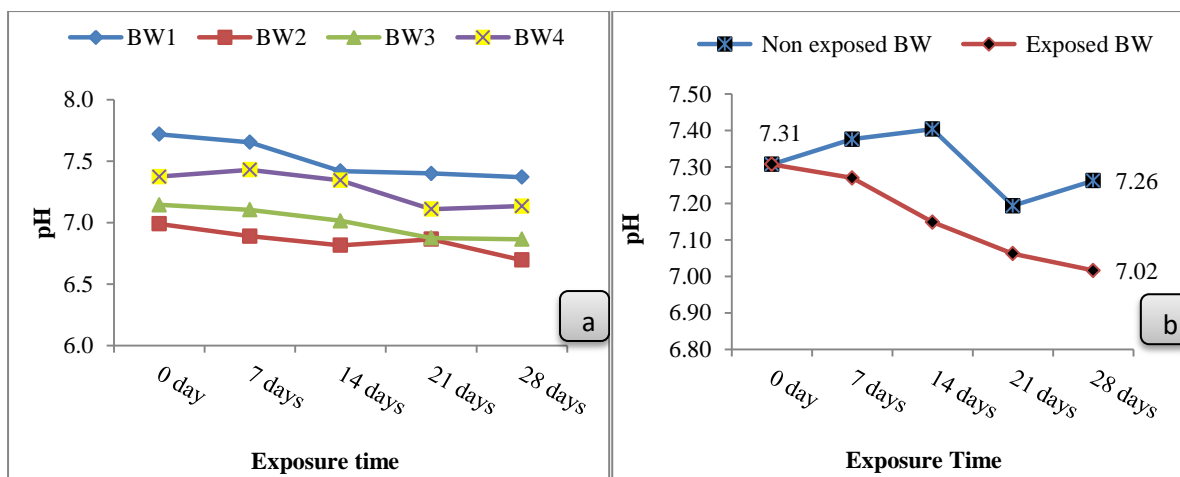


Figure 5.6: Effect of sunlight exposure on the level of pH of BW (a=Exposed BW brands; b=Non-exposed and exposed group)

5.4.6. Nitrite and Nitrate

Nitrite ions were not found in all brands of bottled water at zero-day of exposure. The nitrite ion was detected after 7 days of exposure on three brands of exposed bottled water. At three weeks of sunlight exposure, the nitrite ion was detected in all brands of exposed bottled water. As shown in the figure 5.7, the concentration of nitrite in BW3 and BW4 was sharply increased as sunlight exposure time increased whereas the concentration of nitrite in BW1 and BW2 was slightly increased as sunlight exposure time increased. The concentration of nitrite was increased from 0.00 mg/L at zero day to 0.015 mg/L at 28 days exposure with 0.013 mg/L NO_2^- average increment in each week of exposure (Figure 5.7&5.8). The non-exposed waters were remained nil until the end of the sunlight exposure (Figure 5.8). This shows that the formation of nitrite ion on exposed bottled water was exclusively attributed by sunlight exposure. Those bottled water that had a high TDS level and high amount of NO_3^- ion has a relatively high concentration of nitrite after sunlight exposure. On the contrary, bottled water which has low TDS and NO_3^- concentration had low nitrite concentration during the exposure time. The concentration of NO_3^- ions in exposed bottled water was slightly decreased as the sunlight exposure time increased. However, the concentration of nitrite and nitrate in all sample of bottled water was within the standards set by ECWQS, WHO and IBWA. The Wilcoxon signed rank test showed that there was significant difference between the mean value exposed and non-exposed groups for nitrite ($z=-3.299$, $p=0.000$) whereas there was no significance difference between the two groups for nitrate ($Z=-1.161$, $p=0.268$).

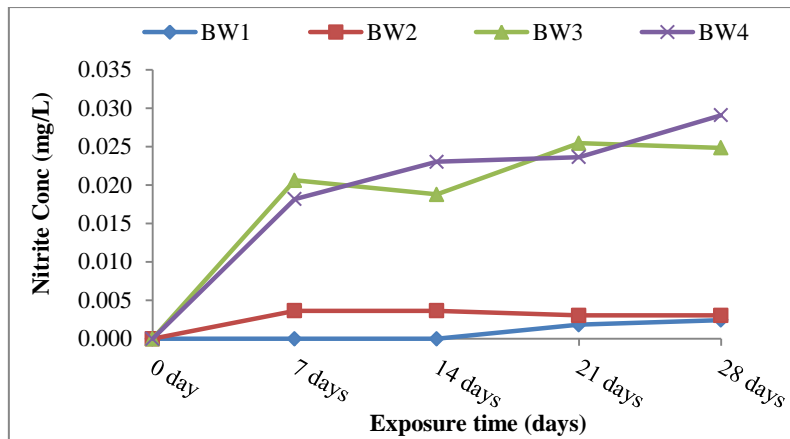


Figure 5.7: Effect of sunlight exposure on Nitrite ion concentration of each brand of BW

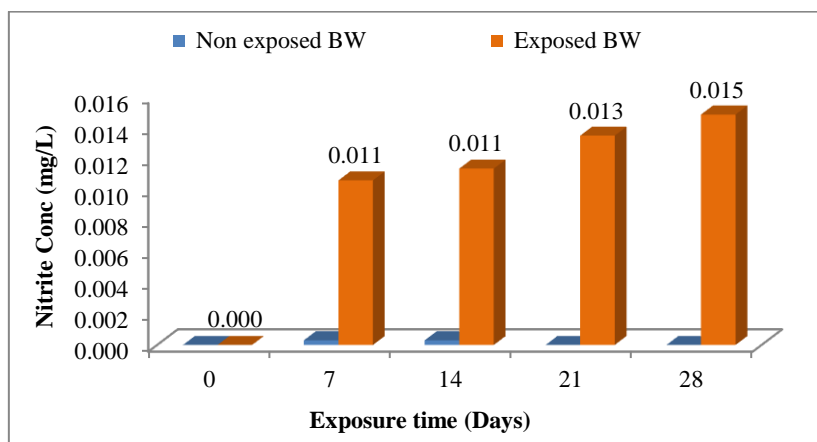


Figure 5.8: Effects of sunlight on Nitrite ion concentration of non-exposed and exposed BW

5.4.7. Turbidity

Initially, none of the sampled bottled water has had turbidity. After exposure to sunlight, the mean turbidity level of exposed bottled water was found to be 0.03 ± 0.03 NTU at 7 days, 0.02 ± 0.03 NTU at 14 days, 0.06 ± 0.07 NTU at 21 days, and 0.57 ± 0.03 NTU at 28 days. The mean value of exposed groups at 28 days was more than two times higher than that of the mean value of non-exposed BW. The trend shows that the level of turbidity increased as the sunlight exposure time increased (Figure 5.9). The values of turbidity for both exposed and non-exposed groups of bottled water were within the recommended limit of WHO and ECWQS. But the values of exposed groups were beyond the maximum limit set by IBWA. The Wilcoxon signed rank test showed that there was a significant difference on the level of turbidity between the mean value of exposed and non-exposed groups ($z=-2.669$, $p=0.005$).

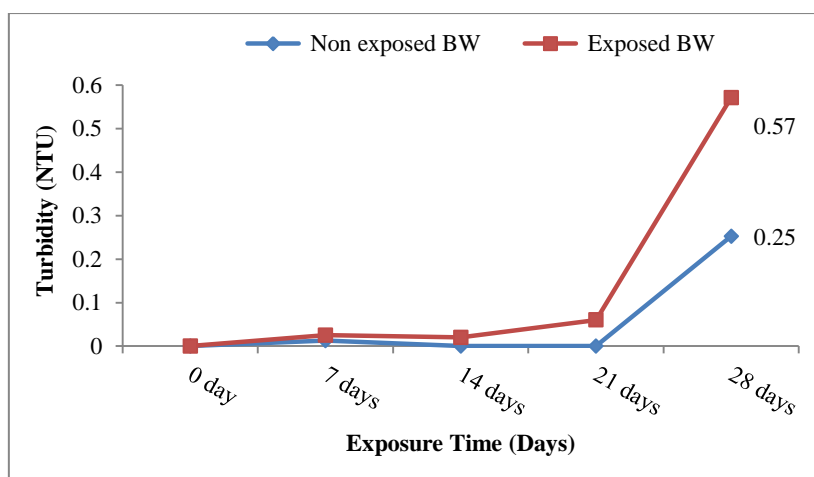


Figure 5.9: Effects of sunlight exposure on turbidity level of exposed and non-exposed BW

5.4.8. Total Hardness

The initial total hardness values of bottled water were measured and found to be in the range of 4.00-78.00 mg/l with a mean of 27.00 ± 34.51 mg/L. As data presented in Table 5.3, 50.00% and 2.56% decrement was obtained in BW4 and BW3 of exposed groups respectively. However, change was not seen in BW1 and BW2 of exposed group. The hardness of the non-exposed group was also decreased similarly except BW2. Calcium and magnesium ions which are responsible for creating hard water were also investigated and similar trend was obtained like that of total hardness. The Wilcoxon signed rank test analysis showed that there was no significant difference between the exposed and non-exposed groups for total hardness calcium and magnesium ($p > 0.05$). The level of total hardness, calcium and magnesium ions were within the recommended value of WHO, IBWA, and ECWQS.

Table 5.3: Effects of sunlight exposure on the total hardness level of Bottled water

BW Brands		0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	4.00	4.00	5.00	4.00	4.00	0.00	0.00
	E		6.00	6.00	5.00	4.00	0.00	0.00
BW2	C	18.00	16.00	14.00	20.00	16.00	2.00	11.11
	E		16.00	14.00	16.00	18.00	0.00	0.00
BW3	C	78.00	80.00	78.00	68.00	76.00	2.00	2.56
	E		78.00	78.00	72.00	76.00	2.00	2.56
BW4	C	8.00	8.00	8.00	4.00	4.00	4.00	50.00
	E		8.00	8.00	6.00	4.00	4.00	50.00
Mean	C	27.00	27.00	26.25	24.00	25.00	2.00	7.41
	E		27.00	26.50	24.75	25.50	1.50	5.56
SD	C	34.51	35.68	34.70	30.29	34.47	1.63	23.21
	E		34.27	34.50	31.89	34.31	1.91	24.60

5.5. Comparison of Non exposed and Exposed Groups

Comparison between the mean values of physicochemical parameters of exposed and non-exposed groups of bottled water were done using parametric and non-parametric test. The mean difference value of pH, TDS and fluoride of exposed and non-exposed groups fulfilled the normality assumption and which were done by Shapiro Wilk test. Hence these three parameters were done using paired sample T-test whereas the rest parameters were done by Wilcoxon signed rank test because the mean difference of exposed and non-exposed didn't fulfil the normality assumption.

The paired sample T-test showed that there was a significant difference between the mean value of pH and fluoride of exposed and non-exposed groups whereas there was no significant difference between the mean values of TDS of the two groups (Table 5.4). And the nonparametric Wilcoxon signed rank test showed that there was a significant difference between turbidity and nitrite value of the two groups whereas the rest parameters (Cl^- , NO_3^- , EC, Hardness, Ca^{2+} and Mg^{2+}) had no significant difference with the mean value of exposed and non-exposed groups of BW (Table 5.5).

Table 5.4: Paired sample t-test comparison of Non- exposed and Exposed BW

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 pH_Non exposed - pH_Exposed	.1847	.115	.029	.124	.246	6.453	15	.000
Pair 2 F-_Non exposed – F-_Exposed	.031	.019	.005	.021	.041	6.666	15	.000
Pair 3 TDS_Non exposed - TDS_Exposed	-.860	1.650	.412	-1.739	.019	-2.086	15	.054

Table 5.5: Wilcoxon signed rank test of exposed and non-exposed group of BW

	NO2-_Exposed - NO2-_Non exposed	Cl-_Exposed - Cl-_Non exposed	EC-_Exposed - EC-_Non exposed	Turbidity_Exposed - Turbidity_Non exposed	Hardness_Exposed - Hardness_Non exposed	Ca2+_Exposed - Ca2+_Non exposed	Mg2+_Exposed - Mg2+_Non exposed	NO3-_Exposed - NO3-_Non exposed
Z	-3.299 ^c	-.425 ^b	-1.863 ^c	-2.669 ^c	-.853 ^c	-1.478 ^c	-.679 ^b	-1.161 ^b
Asymp. Sig. (2-tailed)	.001	.671	.062	.008	.394	.140	.497	.245
Exact Sig. (2- tailed)	.000	.703	.065	.005	.469	.164	.516	.268
Exact Sig. (1- tailed)	.000	.352	.033	.002	.234	.082	.258	.134
Point Probability	.000	.023	.004	.001	.055	.008	.016	.013

b. Based on positive ranks

c. Based on negative ranks

6. Discussion

Based on the experimental findings, the value of Turbidity, Nitrite, and TDS were increased from 0.00 to 0.57 NTU (~100%), 0.00 to 0.02 mg/L (~100%) and 82.82 to 85.24 mg/L (2.9%) respectively at 28 days of sunlight exposure. Whereas the values of Magnesium, Fluoride, Nitrate and pH were decreased from 0.486 to 0.365 mg/L (24.9%), 0.2 to 0.15 mg/L (22.2%), 3.95 to 3.52 mg/L (11.0%) and 7.31 to 7.02 (3.9%) respectively as sunlight exposure increased. The values of the rest parameters of exposed groups (Chloride, Total hardness, Calcium and EC) were decreased from the baseline values by 69.5%, 5.6%, 4.0% and 0.2% respectively irrespective of the sunlight exposure.

Most of the measured value of the physicochemical parameters except pH (all BW brands) and K⁺ and Cl⁻ (BW1) were not matched with the label of the bottled water. The finding of this study is similar to the study conducted on the quality of bottled water marketed in Addis Ababa, Ethiopia and Malawi, and they reported that few physicochemical parameters were matched with measured value ([10](#), [42](#)). In contrast, J.J. Toma et al (Erbil city, Iraq) have investigated that fifty percent of the measured values of physicochemical parameters were matched with the label of the bottled water ([14](#)). The variation might be due to the difference in regulation among countries and the daily monitoring capacity of the bottled water company ([10](#)).

Except for fluoride ion, the baseline values of all physicochemical parameters of bottled waters were within the minimum and maximum permissible limit set by WHO, IBWA and ECWQS to safeguard the health of the people. This finding agreed with the study conducted in Gondar town and Addis Ababa city of Ethiopia and Portugal, Porto ([10](#), [23](#), [43](#)).

The lowest level of sunlight intensity and sunshine hour was observed at the second week of the study period. At this week, the value of physicochemical parameters such as fluoride, nitrite and turbidity decreased or increased relatively in small percent as compared to the other weeks. This shows that the level of these physicochemical parameters were significantly associated with the level of Sunlight intensity and sunshine hour.

In this study, the TDS and EC value couldn't significantly change with increasing sunlight exposure and the exposed and non-exposed groups of BW were almost similar value at each observation with no statistically significant difference ($p=0.054$ for TDS and $p=0.065$ for EC). This shows that the effect of sunlight intensity and sunshine hour on the TDS and EC

value of bottled water was very minimal during the study period. But the study conducted in Nigeria on thirty bottled water for three days of sunlight exposure showed that the value of TDS significantly increased due to sunlight exposure increased ($p=0.000$) (18). Muhamad et al (2011) and Toma et al (2013) also assessed the effect of sunlight exposure on EC and TDS and found that the parameters were increased with increasing sunlight exposure (14, 18). The difference might be due to the variation in sunlight intensity and sunshine hour of the study period and the properties of the plastic bottles. For aesthetic reasons, a maximum limit of 1000mg/L TDS level has been established by WHO and ECWQS (5, 15) and 500mg/L by IBWA (5, 15, 30). In most of the previous studies (11, 13, 16, 18) and this study, none of the sampled Bottled water was beyond the maximum limit and couldn't affect the palatability of the bottled water.

The fluoride concentration of exposed was decreased from 0.20 to 0.15 mg/L at 28 days with significant difference between the mean value of the two groups of BW ($p=0.000$). Similar results were obtained by Muhamed et al (2011) on that fluoride ion concentration decreased with increasing sunlight exposure over a month (13). The decreasing of fluoride concentration in exposed bottled water might be the fluorination reaction by UV light and conversion to hydrogen fluoride (13, 44). Fluoride ion is one of the physicochemical parameters of water that has public health importance in both extremities. A low concentration of fluoride in water (below 0.5 mg/l) results dental caries especially in children and affects the mineralization process of bones and cartilage (22, 25). These group of people especially children may affected by dental caries with chronic exposure.

The chloride ion concentration was decreased irrespective of storage conditions from 7.37 to 4.87 mg/L for non-exposed and from 7.37 to 5.12 mg/L for exposed groups. This finding is agreed with the study conducted in Ghana on two bottled water over three months' exposure time. The study indicated that the chloride concentration was decreased in all storage conditions (refrigerators, normal room temperature and sunlight exposure) even if the reduction was very small (17). This shows that chloride concentration was decreased through time without the effects of storage conditions. The decrement of chloride ion is probably due to the chlorination reaction inside the BW that results formation of toxic by-products such as chloroform and haloacetic acids (45, 46). Whatever the reduction rate happened in bottled water; all bottled water met the maximum permissible (250 mg/L) set by WHO, IBWA and

ECWQS. The main issue here is the formation of toxic substances and results health effect on the consumer even if there are limited studies on this area.

Nitrite ions were not found in all brands of bottled water at zero-day of exposure. The concentration of nitrite was increased with increasing sunlight exposure (from 0.000 mg/l to 0.015 mg/l at 28 days) with a significant difference among non-exposed and exposed group ($p=0.000$). The increment of nitrite in bottled water particularly those BW which have high TDS and nitrate was attributed by sunlight exposure. The increment of nitrite in this study was similar with the study conducted in Nigeria by Chinenye et al (2017) and found that significant difference between exposed and non-exposed group ($p<0.05$) (16). This might be due to the reduction of nitrate into nitrite by sunlight exposure (47).

The concentration of nitrate was decreased slightly with increasing sunlight exposure. Similar trend was reported while studying the effects of storage conditions in four bottled water for two weeks (14, 44). In contrast, another study in Iraq and Nigeria for one month revealed that nitrate was increased with sunlight exposure due to the conversion of organic compounds into inorganic species by photo-degradation (13, 38). No other study has been found to reconcile these two different findings. It is known that methemoglobinemia (blue baby syndrome) happens if the concentration passes the maximum limit (5, 21, 27). But the value was not still beyond the limit. The trend of this study shows that the maximum limit of nitrite may reach if the BW exposed more than a month.

The pH of exposed bottled water was decreased from 7.31 to 7.02 with a significant difference among an exposed and non-exposed group ($p=0.000$). Similar trend were obtained in studies conducted in Iraq, Ghana, and Nigeria (11, 13, 14, 16-18, 38, 48). However, Akharamé et al (2018) and Obiskie et al (2016) were investigated that the pH value decreased below the standards (11, 18). The reasons for the difference probably due to variation in the length of sunlight exposure, way of exposing bottled water and strength of sunlight intensity of the countries. The formation of genotoxic compounds such as terephthalic acid and haloacetic acid by sunlight exposure (45, 46, 49) and conversion of nitrate, chloride and fluoride into acids (44) might be the reason for the decrement of pH.

The level of turbidity was increased as sunlight exposure increased with a maximum increment observed at three weeks of exposure. The sunshine intensity and sunshine hour was decreased for 14 days of exposure and after that it increased gradually up to 28 days. Hence

the reason of increment of turbidity at 21 and 28 days of exposure might be related to this phenomenon. This study is similar with the study conducted on four week exposure in Nigeria and for 20 days exposure in Kirkuk, Iraq (16, 37). In contrast, Duwiejuah et al (2013) was obtained that storage conditions (refrigerator or sunlight) had no effect on the level of turbidity (17). The difference might be due to variation way of exposing bottled water samples.

Although the turbidity level of both exposed and non-exposed group of BW of this study was within the recommended limit of WHO and ECWQS (<5NTU), the exposed groups were beyond the IBWA standards (<0.5 NTU). The recent studies indicate that there is a probability of increasing the concentration of turbidity due to the existence of micro-plastics in bottled water. The caps of bottled water made of polypropylene (PP) and PET bottles of phthalate might be the sources of micro-plastics due to storage conditions (28). Micro-plastics are currently the concern of most of the expert and have numerous health effects on the health of human being and the environment (28, 29). Since the sample of bottles of this study made of PET and the caps made of PP, the reason of turbidity increment probably due to degradation of bottles materials by sunlight exposure.

The level of total hardness, calcium and magnesium were slightly decreased irrespective of the storage conditions and no significant difference was observed among exposed and non-exposed groups. A similar finding was obtained in Ghana and they investigated that there was no significant difference among storage conditions (at room, sun and refrigerator) on the level total hardness, calcium and magnesium supported our finding (17). In contrast, the study conducted in Iraq showed an increment of these parameters with increasing sunlight exposure because of the leaching of metals (14). The difference might be probably due to the variation of the water container. Like that of other ions and values, the level of total hardness, calcium and magnesium ions was within the recommended value of WHO, IBWA and ECWQS. But, hard water containing 150 - 200 mg CaCO₃/L (moderately hard) is essential for normal growth and health in addition to palatability to water (17).

7. Conclusion and Recommendations

7.1. Conclusion

The effect of sunlight exposure was mainly observed in four parameters of bottled water namely pH, fluoride, nitrite and turbidity with significant difference between the mean value of non-exposed and exposed groups of BW. The values of physicochemical parameters of exposed bottled waters were still within standards except for fluoride and turbidity (IBWA standards only). However, decrement of fluoride concentration and the increment of turbidity level may result health effect on consumer who drink bottled water consistently for long time. Generally, the consumption of bottled water has been increasing for various reasons mainly its safety and potential health benefits. Due to these children, elders and ill persons mostly use bottled water for drinking purposes which are susceptible to diseases and other health effects. Hence, protecting bottled water from long time direct sunlight exposure has to be given attention to be on the safe side.

7.2. Recommendations

This research paper is mainly focused on assessing the effects of direct sunlight exposure on the physicochemical parameters of bottled water. The findings of the study help the regulatory bodies that work on inspection and quality control like food and drug administration (FDA) to set standards on handling and storage of bottled water. Besides, the study gives information to the consumer on the proper storage of plastic bottled water. The study may also use as a reference for academic knowledge and further investigation on the effect of sunlight exposure on bottled water and its health concerns on a human being. In general, the following recommendations are provided based on this study.

- ❖ The bottled water should regularly checked by the company and the regulatory bodies to ensure the compliance with the labelled parameters.
- ❖ Though the effects of sunlight exposure didn't exceed most of the permissible limit, BW never exposed to direct sunlight for prolonged time.
- ❖ The bottled water companies should practice fluoridation method to maintain fluoride level in the acceptable range.
- ❖ The physicochemical parameters of exposed bottled waters should be analyzed based on not only the guideline value but also the exposure status and its possibility for the formation of other toxic substances.

8. Strength and Limitation of the Study

8.1. Strength

The experimental study was conducted on accredited national laboratory of Ethiopian Public Health Institute (EPHI). The experimental analysis of the study was done by following the Standard procedures of American Public Health Association (APHA). For each experimental group, there was control group which enhance the quality of the study.

8.2. Limitations

In this study, the samples of bottled water were limited in place (around Addis Ababa) due to financial constraints and the ability to perform the task. The thickness of the plastic bottles was not characterized. The result of this study is not well discussed due to limited research on this area.

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Annexes

Annex I: Procedures for Determination of Physicochemical Parameters of Water

I. pH : using pH meter

1. Calibrate the pH meter with standard buffer solutions before actual measurement is done
2. Rinse the electrode with distilled water and dry with Kim-wipes
3. Take sample
4. Immerse pH electrode tip and temperature probe approximately 4 cm into the solution to be tested and wait until stable result displayed.
5. Record the result and report as it is.

II. Turbidity: Using turbidity meter

1. Calibrate the instrument using known turbid solution(0.2, 20, 200, 800 NTU)
2. Rinse out the clean vial with the sample to be tested.
3. Take water sample (before filtration)
4. Measure the turbidity value and report the value as it is using the unit NTU

III. Electrical Conductivity (EC): using conductivity meter

1. Calibrate (adjust) the instrument (conductivity meter)
2. Take sample water (before filtration) and measure EC
3. Adjust the Conductivity meter at EC
4. Rinse the electrode with distilled water and make it dry with Kim-wipes
5. Immerse the electrode in to the sample
6. Wait few time to take stable result
7. Record the result and report the result

IV. Total dissolved solids (TDS):

Use conductivity meter by adjusting at TDS measurement.

V. Hardness: Using EDTA titrimetric method

1. Take measured amount of sample (25 ml)
2. Add 2ml of ammonium buffer solution
3. Add EBT(Eriochrome Black T) indicator
4. Titrate with 0.01N EDTA until colour changes to blue

Calculation:

EDTA (total) hardness as mg CaCO₃/L == (A*B* C*1000)/ml of sample

Where:

- A-ml of titrant for sample (ml of EDTA used for titration)
- B-concentration of EDTA
- C-molecular weight of calcium carbonate, 100

VI. Calcium, Ca²⁺: EDTA titrimetric method

1. Take measured amount of sample (25 ml)
2. Add 1.5 ml 1N NaOH (buffer) to increase the PH to 12 to 13
3. Add Ca²⁺ indicator (Eriochrome Blue T)
4. Titrate with 0.01N EDTA
5. Record the volume of EDTA consumed
6. Calculate the value of Calcium by using the following formula

Calculation:

$$\text{mg Ca}^{2+} / \text{L} = (\text{A} * \text{B} * \text{C} * 1000) / \text{ml of sample}$$

Where:

- A-ml of titrant for sample (ml of EDTA used for titration)
- B-concentration of EDTA
- C-molecular weight of calcium, 40.08

VII. Magnesium Mg²⁺:

The concentration of magnesium is calculated from the total hardness and the Calcium value as follows:

Calculation:

$$\text{mg Mg}^{2+} / \text{L} = ((\text{H}-\text{A}) * \text{B} * \text{C} * 1000) / \text{ml of sample}$$

Where:

- H- ml of titrant for total hardness (ml of EDTA used for hardness)
- A-ml of titrant for calcium (ml of EDTA used for calcium)
- B-concentration of EDTA
- C-molecular weight of magnesium, 24.32

VIII. Chloride: using Argentometric method

1. Take measured amount of sample and blank (25 ml)
2. Add 5 drops potassium chromate (K_2CrO_4) indicator
3. Titrate both with 0.0141N $AgNO_3$ until the color changes from pinkish to light red /brown
4. Record the volume of silver nitrate consumed during titration
5. Calculate the concentration of chloride using the following formula

Calculation:

$$\text{mg/L(Cl}^-) = [(A-B)*C*Eq*1000)]/\text{ml of sample}$$

Where:

- A-volume of $AgNO_3$, ml, for the sample
- B-volume of $AgNO_3$, ml, for the blank
- C-normality of $AgNO_3$, 0.0141N
- Eq-equivalent weight of Cl^- , 35.45

IX. Fluoride: Using ion selective electrode method

1. Calibrate the electrode using 4 point calibration standards (fluoride concentration of 0.1, 1.0, 10 and 100mg/L) starting from low to high concentration.
2. Measure 5ml sample
3. Add 5ml TISAB solution to obtain a pH of 5.2-5.4 which is the optimal pH range for fluoride determination
4. Mix the sample water and the TISAB solution slowly
5. Rinse the electrode with distilled water and plot dry before each experiments
6. Immerse the electrode to the solution and wait until stable result displayed on the screen
7. Record the value

X. Nitrogen (Nitrite, NO_2^-): using colorimetric method

1. Calibrate the UV spectrophotometer using standard solution and make calibration curve
2. Take measured amount of water sample (50 ml) and blank sample (50 ml)
3. Add 2ml of colour reagent
4. Read the absorbance of blank sample using UV-spectrophotometer and make it out of zero.

5. Then read the absorbance of the water sample consecutively at 540 nm, between 10 minute to 2 hours
6. Calculate the concentration of nitrite using the absorbance and the calibration curve.

Calculation:

$$\text{mg/L (NO}_2^-) = (A*3.29)/(\text{ml of sample*slope})$$

Where: $3.29 = \text{wt. NO}_2^- / \text{wt. N} = (14+32)/14$

XI. Nitrate NO₃⁻ : Using UV spectrophotometry

1. Calibrate the UV spectrophotometer using standard solution and make calibration curve
2. Take 50 ml of filtered sample water and 50 ml blank(Distilled water)
3. Add 1 ml of 1N HCl to each sample and blank
4. Read the absorbance of blank sample using UV-spectrophotometer and make it out of zero.
5. Then read the absorbance of the water sample consecutively at 220 nm
6. Calculate the concentration of nitrite using the absorbance and the calibration curve.

Calculation:

$$\text{mg/L (NO}_3^-) = (A*4.43)/(\text{ml of sample*slope})$$

Where: $4.43 = \text{wt. NO}_3^- / \text{wt. N} = (14+48)/14$

XII. Sodium, Na⁺: using flame emission photometric method

1. Open the air compressor and adjust the gauge at 10 lb/in²
2. Open the gas cylinder and ignite and adjust the flame
3. Arrange the slide and wait until it warm
4. Calibrate the flame photometer with 7.75 mg/L NaCl at 90 and distilled water at 0
5. Take water sample and measure the read with frequent checking using distilled water

Calculation:

$$\text{mg Na}^+/\text{L} = A*DF*0.034$$

Where: A =instrument reading and DF=dilution factor

XIII. Potassium, K⁺: using flame emission photometric method: the same as sodium except:

1. Open the air compressor and adjust the gauge at 10 lb/in²
2. Open the gas cylinder and ignite and adjust the flame
3. Arrange the slide and wait until it warm
4. Calibrate the flame photometer with 6 mg/L KCl at 100 and distilled water at 0
5. Take water sample and measure the read with frequent checking using distilled water

Calculation:

$$\text{mg/L (K}^{\text{+}}\text{)} = A * DF * 0.033$$

Where: A =instrument reading and DF=dilution factor

Annex II. Standard Operating Procedures for Exposing Bottled Water

1. Collect the sample bottled water from the factory directly before sunlight exposure
2. Group into experimental and control group
3. Place the control sample inside the office at room temperature
4. Place the experimental bottled water sample in a proper place. i.e make sure that there is no obstruction of sunlight by buildings or any trees and secure the place
5. Expose the bottled water from 8:00 am to 5:00 pm
6. After 5:00 pm, the experimental group was brought to secured place in order to prevent any damage at night and at the morning it brought back to the place
7. Every week the experimental and control group were analysed

Annex III. Questionnaire for Bottled Water Company

Effects of sunlight exposure on physicochemical parameters of Bottled water in Addis Ababa
Ethiopia

Code No: _____

Dear Respondents!

This short questionnaire is intended to gather facts with regard to plastic bottles constituents and manufacturing process so as to study the effect of sunlight exposure on the physicochemical parameters of bottled water. Your genuine response to the scientific inquiry will help to draw valid conclusions that will in turn help concerned bodies like Food and Drug Administration (FDA) to incorporate handling and storage practices in their guidelines. Therefore, the researcher kindly requests your response's impartiality and kind cooperation to respond to the questions fully. I will assure you that your responses will not be disclosed by the organization's name and survey responses will be reported with codes. If you have question, you can ask at any time. If you are not comfortable due to the questions you can pass or totally you can stop.

Thank you in advance for your cooperation!

Plastic bottles constituents and Exposure status

1. The type of water you are packaging? a. Purified water b. Natural Water
2. The type of plastic bottles used (made of)
 - a. Polyethylene Terephthalate/PET/
 - b. High Density Polyethylene/HDPE/
 - c. Polyvinyl chloride/PVC/
 - d. Low Density Polyethylene/LDPE/
 - e. Polypropylene/PP/
 - f. Polystyrene/PS/
 - g. Others _____

3. The caps of the plastic bottles made of
 - a. Polyethylene Terephthalate/PET/
 - b. High Density Polyethylene/HDPE/
 - c. Polyvinyl chloride/PVC/
 - d. Low Density Polyethylene/LDPE/
 - e. Polypropylene/PP/
 - f. Polystyrene/PS/
 - g. Others _____
4. The thickness of the plastic bottle (If it is known) -----mm
5. Are the plastic bottles exposed to sunlight before water filling?
 - a. Yes
 - b. No
6. Are the plastic bottles exposed to high temperature (above 40 °C) before water filling?
 - a. Yes
 - b. No
7. Is there precaution “don’t exposed to direct sunlight” on the label of your bottled water (Observation) a. Yes b. No
8. Do you use recycled plastic bottles?
 - a. Yes
 - b. No

Annex IV. Information Sheet and Consent form

My name is Yibeyin Muluaem. I am a student at Addis Ababa University, college of Health science, school of public health, in Addis Ababa, Ethiopia. I am conducting a research in partial fulfilment of the requirements for masters of public Health.

Research title: Assessing the effect of sunlight exposure on physicochemical parameters of bottled water in Addis Ababa, Ethiopia

The objective of this experimental study: To assess the effect of direct sunlight exposure on selected physicochemical parameters of bottled water in Addis Ababa Ethiopia.

Participation: The bottle water companies are selected based on the preference of the consumers and their TDS level. The company was participated in voluntary basis and may refuse to give sample of bottle water.

Sample taking process: After obtaining their informed consent, enough sample of bottled water was taken from the factory.

Benefit and Possible discomfort: Giving sample to this research does not cause any harm to the company. Probably the finding may help to protect the bottled water from sunlight exposure if the regulatory body act up on it. This perhaps increase the palatability of water

Confidentiality and privacy protection: To ensure confidentiality and protect the company, the bottled water sample will kept in a secured place; the labelling was removed and was coded with number. The data was accessible only to the researcher.

Disseminating research report: The final research finding is submitted to the School of public health, Addis Ababa University. The study results may be presented in the seminars and conferences and published in academic journals.

Confirmation: If you are willing to participate in this study based on what you read in the above, please sign two copies of this informed consent form and return one copy to the researcher and keep the other copy with you.

Participant's Name _____ Signature _____ Date _____

Researcher's Name _____ Signature _____ Date _____

Thank you for your willingness to participate in this study and give a sample!

አባሪ : የመረጃ ቅጽ እና የፍቃድኝነት መጠየቂያ ፎርም (አማርኛ ቅጽ)

ስሜ ይበይን ሙሉዓለም ይባላል :: በአዲስ አበባ ዩኒቨርሲቲ ጤና ሳይንስ ኮሌጅ የህብረተሰብ ጤና ትምህርት ክፍል የሁለተኛ ዲግሪ ተማሪ ነኝ :: የመመረቂያ ምርምር ጽሁፍ እየሰራሁ እገኛለሁ::

የጥናቱ ርዕስ: የታሸጉ የፕላስቲክ ውሃዎች በጸሀይ ብርሃን መጋለጥ በውሃው ፊደሮች ኬሚካል መለኪያዎች ላይ የሚያደርሰው ተጽዕኖ በአዲስ አበባ ኢትዮጵያ የሚል ነው::

የጥናቱ አላማ: የታሸጉ የፕላስቲክ ውሃዎች በጸሀይ ብርሃን መጋለጥ በውሃው ፊደሮች ኬሚካል መለኪያዎች ላይ የሚያደርሰው ተጽዕኖ መዳሰስ ነው ::

ተሳትፎ: በጥናቱ የሚሳተፉ የውሃ አምራች ድርጅቶች የተመረጡት ባላቸው የቲዲኤስ መጠን በሁለት ምድብ ከተከፈሉ በኋላ ዕጣ በማውጣት ነው:: ድርጅቶቹ የሚሳተፉት በፈቃድኝነት ሲሆን በማንኛውም ጊዜ ናሙና አለመስጠት ይችላሉ::

የናሙና አውሳሰድ ሂደት: ከድርጅቱ ፍቃድ ከተገኘ በኋላ በቂ የውሃ ናሙና ይወሰዳል ::

የጥናቱ ጥምና ጉዳቱ : ለዚህ ጥናት የውሃ ናሙና መስጠት ምንም ዓይነት ጉዳት የሌለው ሲሆን ጥናቱ ምናልባትም የፕላስቲክ ውሃዎችን ከጸሀይ ብርሃን ለመከላከል ሊያግዝ ይችላል ተቆጣጣሪ መስሪያ ቤቱ የሚጠቀምበት ከሆነ :: ይህም የውሃውን ጣዕም የመጠጣት ደረጃውን ይጨምራል ::

ሚስጥራዊነት መጠበቅ : የውሃ ናሙናዎች ከተሰበሰቡ በኋላ በጥንቃቄ ይቆይባሉ :: ሚስጥራዊነታቸውን ለመጠበቅ ስማቸው በኮድ ይቀየራል:: የላብራቶሪ ውጤቶች ተመራማሪው ብቻ አእንዲይዛቸው ይደረጋል ::

ግኝቱን ስለማሳወቅ : የጥናቱ ውጤት ለአዲስ አበባ ዩኒቨርሲቲ ጤና ሳይንስ ኮሌጅ ሪፖርት ይደረጋል :: አስፈላጊ ሆኖ ከተገኘ በተለያዩ አውድ ጥናቶች ሊቀርብ ይችላል ::

ማረጋገጫ: ከላይ በተጠቀሱት ጉዳዮች ከተሰማሙ በሚቅጥለው ላይ ስሞትንና ፊርማዎን ያስቅምጡ :: አንዱን ኮፒ ለራስዎ ይውሰዱ ::

የተሳታፊ ስም : ----- ፊርማ ----- ቀን -----

የመረጃ ሰብሳቢ ስም : ----- ፊርማ ----- ቀን -----

በጥናቱ ስለተሳተፉ እና ናሙና ስለሰጡን በጣም አመሰግናለሁ !!!!!!!!

Annex V. Result of the effect of sunlight exposure on physiochemical parameters of BW

Table 1: Effects of sunlight exposure on EC of bottled waters

Exposure		0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	12.01	12.12	11.94	11.02	10.78	1.23	10.25
	E		11.00	11.31	10.77	11.68	0.32	2.71
BW2	C	50.15	49.10	48.70	49.35	49.05	1.10	2.19
	E		49.25	49.90	49.55	49.60	0.55	1.10
BW3	C	149.70	150.00	150.60	150.50	147.50	2.20	1.47
	E		150.50	152.25	151.30	150.75	-1.05	-0.70
BW4	C	253.00	254.00	253.50	257.00	247.00	6.00	2.37
	E		253.50	256.00	256.50	253.50	-0.50	-0.20
Mean	C	116.21	116.31	116.18	116.97	113.58	2.63	2.27
	E		116.06	117.37	117.03	116.38	-0.17	-0.15
SD	C	108.10	108.73	108.72	110.35	105.96	2.30	4.14
	E		108.90	109.90	110.26	108.64	0.74	1.52

C= Control (non-exposed) E= Experimental (Exposed)

Table 2: Effects of sunlight exposure on TDS of bottled waters

BW Brands		0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	7.12	7.21	7.45	7.26	7.07	-0.36	-4.99
	E		7.22	7.56	7.00	7.71	-0.60	-8.36
BW2	C	33.15	35.25	35.20	35.65	35.95	-2.80	-8.45
	E		35.45	35.55	35.75	35.25	-2.10	-6.33
BW3	C	107.50	109.00	109.50	111.00	109.50	-2.00	-1.86
	E		110.50	112.50	112.00	111.00	-3.50	-3.26
BW4	C	183.50	186.00	185.50	191.00	182.50	1.00	0.54
	E		188.50	188.00	189.00	187.00	-3.50	-1.91
Mean	C	82.82	84.37	84.41	86.23	83.86	-1.04	-1.25
	E		85.42	85.90	85.94	85.24	-2.42	-2.93
SD	C	79.46	80.21	79.99	82.43	78.57	1.76	4.27
	E		81.38	81.25	81.75	80.68	1.39	2.93

C= Control (Non-exposed) E= Experimental (Exposed)

Table 3: Effects of sunlight exposure on Fluoride ion concentration of bottled waters

BW Brands	Group	0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	0.11	0.10	0.10	0.11	0.10	0.02	13.64
	E		0.08	0.08	0.07	0.07	0.05	40.91
BW2	C	0.10	0.12	0.12	0.09	0.11	-0.01	-10.53
	E		0.09	0.08	0.08	0.08	0.02	15.79
BW3	C	0.22	0.20	0.20	0.19	0.21	0.01	4.55
	E		0.18	0.18	0.17	0.16	0.06	27.27
BW4	C	0.37	0.37	0.37	0.32	0.32	0.05	13.70
	E		0.29	0.31	0.30	0.31	0.06	15.07
Mean	C	0.20	0.20	0.20	0.18	0.18	0.02	8.23
	E		0.16	0.16	0.15	0.15	0.04	22.15
SD	C	0.12	0.12	0.12	0.11	0.10	0.02	11.42
	E		0.10	0.11	0.11	0.11	0.02	12.13

C= Control (Non-exposed) E= Experimental (Exposed)

Table 4: Effects of sunlight exposure on the pH level of bottled waters

Exposure		0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	7.72	7.71	7.71	7.51	7.58	0.15	1.88
	E		7.66	7.42	7.40	7.37	0.35	4.53
BW2	C	6.99	7.05	7.07	7.02	6.79	0.20	2.86
	E		6.89	6.82	6.87	6.70	0.30	4.22
BW3	C	7.15	7.31	7.33	7.09	7.34	-0.20	-2.73
	E		7.11	7.02	6.88	6.87	0.28	3.92
BW4	C	7.38	7.45	7.51	7.17	7.35	0.03	0.41
	E		7.43	7.35	7.11	7.14	0.24	3.25
Mean	C	7.31	7.38	7.40	7.19	7.26	0.05	0.62
	E		7.27	7.15	7.06	7.02	0.29	3.99
SD	C	0.32	0.28	0.27	0.22	0.33	-0.02	-5.13
	E		0.34	0.28	0.25	0.30	0.02	6.26

Table 5: Effects of sunlight exposure on chloride ion concentration of bottled waters

Exposure		0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	6.00	3.50	3.00	0.00	0.00	6.00	100.00
	E		3.00	2.80	0.00	0.00	6.00	100.00
BW2	C	4.00	3.00	2.00	0.00	0.00	4.00	100.00
	E		2.00	2.00	0.00	0.00	4.00	100.00
BW3	C	10.00	7.00	8.00	6.00	4.00	6.00	60.00
	E		8.00	8.00	6.00	4.00	6.00	60.00
BW4	C	9.50	8.00	9.00	7.00	6.00	3.50	36.84
	E		8.50	8.00	8.00	5.00	4.50	47.37
Mean	C	7.37	5.37	5.50	3.25	2.50	4.87	66.10
	E		5.37	5.20	3.50	2.25	5.12	69.49
SD	C	2.87	2.50	3.51	3.77	3.00	1.31	31.24
	E		3.35	3.25	4.12	2.63	1.03	27.23

C= Control (Non-exposed) E= Experimental (Exposed)

Table 6: Effects of sunlight exposure on the concentration of nitrite

Exposure		0 day	7 days	14 days	21 days	28 days	Difference	%
BW1	C	0.000	0.000	0.000	0.000	0.000	0.000	
	E		0.000	0.000	0.002	0.002	-0.002	
BW2	C	0.000	0.000	0.000	0.000	0.000	0.000	
	E		0.004	0.004	0.003	0.003	-0.003	
BW3	C	0.000	0.000	0.000	0.000	0.000	0.000	
	E		0.021	0.019	0.025	0.025	-0.025	
BW4	C	0.000	0.001	0.001	0.000	0.000	0.000	
	E		0.018	0.023	0.024	0.029	-0.029	
Mean	C	0.000	0.000	0.000	0.000	0.000	0.000	
	E		0.011	0.011	0.013	0.015	-0.015	
SD	C	0.000	0.001	0.001	0.000	0.000	0.000	
	E		0.010	0.011	0.013	0.014	0.014	

Table 7: Effects of sunlight exposure on the total hardness level of Bottled water

BW Brand	Group	0 day	7 days	14 days	21 days	28 days	Difference (Before-After)	%
BW1	C	4.00	4.00	8.00	2.00	4.00	0.00	0.00
	E		6.00	8.00	2.00	4.00	0.00	0.00
BW2	C	18.00	16.00	18.00	20.00	16.00	2.00	11.11
	E		16.00	18.00	16.00	18.00	0.00	0.00
BW3	C	78.00	80.00	78.00	68.00	76.00	2.00	2.56
	E		78.00	78.00	72.00	76.00	2.00	2.56
BW4	C	8.00	8.00	8.00	4.00	4.00	4.00	50.00
	E		8.00	8.00	2.00	4.00	4.00	50.00
Mean	C	27.00	27.00	28.00	23.50	25.00	2.00	7.41
	E		27.00	28.00	23.00	25.50	1.50	5.56
SD	C	34.51	35.68	33.67	30.74	34.47	1.63	23.21
	E		34.27	33.67	33.33	34.31	1.91	24.60

Table 8: Effects of sunlight exposure on the nitrate level of Bottled water

Exposure		0 day	7 days	14 days	21 days	28 days	Difference	%
BW1	C	0.97	0.92	0.92	0.48	0.50	0.47	48.11
	E		1.01	0.92	0.72	0.51	0.46	47.17
BW2	C	1.56	1.63	1.56	1.12	1.01	0.55	35.29
	E		1.46	1.37	1.09	0.87	0.69	44.12
BW3	C	8.42	8.47	8.33	8.11	8.35	0.07	0.87
	E		8.70	7.43	8.11	8.09	0.33	3.91
BW4	C	4.85	4.96	4.67	5.05	4.58	0.27	5.66
	E		5.17	3.94	4.56	4.59	0.26	5.28
Mean	C	3.95	4.00	3.87	3.69	3.61	0.34	8.63
	E		4.08	3.41	3.62	3.52	0.43	10.95
SD	C	3.44	3.46	3.40	3.57	3.64	0.21	22.89
	E		3.60	2.99	3.46	3.56	0.19	23.74

Annex VI: Metrological Data of the Study Period and the year 2020

Table 8: Sunshine hour, Sunlight Intensity and Temperature of the study period (October 3-30/2020)

Date	Sunshine hour per day (hr)	Sunlight Intensity (W/M2)	Air Temperature (°C)
3	3.2	154.7	17.75
4	6.5	204.5	16.0
5	9.0	240.9	17.0
6	6.3	198.1	16.75
7	8.3	244.9	17.35
8	7.2	197.1	18.3
9	8.0	222.1	17.8
10	4.0	131.2	18.05
11	5.6	197.8	16.9
12	5.4	197.1	17.25
13	5.5	209.0	17.9
14	2.0	180.8	18.5
15	6.3	166.0	17.8
16	5.4	148.0	18.25
17	2.0	136.9	18.5
18	5.5	147.2	19.05
19	8.0	206.2	18.0
20	5.5	169.7	18.6
21	10.5	211.2	18.3
22	10.5	221.6	17.67
23	10.2	220.6	18.05
24	6.8	190.0	18.5
25	10.5	222.2	17.8
26	10.4	225.8	18
27	10.4	226.0	17.35
28	10.3	222.7	17
29	10.7	222.5	17.5
30	10.2	220.1	17.1

Table 9: Monthly Sunshine hour, Sunlight Intensity and Temperature of one year (From October 2019-October 2020)

Month	Sunshine hour per day (hr)	Sunlight Intensity (W/M2)	Air Temperature (°C)
November 2019	NI	177.21	NI
December 2019	NI	170.93	NI
January 2020	8.82	171.10	17.75
February 2020	8.52	184.91	18.81
March 2020	10.26	203.70	20.48
April 2020	6.86	NI	19.88
May 2020	6.60	NI	19.63
June 2020	4.50	139.45	17.93
July2020	2.16	110.04	16.34
August 2020	0.60	122.62	18.02
September 2020	3.89	145.86	17.32
October 2020	7.06	193.83	17.71

Where NI=Not Indicated

Annex VII. List of Bottled Water Company/Brands

Table 10: List of Bottled water brands found in Addis Ababa and Oromia special zone of oromia region, November 2019

S.No	Name of bottled water barnds	Place found	TDS
1	Daily	Menagesha	8.43
2	Gold	Tatek	8.50
3	Yes	Alemgena	10.00
4	Top	Burayu	10.00
5	Kiya	Bishoftu	10.00
6	Today	Sululta	12.00
7	Sheger	sebeta	20.00
8	Ava	Burayu	20.00
9	Agmas	Ayer tena	21.40
10	Aqua addis	Burayu	21.00
11	Konjo	Menagesha	23.00
12	One	Sebeta	30.00
13	Pacific	Menagesha	50.00
14	Gift	Sululta	50.00
15	Care	Sebeta	56.00
16	Hiwot	Alemgena	134.00
17	Classy	Sululta	144.00
18	Abyssiniya	Sululta	149.00
19	Prima	Akaki	150.00
20	Arki	Sululta	150.00
21	Fham	Tatek/Gefersa	155.00
22	Origin	Alemgena	155.00
23	Unique	Alemgena	160.00

Annex VIII: Photographic Images of Sunlight Exposure and Experimental Analysis



Figure 1: The place where the bottled water exposed to sunlight (Pointed by red arrow)



Figure 2: Bottled water exposed to direct sunlight-Exposed Group



Figure 3: Experimental analysis of Argentometric titration method - Chloride



Figure 4: Experimental analysis using turbidity meter-Turbidity

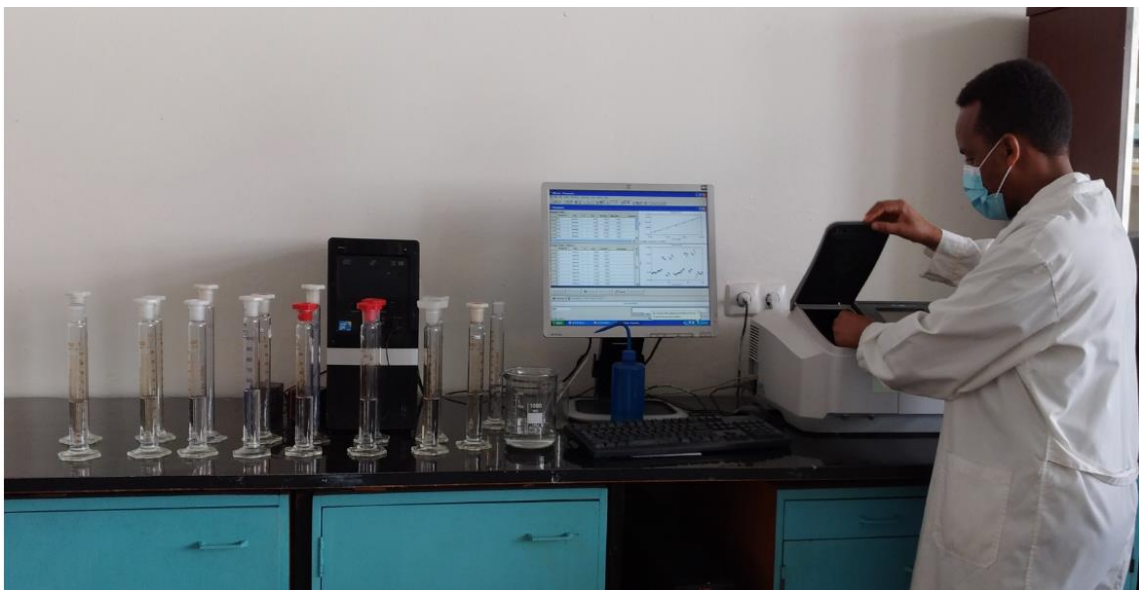


Figure 5: UV- Spectrophotometry for Nitrate and Nitrite measurement



Fig 6: Experimental analysis- Hardness



Fig 7: Experimental analysis-TDS and EC

CURRICULUM VITAE/CV/

1. PERSONAL PROFILE

Full Name	Yibeyin Mulualem Melis
Sex	Male
Date of birth	06 June 1988
Nationality	Ethiopian

2. EDUCATION

-
- Masters of degree in Environmental Engineering from AASTU in 2018.
 - Bachelor degree in Environmental Health from Jimma University in 2008
-

3. LANGUAGE

- Amharic and English: Fluent in Speaking, Writing and Listening

4. EXPERIENCE

I do have 10 years work experience on different areas and positions.

- Public health emergency management Officer at Ethiopian Public Health Institute (EPHI) from November
- Hygiene and sanitation promotion officer at Akaki Kality sub-city health office, Addis Ababa city Administration
- Head of Health Center and EHO officer at Amber health center, East Gojjam Zone, Amhara region
- Health extension programme coordinator at E/Enawiga WHO, Amhara region.

5. Publications

- Adsorption of fluoride from aqueous solution and ground water onto activated avocado seed carbon.
- Assessment of Water, Sanitation and Hygiene status of Selected Investment sites in Ethiopia relation to cholera outbreak, 2020. Technical Report-on progress

6. Training

- I have taken different training on WASH, Nutrition, MCH, Data collection etc.

7. Awards

- Certificate of recognition for the service provided as National Cholera Response Team member in Emergency Operating Center at Ethiopian Public Health Institute, 2019

Certificate

This is to certify that the thesis prepared by **Mr. Yibeyin Mulualem Melis** entitled **“Assessing the effect of sunlight exposure on physicochemical parameters of Bottled water in Addis Ababa, Ethiopia”** and submitted in fulfilment of the requirements for the degree of master of public health complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by Examining Board:

External Examiner:

Name: _____

Signature: _____ Date: _____

Internal Examiner:

Name: _____

Signature: _____ Date: _____

Thesis Primary Advisor:

Name: _____

Signature: _____ Date: _____

Declaration

I the undersigned declare that this is my original work and has not been presented in this or any other Universities and all sources of materials used for the thesis have been fully acknowledged.

Name of principal investigator: YIBEYIN MULUALEM MELIS

Signature _____ Date. _____

Place: Addis Ababa University College of Health Science School of Public Health
Department of General Masters of Public Health

Advisor: ABERA KUMIE (Associate Prof.)