A METHOD OF MINIMIZING THE PROLIFERATION OF ALGAE/CYANOBACTERIA SPECIES ON CLAY BRICKS

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Declaration

I Khethani Muditambi Bronie, declare that this dissertation is my own hard work and has not been submitted for any degree at this university or any other institution. The proposal does not contain another's writing, except where otherwise acknowledged and referenced accordingly.

Student's Signature: …… Date: 08/09/2023……

Dedication

I would like to dedicate this work to God almighty for all his blessing and mercy upon me. I also dedicate this work to my late uncle Prince Tshianeo Khethani, my mother Queen Khethani, my father Levy Phuravhathu, my twin sister Thakhani Khethani, my fiancé Madonsela Prince, my late son Madonsela Munakisi Dylan, my late grandmother Khethani Agnes, my grandmother Christinah Mahanya, my grandmother Tshifure Elizabeth and my grandfather Patrick Tshifure who always support and believed in me.

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ABSTRACT

The presence of Algae/Cyanobacteria in different environments such as water and or hard surfaces (brick pavements) is unwelcome due to either secretion of cyanotoxins and or mucilage. These secretions may be harmful to humans. The main purpose of this study was to develop a formula for making clay bricks incorporating banana matrix and coal powder. The objective of this study was to review the state of knowledge in terms of control of algae/cyanobacteria in general and clay, coal, and banana chemical composition, controlling the algae/cyanobacteria growth using modified clay bricks. The bricks' physical properties were examined, including water absorption, compressive strength, color, impact, efflorescence, dimensional stability, tolerance, and wrappage tests. Banana peels (*Musa sapientum*) were gathered from farms and markets, dried by the sun, pounded in a pestle and mortar, and sieved through (<2 mm) before being subjected to analysis. A jaw crusher, milling machine, oven, CBR, weighing balance, spectrophotometer, and ICP-OES were utilized. A small metal brick-box frame, a hand mixing machine, and a measured water jug were used when building clay bricks. Modified bricks were made of clay soil, coal powder, and banana powder, in different composition). The modified clay bricks were then submerged in BG 11 liquid media with growing algae/cyanobacteria suspension for a period of 90 days. The samples' pH, temperature, total dissolved solids, electrical conductivity, and absorbance levels were all measured. The single factor ANOVA showed a significant difference between the treated samples B1, B2, B3, B4, B5, B6, and B7 and the control from day 1 through month 3. The p-values for this difference from day 1 through month 3 were 0.017, 0.007, 0.011, 0.007, 0.009, 0.001, 0.003, 0.001, 0.015, 0.015, and 0.001 The single-factor ANOVA found a significant difference between the treated samples CB1, CB2, CB3, CB4, CB5, CB6, and CB7. The p-value was $p<5$ from day 1 to week 4, 0.005 to 0.003, 0.005 to 0.003414, 0.004 to 0.002, 0.011 to 0.017, and 0.012 to 0.007. There was no significant difference in coal in 1 and 2 months. It was found that the absorbance on the untreated and control samples was not inhibiting the algae. It continued to develop. The untreated samples C1, C2, C3, C4, C5, C6, and C7 significantly differed, according to the single factor ANOVA. The p-value was $p<5$ and within the 95% confidence range from day 1 to month 3, and it was 0.011, 0.004, 0.006, 0.003, 0.023, 0.018, 0.004, 0.003, 0.006, 0.004, and 0.004. According to this study, using banana peel powder effectively inhibited algae and cyanobacterial species from growing on clay bricks. The outcomes also demonstrated that using coal + banana powder effectively inhibited cyanobacteria. Based on the findings, banana powder has been shown to have a high potassium content, which is

supported by ICP-OES results.

Additionally, modified clay (banana) bricks were analysed and were found to have a higher potassium concentration than other bricks when compared to other metals (Ni, Na, and Mn). Overall the modified clay bricks with banana biomass displayed excellent characteristics in inhibiting blue-green algae/cyanobacteria. They may be applied to an environment where the blue- green algae/cyanobacteria are proliferating to reduce or eliminate its harmful algal bloom.

Key words: Algae/Cyanobacteria, Clay bricks, Banana biomass, Coal, Potassium

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List of Abbreviations

Abs	Absorbance
DO	Total Dissolved Oxygen
EC	Electrical Conductivity
TDS	Total Dissolved Oxygen
Mg	Milligram
Km	Kilometre
Cm	Centimeters
ICP-OES	Inductive coupled plasma optical emission spectroscopy
Rpm	Revolution per minute
HABs	Harmful algal blooms

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CHAPTER 1: INTRODUCTION

1.1 Background

The algae are plains of Jane classified in kingdom plantae (Hentati et al., 2015). They do not have petals, stamens, or bark to prevent them from drying out or wood to keep them upright, channelling much more energy than the sun to multiply. They are dozens of times more productive than plants in producing carbohydrates, proteins, vitamins, and oils (Kassinger, 2019). The smallest and oldest are the internally simple single-celled blue-green algae known as cyanobacteria (Baldwin & Whitton, 2016).

Clay bricks owe their colour to the abundant growth of algae, which, during the rainy season, are generated and multiplied rapidly after the onset of the warm season (Fritsch, 2016). The underside of these is usually reddish or brick-coloured, especially when dry. If this reddish material is discarded, it was seen to consist of a number around the cells. Bacteria, single-celled algae, and cyanobacteria (blue-green algae) colonize clay bricks if conditions are suitable (Jayakumar, 2015).

High temperatures and a humid atmosphere are essential for developing a luxurious algae cover. But these two factors do not explain the abundant growth of blue-green algae and the virtual lack of subaerial green forms (Fritsch, 2016). The presence of moisture and nutrients, nitrates and phosphates triggers a proliferation of cyanobacterial growth (Munyai et al., 2019). The latter's absence is due to the operation of a third factor, light. It is known that chlorophyll in plants is broken down by light at certain intensities (Özyiğitoğlu, 2020).

There are several factors involved in the management and death of cyanobacteria. In algae, iron-containing catalysts play an important indirect role in cellular metabolism by regulating enzyme activity, which is essential for the biosynthesis of chlorophyll molecules (Yu et al., 2015). Manganese is used in plants and algae as an important contributor and coenzyme in photosynthesis, respiration, and nitrogen assimilation (Kochian et al., 2017). Copper is another essential cofactor for managing the response to oxidative stress and in coenzymes such as cytochrome oxidases due to its ability to switch between Cu^{2+} and Cu^{+} (Huertas et al., 2014). However, if a high concentration of copper is used as an algaecide, it kills cyanobacteria (Gumbo and Cloete, 2013). Numerous clay bricks in the Limpopo province use different methods to make their clay bricks. Munyai et al. (2019) showed algae colonisation in the brick pavement, resulting in a slippery surface that was

hazardous to users. This study focused on developing a method to minimize algae/cyanobacteria species on clay bricks by modifying the chemical composition of clay material used to make bricks.

1.2 Hypothesis and Research Objectives

1.2.1 Hypothesis

This study will hypothesize that the modified bricks with (banana biomass, coal and clay) will minimize the growth of algae/cyanobacteria levels.

1.2.2 Main objective

The main objective of this research was to develop a method of minimizing algae/cyanobacteria species using modified clay bricks produced in Limpopo, South Africa.

1.2.3 Specific objectives and chapter outline

To review the state of knowledge regarding control of algae/cyanobacteria in general and clay, coal, and banana chemical composition-*Chapter 2.*

- Materials and methods to achieve the specific objectives below-*Chapter 3.*
- To control the algae/cyanobacteria growth using modified clay bricks (with either banana biomass and coal and or with coal and or with banana biomass-*Chapter 4*.
- To investigate the bricks in terms of their physical characteristics (water absorption, compressive strength, colour test, impact test, efflorescence, dimensional test, tolerance test and wrappage test)-*Chapter 5.*
- To analyze the metal content of the modified bricks (with either banana biomass and coal or with coal and or with banana biomass)-*Chapter 6.*

1.3 Research Questions

- How does the coal, banana biomass control the algae/cyanobacteria on modified clay bricks?
- What are the physical characteristics of the modified clays bricks?
- What is the metal content of the modified clays that successfully controlled the algae/cyanobacteria?

1.4 Problem Statement

Algae/cyanobacteria species are dangerous to aquatic life, in human drinking water and on clay bricks when used for paving (Lin, 2018). Clay soil produces clay bricks that people have made with pavements exposed to elements such as rain and sun. The presence of moisture, nutrients, nitrates and phosphates trigger the proliferation of cyanobacterial growth. Clay brick floors become slippery when made up of cyanobacteria species and are dangerous to people walking on, and can cause injury. Clay bricks contain high metals that cause algal colonization (Munyai et al., 2019).

1.5 Research Justification

This research came up with new knowledge minimizing the growth of Algae/cyanobacteria species on clay bricks. Such knowledge helped in improving the current state of technology in brickmaking and will go a long way in assisting the rural communities which are mining clay without knowledge and understanding of appropriate procedures to be followed in order to manufacture clay bricks that does not colonized Algae/cyanobacteria. This research will also be beneficial to the workers, clay mines management and any individual who are involved in clay mining.. Future researchers that are to carry out studies which may be related to this topic can use this research as a guideline.

CHAPTER 2: LITERATURE REVIEW

This chapter critically reviews existing literature on the general overview of the Algae/cyanobacteria. Review current literature on the chemical control of blue-green algae/cyanobacteria. Also, this study will investigate the physical and chemical properties of clay, coal, and banana composition.

Abstract

Clay occurs abundantly in all regions but differs in mineralogical, chemical, and physical properties. Clays used to manufacture bricks include kaolinite, montmorillonite, illite, micas, and chlorites which contain enough calcium carbonate. The clay bricks are also mixed with coal when they are manufactured for them to burn fast.Cyanobacteria are categorized in the group of prokaryotes, which have oxygenic photosynthesis and are amongst the most successful and oldest life forms present on the planet formed in. Cyanobacteria are common in fishponds and other bodies of water, but they only pose a concern when they begin to produce toxins. Cyanobacteria, which affects fish output and water quality. Although some of them have a negative effect on fishponds and water quality, dinoflagellates such *Anabaena, Microcystis aeruginosa, Cylindrospermopsis,* and *Microcystis* have been detected and biological control has been utilized in most countries. Cyanobacteria can injure both humans and animals when come into contact with it, the slippery mucilage produced by the cyanobacteria, *Microcystis*, puts people's lives in risk when it develops on clay brick pavement that people used to walk on every day. It also kills animals when it develops in water because aquatic animals eat it through water plants as food. Humans use both physical and chemical means to control the growth of algae, such as leaking oil to remove surface scums and mopping the floor with a broom and water. Banana peels consist of high potassium, and it helps to inhibit the growth of cyanobacteria. A banana peel's mineral composition consists mostly of potassium (78.10 mg/g) and manganese 76.20 mg/g, sodium (24.30 mg/g), calcium (19.20 mg/g), and iron (0.61 mg/g) are additional minerals that are found if consumed orally, the peel's high potassium concentration.

Keywords: **Cyanobacteria, Human, Clay, Coal and Banana matrix**

2.1 Blue-green algae/cyanobacteria

Blue-green algae or cyanobacteria are either single or multi-cellular organisms that utilize carbon dioxide and water with dissolved with nutrients in the presence of sunlight to carry out photosynthesis process to produce oxygen (Maruyama and Kim, 2020; Blankenship, 2021). Still, some species are harmful to humans and animals, these produce toxins such as *Microcystis* of which they are 180 variants (Blankership, 2021). They produce mucilage which is slippery (Bhattacharya & Price, 2020). Zhanga et al. (2021) explained that *Microcystis* is a cyanobacteria genus that comes in a variety of shapes and sizes.

Microcystis aeruginosa (*M. aeruginosa*) can produce *microcystins* (MCs) that are highly toxic to the human liver. Phosphorus (P) is a standard *M. aeruginosa* growth limiting factor. Though various types and concentrations of P are found in natural water, the molecular responses of *M. aeruginosa* in terms of growth and MC formation are unknown. In a study by Zhanga et al. 2021, *M. aeruginosa* growth was inhibited under low concentrations of dissolved inorganic phosphorus (DIP) of 0.02 mg P/L but promoted by high concentations of DIP (> 0.2 mg P/L). *M. aeruginosa* could not grow in the presence of dissolved organic phosphorus (DOP) at low or high concentrations (Zhanga et al., 2021). When the concentration of extracellular DOP was high, the expression of phosphate transporters decreased, and the ability to transport P decreased, resulting in the inhibition of cell growth (Zhanga et al., 2021). High concentrations of DIP promoted the production of MCs, whereas the concentration of DOP did not affect MCs production. However, part of *M. aeruginosa* died and lysed due to insufficient P uptake at high concentrations of DOP, resulting in a small amount of release of intracellular MCs to the extracellular membrane (Zhanga et al., 2021).

2.2 Human involvement with blue-green algae/cyanobacteria

Humans do eat cyanobacteria such *Spirulina* for thousands of years. In Africa, people in Chad have been consuming *Spirulina* as part of their diet (Ramanan et al. 2016), *Spirulina* can also be accessed through the intake of the tablet, which is excellent alternative food for providing high quality protein, beta-carotene, vitamins, and minerals to human beings. People also use *Spirulina* to manage weight loss through eating and health benefits related to plant-derived proteins and polyunsaturated fatty acids. In contrast, the protein source is cholesterol-free and low in calories (Shao et al., 2019).

Green tides cyanobacteria species are known to produce toxins that affect humans and animals, resulting in their deaths (Roberts et al., 2020). Due to the health threats arising from toxic gasses produced during algae decomposition on the beaches, the consequence of green tides is an excessive richness of nutrient which causes eutrophication. Algae growth occurs when rivers discharged nutrients diffuse with non-living things (Zheng et al., 2021).

Red tides are harmful algal blooms (HABs) due to cyanobacteria called dinoflagellate, it occurs when microscopic algae multiply to higher-than-normal concentrations, often discolouring the water (Ibrahim, 2017). The microscopic algae it produces toxins that kill fish and make shellfish dangerous for human to eat (Jipanin et al., 2019). The toxins may also make the surrounding air difficult to breathe. The bloom of algae often turns the water red. HABs are a national concern because they affect the health of people and marine ecosystems and local and regional economies (Anderson et al., 2015). But not all algal blooms are harmful. Most blooms, in fact, are beneficial because the tiny plants are food for animals in the ocean. In fact, they are the major source of energy that fuels the ocean food web (Glibert, 2021).

2.3 Physical and Chemical control of blue-green algae/cyanobacteria

When harmful algal blooms exist, steps can be made to slow down phytoplankton growth and manage them. The typical physical and chemical remedies for cyanobacterial blooms in surface waters are listed in Table 2.1, with details on how well they work and any potential risks (Ghadage and Karande, 2019).

Table 2.1: The physical and chemical control of blue-green algae.

Physical Control				
Water body management	Description	Effectiveness	Limitations	References
Aeration	Air is pumped through a diffuser towards the bottom of the waterbody by aerators, which causes plumes to emerge that rise to the surface and spread outward to form vertical circulation cells. In addition to reducing the availability of nutrients, this mixing of the water column prevents cyanobacteria from migrating vertically. Air is pumped through a diffuser towards the bottom of the waterbody by aerators, which causes plumes to emerge that rise to the surface and spread outward to form vertical circulation cells. In addition to reducing the availability of nutrients, this mixing of the water column prevents cyanobacteria from migrating vertically.	successfully applied to small waterbodies and ponds. may potentially present rival organisms with better growing conditions.	In deeper water columns, efficiency often increases. Additionally, greatly influenced by the level of stratification and the airflow velocity.	(Asadi et al., 2017)
Hydrologic manipulation	altering the system's water inflow and outflow to prevent stratification and manage cyanobacterial growth	Simple to apply in regulated systems (i.e., reservoirs, dams, treatment facilities).	need a large enough amount of water and the capability to control flow. It can sometimes be pricey. There may be unintended effects on other aquatic creatures.	(Rolls et al., 2017)
Mechanical (mixing circulation)	Mechanical mixers are often surface mounted, which limits nutrient accessibility while also interfering with cyanobacteria's ability to move vertically.	Successfully pump water from the surface layer downwards or draw water up from the bottom to the surface disrupting the bloom.	Since individual devices have a limited range, farther-off regions may continue to be stratified and provide a suitable environment for growth.	(van der Boog et al., 2021)

Reservoir drawdown/desiccation	Water levels can be lowered by reservoirs and other managed waterbodies to the point that cyanobacteria accumulations are visible above the waterline. Additional to the reinjection of water into the system, desiccation and/or scraping to remove the layer of cyanobacteria adhered to silt or rock are necessary.	Simple to apply in regulated systems (i.e., reservoirs, dams, treatment facilities).	can significantly affect the system's other aquatic creatures. is potentially expensive and calls for a large resource investment.	(Sha et al., 2020)
Surface Skimming	Surface scums are frequently formed by cyanobacterial blooms, particularly in their later phases. These surface scums have been cleaned of cyanobacteria using oil-spill skimmers. This method is frequently used in conjunction with the use of a coagulant or flocculant.	a useful technique for blooms that are advanced and have surface scums.	This method can't be used effectively until a bloom is far into its later phases, by which time many of its negative characteristics have already manifested. requires the right tools before implementation.	(El-Sheek et al., 2019)
Ultrasound	By releasing ultrasonic waves at a specific frequency, an ultrasound device can be utilized to control HABs by destroying the cyanobacteria's cellular structure by rupturing internal gas vehicles that are responsible for buoyancy regulation.	successfully used in ponds and other tiny bodies of water. Up to 8 acres can be covered with a single device. Cheap and non-chemical.	also interferes with how green algae function cellularly. Geometry of the waterbody and the type of cyanobacteria play a role in effectiveness. It is necessary to conduct more method study.	(Carreira-Casais et al., 2021)
Chemical control				
Algaecide	Chemical substances known as algaecides are added to a body of water to eradicate the bloom and kill cyanobacteria. Here are a few instances: algaecide made of copper (copper sulphate, copper II alkanolamine, copper citrate, etc.) -Permanganate of potassium -Chlorine -Lime	several chemicals have a track record of use. Well-known and rather quick approach. Compounds' characteristics and effects are frequently well understood.	Risk of toxic releases and cell lyses. Consequently, is frequently employed in the early phases of a bloom. Some algaecides are poisonous to fish, other invertebrates, and zooplankton, among other creatures.	(Shen et al., 2020)

Barley straw	Bales made of barley straw are placed all around the waterbody's edge. When exposed to sunshine and oxygen, barley straw creates a chemical that prevents the growth of algae. Field research points to large agitate effects. Numerous reasons for the effects that have been observed have been put forth, however it is unclear how this process works exactly.	According to studies, decomposing barley straw prevents the cyanobacterium *Microcystis* sp. from growing.	prevents the creation of new algae but does not destroy already existing algae. The time it takes for the barley straw to start producing active chemicals might range from 2 to 8 weeks. Deoxygenation of the waterbody brought on by decomposition has the potential to kill fish.	(Iqbal et al., 2020)
Coagulation	The sedimentation of cyanobacteria cells to the anoxic bottom layer of the water column is aided using coagulants. The cells can't get oxygen, light, or other essential supplies, so they stop growing and finally perish.	Although numerous studies have demonstrated that cells can be coagulated without suffering harm, more analysis is still needed. successfully used at a number of treatment centers.	subject to restrictions on depth. Over time, coagulated cells experience stress and lyse, releasing toxins into the water body.	(Ghernaout et al., 2020)
Flocculation	In order to reduce the amount of nutrients in the waterbody and prevent cyanobacterial growth, flocculants are employed to help nutrients settle to the anoxic bottom layer of the water column.	successfully applied in bigger ponds and lakes.	subject to restrictions on depth.	(Jin et al., 2019)

2.4 Clay occurrence and chemical composition

Clay deposits occur in many parts of the world and are formed due to weathering of parent rock in situ to form residual clay. This process depends on the interaction between factors such as parent rock, climate, time, topography, and vegetation which influences the character and the direction of the movement through alteration zones (Abubakar et al., 2015). However, according to Murray (2018), the clay depends on vegetation. Therefore, the geological history of clay material and its properties and behaviour depend on the environment in which it is formed (Perold, 2017).

Clay occurs abundantly in all the regions but differs with its mineralogical, chemical, and physical properties. Clays used to manufacture clay bricks include kaolinite, montmorillonite, illite, micas, and chlorites, which contain enough calcium carbonate (Rakhimova, 2020). During the process of firing, sodium, iron, and magnesium normally found in clays act as fluxes which produce a glassy phase that can bind the bricks matrix together (Cultrone et al., 2015).

Clays and clay minerals occur under a limited range of geologic conditions. The formation environments include soil horizons, continental and marine sediments, geothermal fields, volcanic deposits, and weathering rock formations. Most clay minerals form when rocks are in contact with water, air, or steam. Examples of these situations include weathering boulders on a hillside, sediments on sea or lake buried sediments containing pore water, and rocks in contact with water heated by magma (molten rock) (Philpotts et al., 2022). All these environments may cause the formation of clay minerals from pre-existing minerals.

2.5 Clay soil and its uses

Clay is the essential raw material needed to produce bricks and other creative ceramics (Babisk et al., 2020). It can be defined as a group of fine-grained soils, consisting of particles smaller than silt particles (Cao et al., 2019. According to the Brick Industry Association (2016), clay soil is a type of soil that exhibits resistance to cutting. Also, depending on the type of clay content in the soil, there may be dissolved salt changes, some clays can be easily degraded and transported (Singh, 2016). Clay bricks are one of the oldest building materials and, in fact, the first to be produced by man (Fernández & Castro, 2016). These bricks remain popular today as a building material primarily for their structural properties, easy availability, relatively low cost, and architectural reasons (Cultrone et al., 2015). Traditionally, clay bricks are a strong and durable

material in normal weather conditions.

When clay deposits are available, clay bricks can be manufactured locally, making them readily available relatively cheaply. In addition, clay bricks have a pleasant colour and can be made with different surface textures that make them more architecturally acceptable (Ahmad et al., 2017). They are widely used as a building envelope and are often part of the brick-clad wall system adopted for the façade of buildings (Perold, 2017).

Many building envelope failures are associated with the disintegration of the brick cladding. Therefore, the quality of the bricks is one of the main requirements to consider in the design and construction of building envelopes. Failure due to deterioration may be a safety concern. In some cases, it can involve costly repairs and there is no guarantee that the deterioration will not recur. Bricks are the basic masonry units used in masonry construction and have the advantage over stone that is easy to build and requires less labor to lay (Cultrone et al., 2015). The ownership of bricks depends on the land used to make them, the manufacturing process, and varies from place to place (Fernandes & Castro, 2016).

2.6 Major characteristics of clay minerals and its level of suitability in making clay bricks

All minerals have great affinity for water, some swell easily and may double in thickness when wet (Murray et al., 2015). Most can soak up ions from a solution and release the ions later when conditions change, water molecules are strongly attracted to clay mineral surfaces (Uddin, 2017). Their small size and large ratio of surface area to volume gives mineral a set of unique properties, including high cations exchange. There are three types of minerals: Bentonite, Kaolin and Illite (Table 2.2).

Table 2.2: characterization of clay minerals (Wang et al., 2020)

Bentonite	Kaolin	Illite
Presents strong colloidal properties and increases its volume several time when meeting water, creating a gelatinous and viscous substance. Its specific properties include swelling, water absorption, viscosity and thixotropy.	Odorless white to yellowish or grayish powder Insoluble in water. Develops earthy odor when is wet.	Contains more water and less potassium than true micas. Poorly crystallized. It is a weathering product of muscovite and alters to montmorillonites.

The clay mineral, any of a group of important hydrous aluminum silicates with a layer (sheetlike) structure and very small particle size, they may contain considerable concentrations of iron, alkali metals, or alkaline earths. Clay mineral is a series of major hydrous aluminum silicates with a layer (sheetlike) structure and very small particle size (Nkansha et al., 2016). Although iron to variable degrees substitutes for aluminum and magnesium, and significant amounts of potassium, sodium, and calcium are frequently found, clay minerals are primarily made up of silica, alumina, or magnesium, or both, and water. Ideal chemical formulations (such as kaolinite, $2SiO_2Al_2O_3$, and $2H_2O$) can be used to describe several clay minerals (Chen et al., 2016).

2.7 Coal occurrence and chemical composition

Coal is defined as a readily combustible organic sedimentary rock containing more than 70% by volume and 50% by weight of carbonaceous material, formed from compaction of variously altered plant materials (Dai et al., 2021). Coal is formed because plant remains accumulate in a specialised deposition environment where such accumulations have been affected by synsedimentary and post-sedimentary influences to produce coals of diverse degree of structural complexity and rank (Mani et al, 2015).

The origin of coal has been studied for over a century and a variety of models exist which attempt

to identify the environment of coal deposition. No single model identified can predict the occurrence, development and coal type (Mani et al., 2015) in (Table 2.3) below. The traditional model is the most common coal depositional model used by numerous workers was based on the 'Cyclothem', a stratigraphic repetition of chemical and siliceous rocks in the equatorial regions of Pangean interior (Roark et al., 2016).

Table 2.3: Coal's macerals and descriptions of each maceral group (Mani et al., 2015).

Maceral Group	Maceral	Morphology	Origin
Vitrinite (huminite)	Telinite	Cellular Composition	Stems, branches, roots, and leaves' cells and walls
	Collinite	Structureless	Reprecipitation of a gel-like state of dissolved organic matter
	Vitrodetrinite	Broken pieces of vitrinite	Early humic peat degradation and plant deterioration
	Sporinite	Type of fossil	Mega-microspores
	Cutinite	Bands with potential appendages	The outer covering of leaves, shoots, and slender stems is called the cuticle.
Exinite (liptinite)	Resinite	Layers of cell filling or distributed	Plant Secretions such as Resins, Wax, and Other
	Alginite	Type of fossil	Algae
	Liptodetrinite	Exinite pieces	Remnants of degradation
	Fusinite	empty or mineral-filled cellular structure; typically, well-preserved cell structure.	charcoal made primarily from oxidized plant material that has been burned.
	Semifusinite	cellular composition.	Plant matter that has partially oxidized.
	Macrinite	Undefined cement.	oxidized gel substance.

Inertinite	Inertodetrinite	Fusinite, semi-fusinite, or macrinite in small spots.	Inertinite deposits.
	Micrinite	Round, granular grains with a diameter of around 1 mm.	Macerals degrade during coalification.
	Sclerotinite	petrified shape.	Fungal are mainly what is left.

Materials were digested in a solution of hydrofluoric, nitric, and perchloric acids. The data were analyzed using ANOVA, and means were separated at the 95% significance level using Duncan's multiple range test. In general, all four grades of coal showed significant variations (p 0.05) in the mean concentration of heavy metals. All coal classes had appreciable differences in the mean Zn, Cu, Ni, and Pb concentrations (p 0.05) (Tang et al., 2018).

2.8 Brick making using clay and main challenges

After the raw materials, have been extracted and stockpiled; it is prepared by crushing, grinding and mixing in a variety of ways, and depending on the type of raw material used, the product and drying and firing method are employed (Charai et al., 2020). Water content is controlled and the material going on to the shaping process may have moisture contents varying from between 17% to 30%, depending on the different raw materials used. As soon as the raw material is extracted (Albitar et al.,2017). Clay is mixed with water to make a dough, the resulting mix characterized by enough plasticity to facilitate the molding, but not “too plastic”, as it can lead to severe shrinkage during the drying phase, resulting in warping, twisting, or cracking the quality of the mixture is checked by squeezing mud in hands, it must not slip through fingers nor be too dry to maintain a shape (Koroth, 2017).

The presence of the traditional process of brick making is currently challenged by the more modern industrial brick production (Kolodziejek & Tey, 2016)**,** some concerns have been raised regarding various environmental and health hazards from the brick making process. On the other hand, as a production process that has been handed down across generation, the brick making process is embedded with various ecological values that are attached to the environmental and cultural context (Coletti et al., 2016).

2.9 Banana biomass and chemical composition

Musa cavendish (Banana) is a herbaceous annual plant grown on an industrial scale and by local populations in tropical areas. In 2018, more than 126 million tons of bananas were produced worldwide (Vu et al.,2018). Banana peel is the outer shell (cover) of the banana fruit. It is a by-product of home consumption and the processing of bananas. However, there are some concerns about the effect of tannin in the husks on the animals that consume it. Banana peels are also used as an ingredient in cooking, water purification, the manufacture of many biochemical products, and inorganic waste production. Banana peels are sometimes used as feedstock for livestock, goats, monkeys, poultry, rabbits, fish, zebras, and many other species (Hassan et al., 2018).

The chemical composition analysis of that specific residue (Nagarajaiah et al.,2017) revealed that their lignin content, though lower compared to woody biomass, was found significant for potential valorization throughout the different platforms. The mineral composition of banana peel was phosphorus, iron, calcium, magnesium, and sodium.

A banana peel's mineral composition consists mostly of potassium (78.10 mg/g) and manganese 7 6.20 mg/g, sodium (24.30 mg/g), calcium (19.20 mg/g), and iron (0.61 mg/g) are additional minerals that are found (Jaishankar et al.,2014). If consumed orally, the peel's high potassium concentration helps to maintain normal blood pressure. An average banana peel contains 91.50 percent organic nutritional matter, which includes lipids, proteins, crude fiber, and carbs (Anyakora, 2022). Fiber makes up about 31.70 percent of the total mass, followed by carbohydrates (59 percent), prot ein (0.9 percent), and lipids (1.7 percent), in that order. Fibre abundance is a natural laxative (Jaishankar et al., 2014).

The Vhembe district has many different banana cultivars, including Luvhele (*Musa*ABB), Mabonde (*Musa*AAA), and Muomva-red (*Musa balbisiana) (*Anyasi et al.,2015*)*, where we may locate banana peels. Both nutritious and nonnutritive substances can be found in banana peels, Banana peels can be used to make a treatment or a poison since they contain ingredients that are both very helpful and very deadly (Jaishankar et al., 2014).

2.10 Concluding remarks.

Individual and group activity, user activities and lake entertainment reduce the amount of nutrients introduced into lakes. Cyanobacteria are common in fishponds and other bodies of water, but they only pose a concern when they begin to produce toxins. Cyanobacteria, which affects fish output and water quality, are a problem in most nations. Although some of them hurt fishponds and water quality, dinoflagellates such *Anabaena, Microcystis aeruginosa, Cylindrospermopsis,* and *Microcystis* have been detected and biological control has been utilized in most countries.

The incidence, classification, and toxicology of algal cyanobacteria blooms are highlighted in this paper. Chemical compounds must be employed to treat waterborne cyanobacteria. Chemical use in natural lakes is not permitted because it may result in additional issues. As a result, using chemicals can impact both species and people because they are hazardous to other forms of life. By reducing the amount of nutrients in lakes, study may shortly find an appropriate answer.

CHAPTER 3: MATERIALS AND METHODS

This chapter describes the methods and procedures used in generating data for this research. The methodology of this research was divided into different stages which is preliminary work that comprises of desktop study, reconnaissance survey, the fieldwork that involve the field characterization, description of clay bricks making processes, Laboratory work and minimization of blue-green algae/cyanobacteria growth species on clay brick. A summary of the methodology used is illustrated in the flow chart below in (Figure 3.1).

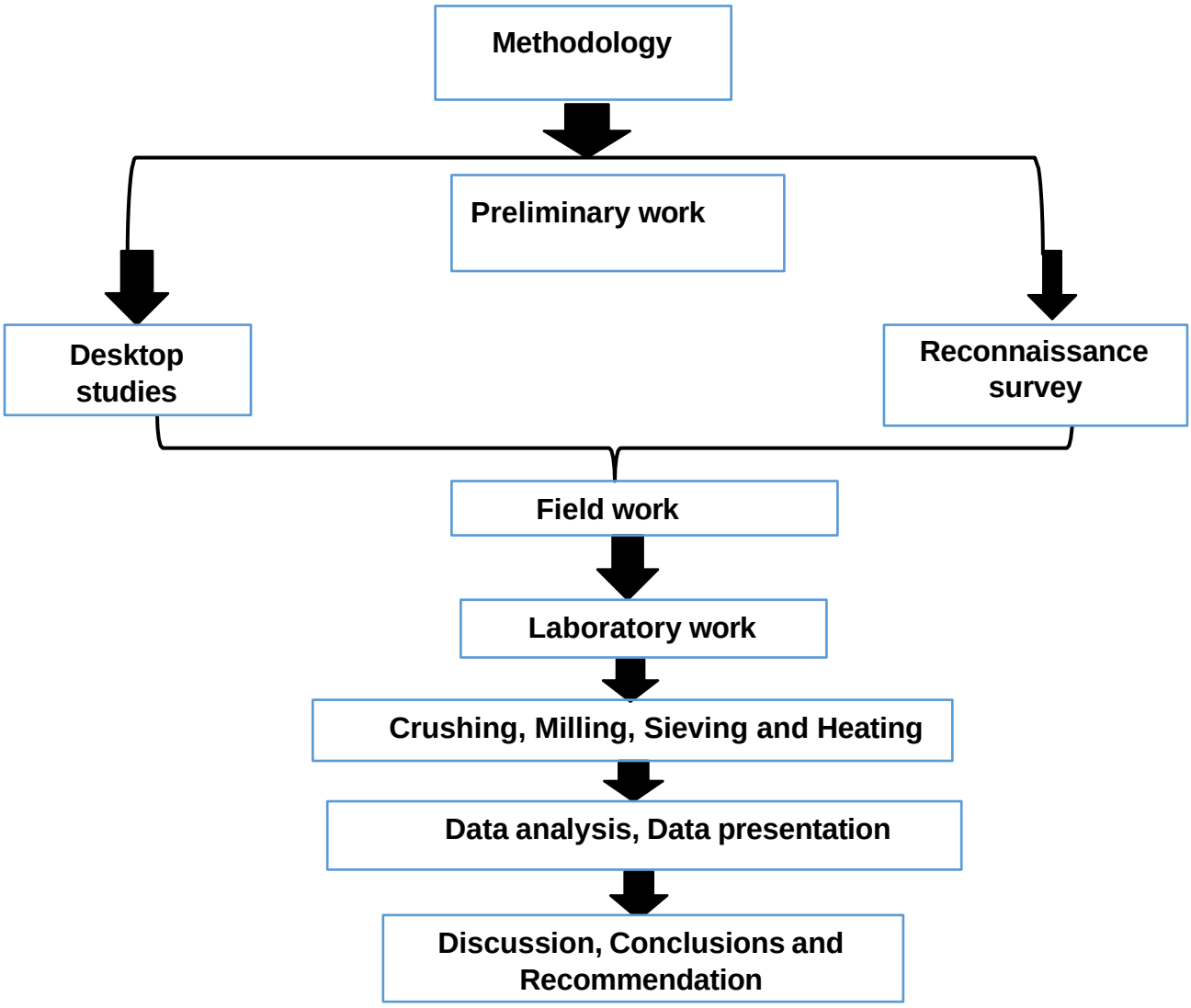

Figure 3. 1: Research methodology flow chart.

3.1 Preliminary Work

The preliminary work is the initial stage of data collection through studying available material and/or carrying out field observation of the study area (Brynard, 2014). This research was done to determine if the purpose of this research is clear, the topic indeed researchable, and the suitability of the data collection methods for this study. The preliminary work was carried out before the fieldwork, divided into the desktop study and reconnaissance survey bricks.

3.1.1 Desktop Study

Desktop study is a preliminary investigation consisting of the evaluation, collection, analysis, and integration of the information already available for the preliminary assessment of site conditions and the appropriateness of the research problems (Asenahabi et al., 2019). It assists in making research planning easy and enables the selection of the most appropriate analytical techniques. It can also highlight issues that may require individual or discrete study.

This research used various sources to obtain information about the study area and the current research topic. The sources such as previous researchers relating to the study were used. Desktop study was used to generate knowledge on the pavement consisting of blue-green Algae/Cyanobacteria. It was conducted before the actual fieldwork.

3.1.2 Reconnaissance Survey

This preliminary research was done to correlate revised literature with reality at the site visit. It involved conducting a general observation of the clay bricks and pavements in the study area through site visits before the actual field work or detailed field survey on site was conducted. The main aim of the survey was to gain first-hand information about the study area. The visit to study area was conducted at the time when brick making process was carried out.

3.2 Collection of materials

The clay soil (kaolin) was collected at Vhavenda Bricks, Vhembe district, Limpopo. It is located about 21 km away from Thohoyandou Town. The mine is in the vicinity of Lwamondo Village. The geographical coordinates of the study area are 23°00’ 17 22” S (latitude) and 30°23’ 19 88” E (longitude). The clay material was selected since it was used in pavement making at the University of Venda (Munyai et al., 2019). The clay material was collected at a random depth of 0 to 20 cm using a spade.

The banana (*Musa sapientum*) peels were collected from markets and the farms, then were dried by the sun, ground by pestle and mortar and sieved by (<2 mm) prior to analyses (Figure 3.2). A miniature brick-box metal frame, a hand-mixing machine and a measured water jug were used when making the clay bricks. The dimension of standard brick is 22 cm long x 10 cm wide x 8 cm high (Mesquita et al., 2018), and the miniature brick is 11 cm long x 5 cm wide and 4 cm high.

Figure 3.2: Process of making modified clay bricks.**A-**Banana Biomass**; B-**Brick making process**; C-**sundried bricks and **(D)** miniture bow box mould.

3.3 Laboratory preparation

The coal samples were crushed by jaw crusher to reduce particle size, each crushed sample was milled with a sample was ground to about 75 rpm using a Retsch RS 200 tungsten carbide milling machine for 8 minutes at 750 revolutions per minute (rpm). To reduce sample contamination, milling pots were first cleaned with quartz. Before milling the actual sample, a tiny amount was first ground to coat the milling pots. The milled coal samples were then placed in Kraft sample bags.

The banana biomass, coal and clay soil were weighed by analytical balance (Radwag model WLC 10/A2, made in Poland) according to the ratio that was calculated and placed in the Kraft sample bags, the four types of bricks were made of (Figure 3.1):

- Coal + clay (control sample)
- Coal +clay + Banana (treated sample)
- Clay +Banana (no coal) (treated sample)
- Clay (no coal, no Banana) (control sample)

Table 3.1: Types of bricks made.

Sample code	Description	Composition of material
CB1	Clay, Coal and Banana	Clay 505 g, Coal (247.5 g), Banana (247.5 g)
CB2	Clay, Coal and Banana	Clay 500,05 g, Coal (249.75 g), Banana (249.75 g)
CB3	Clay, Coal and Banana	Clay 550 g, Coal (225 g), Banana (225 g)
CB4	Clay, Coal and Banana	Clay 600 g, Coal (200 g), Banana (200 g)
CB5	Clay, Coal and Banana	Clay 650 g, Coal (175 g), Banana (175 g)
CB6	Clay, Coal and Banana	Clay 700 g, Coal (150 g), Banana (150 g)
CB7	Clay, Coal and Banana	Clay 750 g, Coal (125 g), Banana (125 g)
B1	Banana +Clay	Clay 999 g, Banana (1 g)
B2	Banana + Clay	Clay 990 g, Banana (10 g)
B3	Banana + Clay	Clay 900 g, Banana (100 g)
B4	Banana + Clay	Clay 800 g, Banana (200 g)
B5	Banana + Clay	Clay 700 g, Banana (300 g)
B6	Banana + Clay	Clay 600 g, Banana (400 g)

B7	Banana + Clay	Clay 500 g, Banana (500 g)
C1	Coal + Clay	Clay 505 g, Coal (495 g)
C2	Coal + Clay	Clay 500.05 g, Coal (499.5 g)
C3	Coal + Clay	Clay 550 g, Coal (450 g)
C4	Coal + Clay	Clay 600 g, Coal (400 g)
C5	Coal + Clay	Clay 650 g, Coal (350 g)
C6	Coal + Clay	Clay 700 g, Coal (300 g)
C7	Coal + Clay	Clay 750 g, Coal (250 g)

The clay soil was collected and mixed with banana biomass based on the given ratio; another clay soil was not mixed with banana biomass. After mixing clay with or without banana biomass the water was added to make a dough. The resulting mix characterized by enough plasticity to facilitate the molding, but not "too plastic", as it can lead to severe shrinkage during the drying phase, resulting in warping, twisting, or cracking (Koroth, 2017). The quality of the mixture was checked by squeezing mud in hands, it must not slip through fingers nor be too dry to maintain a shape. The bricks were sundried and later weighed using an analytical balance (Radwag model WLC 10/A2, made in Poland). The medium was autoclaved for one hour at 121 °C (Lab Tech Daihan Labtech CO., Ltd). Then, under sterile conditions, 1000 ml of modified BG 11 media were put to containers along with 4 ml of cyanobacteria inoculum, the physical parameter such as pH, TDS, EC, Temperature was measured by inserting portable pH meter rod in the media.

3.4 Physical Test on the brick

3.4.1 Hardness test

A hardness test was done to check the hardness of brick. This is an indirect test to determine its compressive strength and how well the brick was kilned. This was tested by using a sharp tool or fingernail and scratching against the brick surface. If there was no impression of scratch on the brick surface, the brick was sufficiently hard and fit for use (Innocent, 2018).

3.4.2 Dimensional tolerance test

The shape and size of the brick were checked using a dimension tolerance test. Four bricks were arranged in this test, along its width and height. The measurements were contrasted with one another and with the norm (Hjerm et al., 2020).

3.4.3 Sound test

To ascertain the caliber of the bricks received, a sound test of a brick was conducted in the field. Two (2) bricks were slammed into one another in this test. When struck together, good-quality bricks should produce a metallic sound (bell ring) and should not break (Kumar & Sinha,

3.4.4 Impact test

Bricks were dropped onto the ground during this experiment from a height of one meter (not hard surface). A sturdy brick did not crumble. It is best not to use it for construction if it breaks (Thakur et al., 2022).

3.4.5 Colour test

A well-kilned (burned) clay brick had a consistent color all its sections and crimson hues. The black bricks were of poor quality and had been overburnt (Poornima et al., 2022).

3.4.6 Water absorption test

A water absorption test determined how much moisture the brick took in. The brickwork's strength will decrease if the bricks absorb more water from the cement mortar than 20% of their dry weight. Hence they shouldn't be utilized for construction. Five sun-dried bricks were picked from the sample for this test, and their dried weights were recorded. Weights were recorded again after the bricks had been heated in the oven. Both weights computed water absorptions (Albitar et al., 2017).

3.4.7 Compressive strength test

The compressive testing machine was used to determine the strength of a brick by repeatedly loading the frog face on top until failure. The mortar on the brick frog's face has been poured and dried for four days. A minimum compressive strength of 3.5 N/mm^2 is required, per codes. In building, bricks with compressive strengths lower than 3.5 N/mm^2 should not be used (Brencich et al., 2021).

3.4.8 Efflorescence

When masonry dries, a fine, white powdery layer of water-soluble salts is left on the surface. Soluble salts should not be present in a good brick. The bricks were submerged in water for 24 hours and then allowed to dry fully. If the brick surface has any white or gray areas, this means the brick contains soluble salts (Nhabih et al., 2020).

3.4.9 Wrappage test

The wrappage test was used to determine the flatness of the brick surface. Wrappage should be within acceptable limits if the bricks are properly heated and cooled. A convex and concave wrappage test is performed (Peng et al., 2020).

3.5 Metal content analysis

3.5.1 Sample preparation and digestion

The glass beakers were, washed with deionized water and then dried for about five minutes in an oven set to 150 ^{o}C. The four clay bricks (C5, B5, CB5, and Control) based on the clay bricks composition and ratio were selected for test, were first crushed in a jaw crusher, and then ground in a mill. Each milled sample was weighed at 500 g using a Radwag analytical balance and was added to the decomposition beakers (Kumar and Sinha, 2020). A few drops of deionized water, 45 ml of HCl, and 15 ml of HNO_3 (Nitric acid) were added for moisture (Lian. The beakers were then set on the hot plate for approximately 90 and 120 min. After decomposition, the samples were left to cool down at room temperature. The prepared samples were then paper filtered (Whatman No 1), mixed with deionized water in a 100 ml volumetric flask, shaken, and allowed to settle for two hours in Figure 3.3. It was then prepared for inductively coupled plasma mass spectrometry (ICP-OES) analysis after placing the decanted sample into the clean centrifuge tube.

Figure 3.3: Acid digestion of clay. **A**-preparation of clay, hydrochloric acid and nitric acid **B**-Hot stove digestion**, C**-Filtering of decomposed samples and **D**- Filtered sample ready for ICP-OES.

3.5.2 The ICP-OES analysis

The metal contents were analyzed by ICP-OES (Optima 8000, Perkin Elmer, Canada) after acid digestion. Leaching of heavy metals except that the brick pieces were acid-digested and then analyzed for major and trace metals. Here, we report on a few metals – K, Na, Mn, and Ni in the results. The 5 standard metal solution, blank and four types of samples which is CB5, B5, C5 and control, were analyzed.

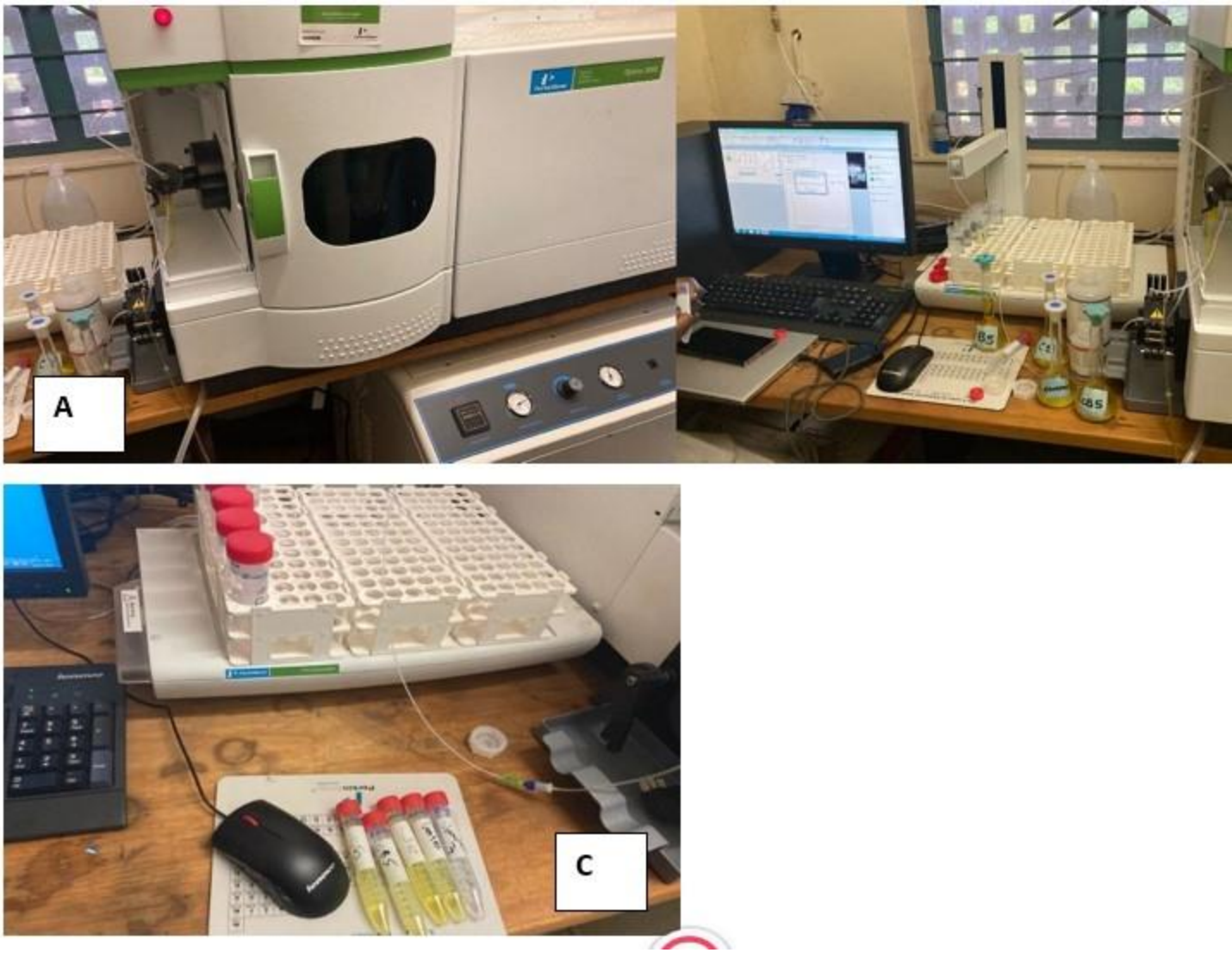

Figure 3.4: Metal Analysis**. A-**ICP-OES**. B-**Preparation of samples **and C-**analyzed samples.

The output of ICP-OES was used to calculate mean metal content (mg per liter). The mean and confidence interval were calculated using the Microsoft Office excel (2019). The final metal content was express as mg per g as the following expression (1).

Metal concentration (mg per gram) = $\frac{x*V}{m}$ $equation\ 1$

Where x mg per L is average reading from the ICP-OES instrument, V is volume (L) 0.1 litre (100 ml volumetric flask where the acid digest was added) and m is mass weighed (g) of ground material was acid-digested.

3.6 Monitoring growth of cyanobacteria

The modified BG 11 medium was created in the lab using the Kruger and Eloff (1997) cyanobacteria culture procedure. In addition to adding the trace elements to the flask in Table 3.3, the medium was created using the mineral composition stated in Table 3.2. 850 ml of deionized water were put into two 1000 ml Erlenmeyer flasks. The flask also received additions of minerals and trace elements. The mixtures were stirred and agitated until the minerals were thoroughly dissolved. Deionized water was added to the Erlenmeyer flask until it held 1000 ml.

The medium was autoclaved for one hour at 121 °C (Lab Tech Daihan Labtech CO., Ltd). Then, under sterile conditions, 1000 ml of modified BG 11 media were put to containers along with 4 ml of cyanobacteria inoculum.

The blue-green algae/cyanobacteria inoculum was the transferred to twenty-two 1000 ml closed containers and then incubated at room temperature at greenhouse facility at the former School of Agriculture (Figure 3.5).

Figure 3.5: Preparation of cyanobacteria suspension

Table 3.2: Modified BG 11 mineral composition concentrations

Components	**Final concentration**
$NaNO_3$	1.500 g
K_2HPO_4	0.040 g
$MgSO_4.7H_2O$	0.075 g
$CaCl_2.2H_2O$	0.036 g
Citric acid	0.006 g
Ferric ammonium citrate	0.006 g
EDTA (disodium salt)	0.001 g
Na_2CO_3	0.020 g
Trace metal mix A5	1.0 ml (from Table 3.3)

Table 3.3: Trace metal solution

Component	**Final concentration**
H3BO3	2.860 g
$MnCl_2.4H_2O$	1.180 g
$ZnSO_4.7H_2O$	0.222 g
$NaMoO_4.2H_2O$	0.390 g
$CuSO_4.5H_2O$	0.079 g
Co $(NO_3)_2.6H_2O$	49.40 mg

The clay bricks were exposed to an aqueous solution containing a suspension of cyanobacteria in a transparent enclosure (containers) in (Figure 3.6). This was exposed to continuous light to stimulate the growth of cyanobacteria. Daily, a visual observation and scrapping was carried out to check the growth of cyanobacteria on the surface of the bricks. The scrapping involved a sharp object to remove the cyanobacteria and determine the biomass. The cyanobacteria biomass was determined by measuring the absorbance at 750 nm wavelength.

Figure 3.6: Cultivation of blue-green Algae/Cyanobacteria in BG11 Medium.

3.7 Measurement of Cyanobacteria Growth

The growth of cyanobacteria was determined through triplicates measurement of absorbance in 22 containers with different bricks. The maximum absorbance was inspected by scanning a sample between 600 and 800 nm in a Spectrophotometer (ORIOON AQUAMATE 700, VIS spectrometer, Made in China, and Designed in the USA) (Mouiya et al., 2019). However, sample absorbance was measured spectrophotometrically at 750 nm for seven days, weekly and monthly to monitor changes in the growth of cyanobacteria (Janatian et al., 2020).

3.8 Data Analysis

The cyanobacteria growth curve was based on absorbance values versus time (days). The graphs and mean were made using Microsoft Office excel software (2019) for both treated samples and control (non-treated) samples. One way ANOVA was used to determine the significance difference between the treated and control samples clay bricks (Table 3.1) at $p < 0.05$.

CHAPTER 4: ASSESSING THE EFFECT MODIFIED CLAY BRICKS ON THE GROWTH OF CYANOBACTERIA

Abstract

This chapter focuses on the presentation and analyses of the data collected, using the One-way Anova and turkey mini tab software to analyze the physical parameter (pH, ECS, TDS, temperature, and absorbance) of modified clay (coal & banana), whereby turkey mini tab was used to compare all pairs of groups, while controlling the simultaneous confidence level. This group have mini separation represented by letters whereby single letter means high factor that cannot be controlled by any treatment . This study used a one-way ANOVA statistical method and identified banana as having a pure significant value. This was also viewed favorably because the treatment materials showed excellent inhibitory capacity during the trial period. The banana and coal samples and the control samples, on the other hand, the findings of the ANOVA analysis showed that from the first day of the experiment to the last day of the third month, demonstrated substantially different values of absorbance. Although the absorbance for the treated (banana) samples was decreasing, the graph for the untreated and control samples was increasing. when compared to control, other samples of coal, coal + banana, and other samples. The absorbance indicated a substantial change from days 0 through 1, 3, 4, 5, 6, and 7 of the 24-hour test period, drastically inhibiting cyanobacteria cell growth. From day 1 through month 3, the single factor ANOVA revealed a significant difference between the treated samples B1, B2, B3, B4, B5, B6, B7, and the control. The following values were used to calculate the p value: 0.017, 0.007, 0.0119, 0.007, 0.009, 0.001, 0.003, 0.001, 0.015, 0.015, and 0.001. which, from day 1 to month 3, was less than 5% and had a 95% confidence level. Day 2 $p>0.05$ indicates a single factor, which non- significant difference was revealed using ANOVA.The simultaneous confidence level was controlled while comparing all group pairs using the turkey mini tab. This group has a small degree of separation, represented by letters, where a single letter denotes a significant component that cannot be treated like other groups share letters. For the 24-hour test period starting on days 0 through 1, 2, 3, 4, 5, and 7 and weeks 2 through 4, the absorbance drastically decreased for coal and banana bricks. From day 1 to week 4, the single factor ANOVA revealed a significant difference between the treated samples CB1, CB2, CB3, CB4, CB5, CB6, and the CB7. From day 1 to week 4, the p value ranged from 0.005 to 0.003, 0.005 to 0.003, 0.004 to 0.002, 0.011 to 0.017, 0.012 to 0.008, all of which were below the 5% threshold. From 2 and 3 month there was no significance difference because of Coal reducing Banana in the process because of its chemical composition. While the

algae kept growing, it was discovered that the absorbance on the untreated samples and control samples was not inhibiting the Cyanobacteria, and the graph for these samples was ascending. A considerable rise in cyanobacteria cells was seen over a test period of 24 hours starting on days 0, 1, 2, 3, 4, 5, and 7. The absorbance greatly varied during weeks 2, 3, and 4, as well as months 2 and 3. From day 1 to month 3, the single factor ANOVA revealed a significant difference between the untreated samples C1, C2, C3, C4, C5, C6, and the C7. From day 1 to month 3, the p value was 0.011, 0.003, 0.006, 0.003, 0.023, 0.018, 0.004, 0.003, 0.006, 0.004, and 0.004 was less than 5% and was within the 95% confidence interval.

Keywords: Cyanobacteria, Banana, Coal, Clay, and ANOVA.

This chapter focuses on the presentation and analyzing of data on how to control the algae/cyanobacteria growth using modified clay bricks (with either banana biomass and coal and or with coal and or with banana biomass.

4.1 Evaluation of modified clay (coal & banana) bricks in inhibition of laboratory blue-green algae/cyanobacteria suspension.

4.1.1 The effect of pH

There was variation in pH for control and treated samples during the study period (Figure 4.1). The alkaline pH for the control samples showed an upward increase from 7.4 to 9.7. The alkaline pH for modified bricks (coal and banana composition) showed variation but was consistent between 7 and 8.5. This pH was expected since algal blooms in alkaline conditions (Vadlamani et al., 2017).

The single factor ANOVA showed significant differences ($p<0.05$) between the treated samples and the control samples (Table A4.1) at Day 3, Day 7, and Week 2, on the other days p was not significant. This implied that addition of coal and banana powder influenced the water pH at day 2 which p is 0.02195. While according to Akintoye et al. (2014), a pH of 7 indicates neutrality, lower pH levels indicate rising acidity. Overall, the pH was the same for control and treated samples for the duration of the study period. Notably, pH level influences other potential toxicants, such as heavy metal bioavailability (Padhan et al., 2021).

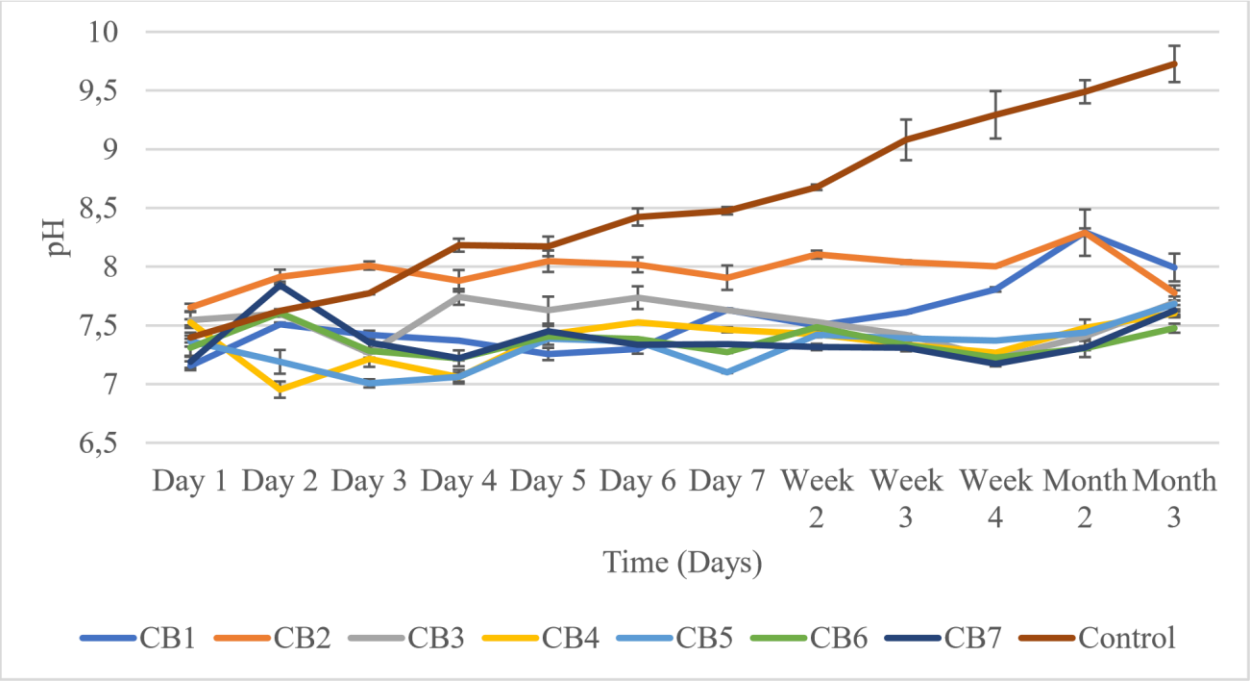

Figure 4.1: The variation of pH value cultured blue green/cyanobacteria suspension samples. Whiskers reflect standard error.

4.1.2 The effect of electrical conductivity

There was variation in the electrical conductivity (EC) for control and treated samples during the study period (Figure 4.2). The EC for the control samples showed an upward increase, from (1084.7 µS/cm to 1603.7 µS/cm). The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.2) at Day 1 to Months 3**.** The electrical conductivity (EC) shows the many soluble salts in the water. It also displays the spread of microphytes and the water's nutritional content (Munyai, 2019). The BG11 produced medium, which contained a high concentration of salts according to the Kruger and Eloff (1977) preparation process, and the clay brick matrix dissolving in the alkaline solution are likely the causes of the high results medium.

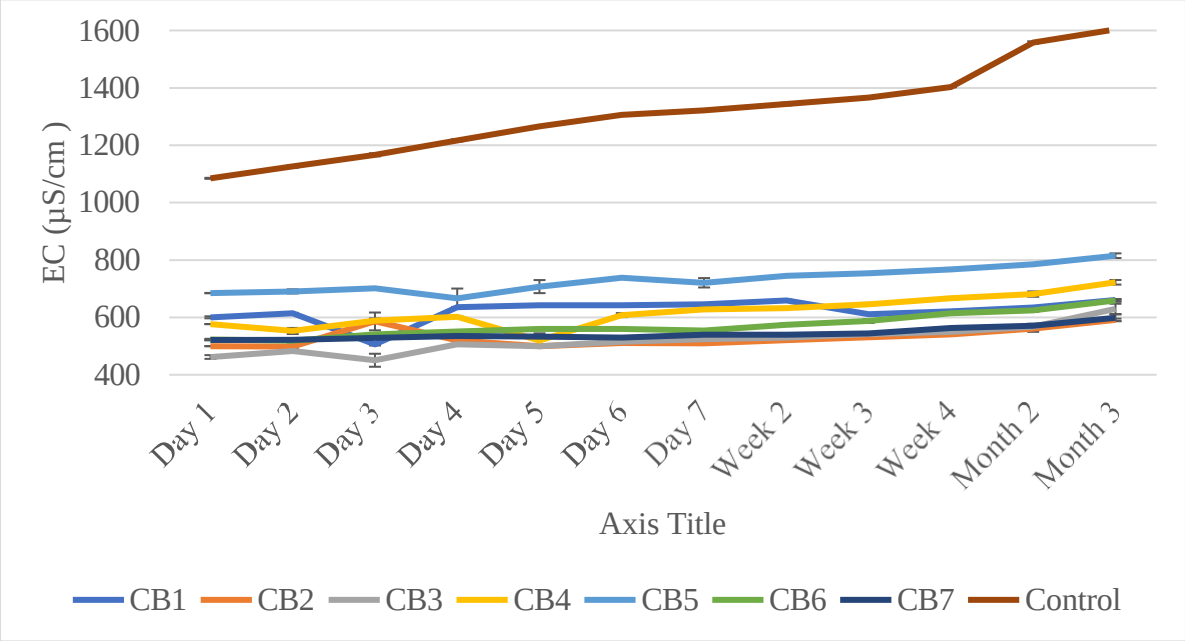

Figure 4.2: ECS value cultured water samples. Whiskers reflect standard error.

4.1.3 The effect of total dissolved solids

There was variation in total dissolved solids (TDS) for control and treated samples during the study period (Figure 4.3). The TDS for the control samples showed an upward increase from 1017.3 to 1403.7. The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.3) at day 1 to month 3. The total dissolved solids (TDS) are a vital factor in determining water quality for drinking and aquatic ecosystems (Naubi et al., 2016).

The TDS imparts flavor to the water while lowering its palatability. The mechanical abrasive impact of suspended particles can lead to biological imbalances in the aquatic environment (Munni et al., 2015). High loads shorten the life span of aquatic species and degrade the water quality. In a water media, suspended solids can take the shape of fine, floating and settling materials/particles. According to department of water affairs standards, the values are within the range recommended for drinking and are suitable for fish life (Ayandiran et al., 2018). The stated TDS values in fish culture are acceptable for a variety of fish production.

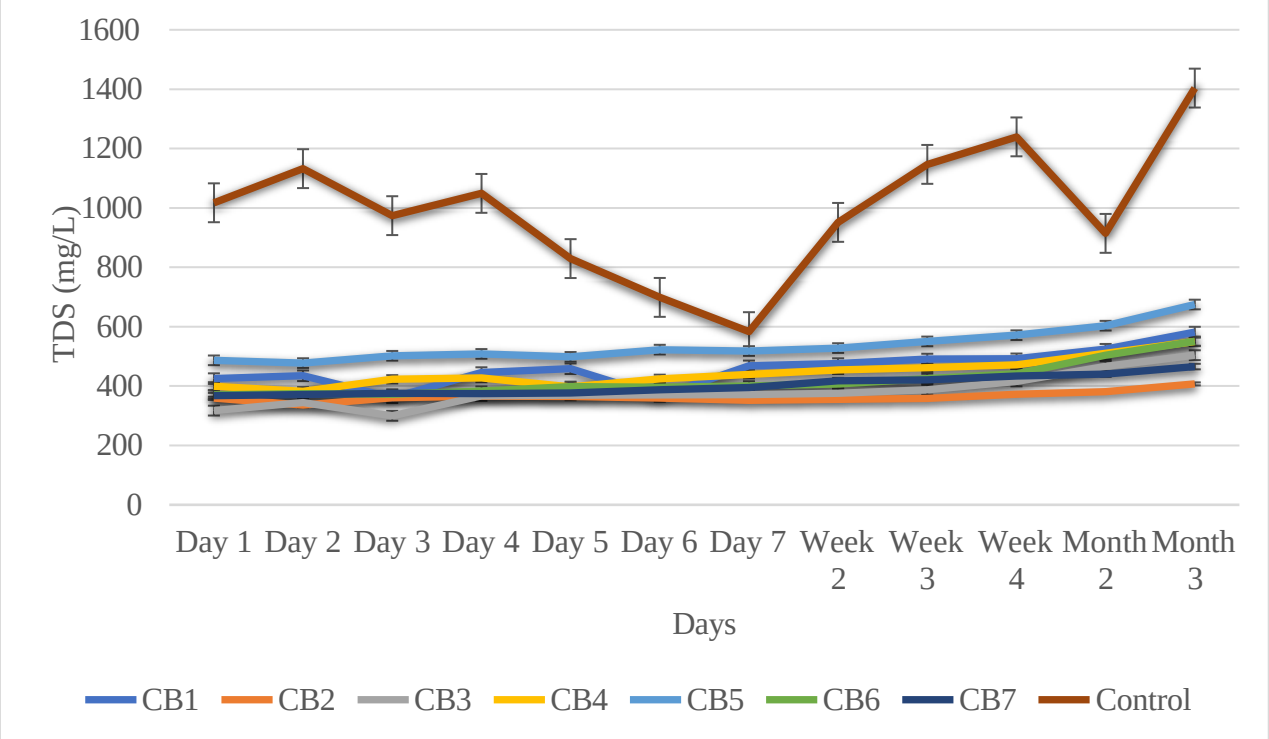

Figure 4.3: TDS value cultured water samples. *Whiskers reflect standard error.*

4.1.4 The effect of temperature

There was variation in temperature for control and treated samples during the study period (Figure 4.4). The temperature for the control samples showed an upward increase, from 20.10 °C to 30.20 °C. The temperature for modified clay bricks (coal and banana composition) showed variation but consistent between 20 °C and 38 °C for the ideal temperature range for freshwater aquaculture is approximately 25–40°C (Munni et al., 2015). Conclusion: All trials' temperatures were appropriate for aquatic species to survive. The single-factor ANOVA showed significant differences ($p<0.05$) in (Table 4.4) in all samples including treatment and control.

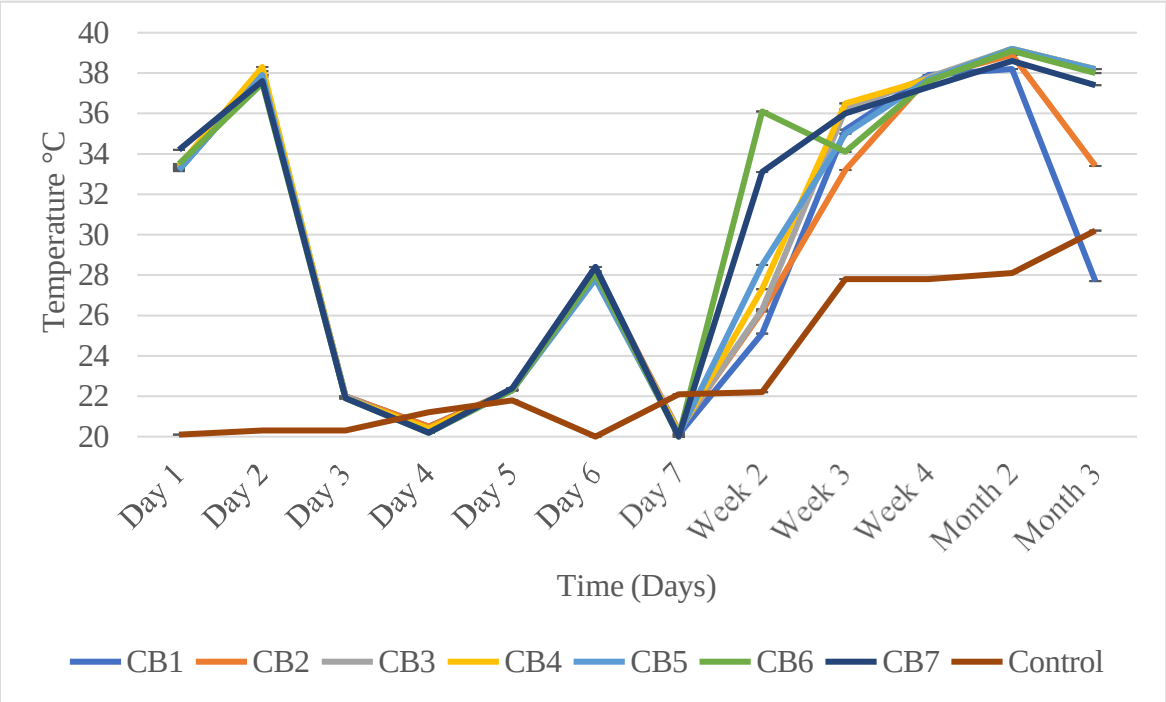

Figure 4.4: Temperature value cultured water samples. Whiskers reflect standard.

4.1.5 The effect of banana matrix (potassium)

The growth of the algae was found to be decreasing in the treated samples, while it continued to grow in the control sample (Figure 4.5). Cyanobacteria cells were significantly reduced for a 24-hour test period beginning on day 0, 1, 2, 3, 4, 5, 6, and 7, and continuing through week 2, week 3, and week 4. From day 1 to week 4, the single factor ANOVA revealed a significant difference between treated samples CB1, CB2, CB3, CB4, CB5, CB6, and CB7 (Table 4.6). From day 1 to week 4, the p values were less than 5% with a 95% confidence level (Table A4.7).

Table 4.6: p-values for modified clay (coal and Banana composition) samples.

Time	p-values
Day 1	0.005
Day 2	0.003
Day 3	0.005
Day 4	0.003
Day 5	0.004
Day 6	0.002
Day 7	0.011
Week 2	0.017
Week 3	0.012
Week 4	0.008
Month 2	0.066
Month 3	0.064

At month 2 and 3 there were no significant differences between control and treated samples. with an increase in gasification temperature, the potassium retention ratio drops, the ability of coal ash to fix potassium during biomass gasification is astounding, blending coal ash with biomass can significantly raise the temperature at which it melts (Zhang et al., 2018).

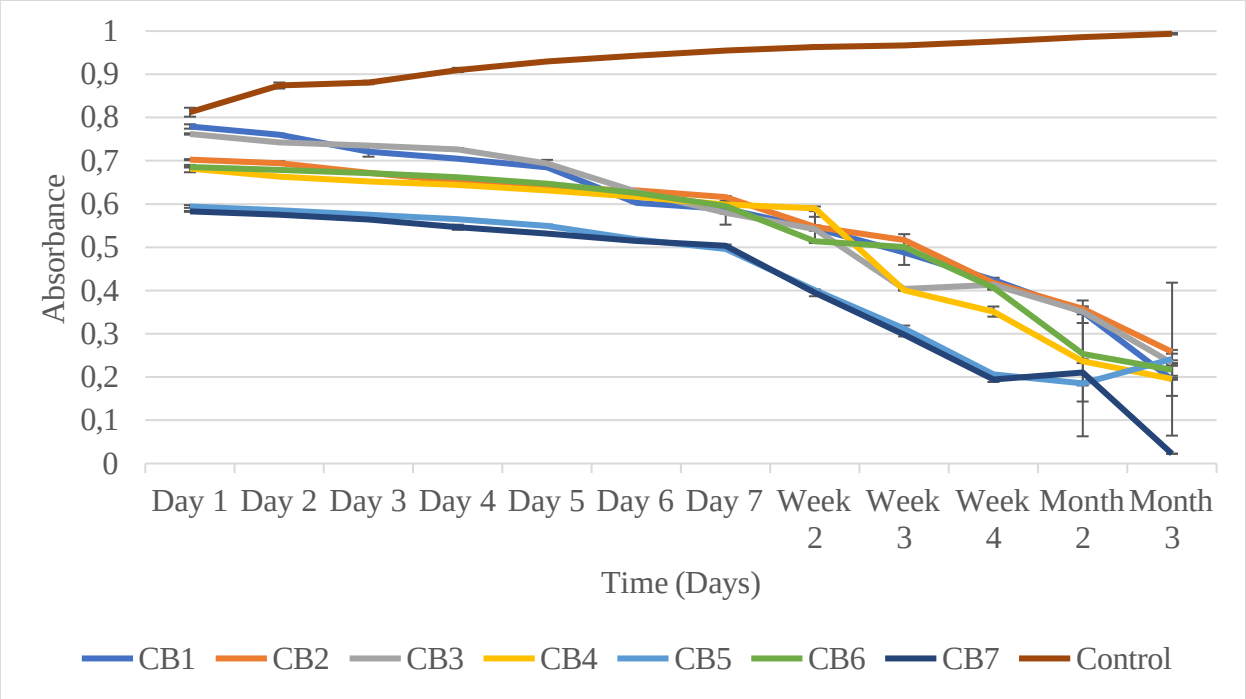

Figure 4.5: The inhibition of cyanobacteria growth treated modified clay (coal + banana) brick.

The inhibitory effect of modified clay (coal +banana) brick matrix was quite distinct as this showed a gradual decrease in growth of cyanobacteria, from day 1, to week 4 and month 3 in the study. The major composition of banana matrix was potassium (Jaishankar et al., 2014). This inbition may be attributed to the presencnce of potassium.

4.2 Evaluation of modified clay (coal) bricks in inhibition of laboratory blue-green algae/cyanobacteria suspension

4.2.1 The effect of pH

There was variation in pH for control and treated samples during the study period (Figure 4.6). The alkaline pH for the control samples showed an upward increase from 9.500 to 9.800. The alkaline pH for Coal bricks showed a decrease and increase but was consistent between 7 and 8.5. This alkaline pH is expected since algal blooms in alkaline conditions (Vadlamani et al., 2017).

The single factor ANOVA showed significant differences ($p<0.05$) between the untreated samples and the control sample (Table A4.8). on days 3, 7, and 2 of week 2, with $p=0.026$, $p=0.024$, and $p=0.023$. This could imply that the addition of coal powder in the bricks influenced the pH of the water (Table 4.9).

Table 4.9: P-value for coal pH

Period	P value
Day 3	0.026
Day 7	0.026
Week 7	0.024

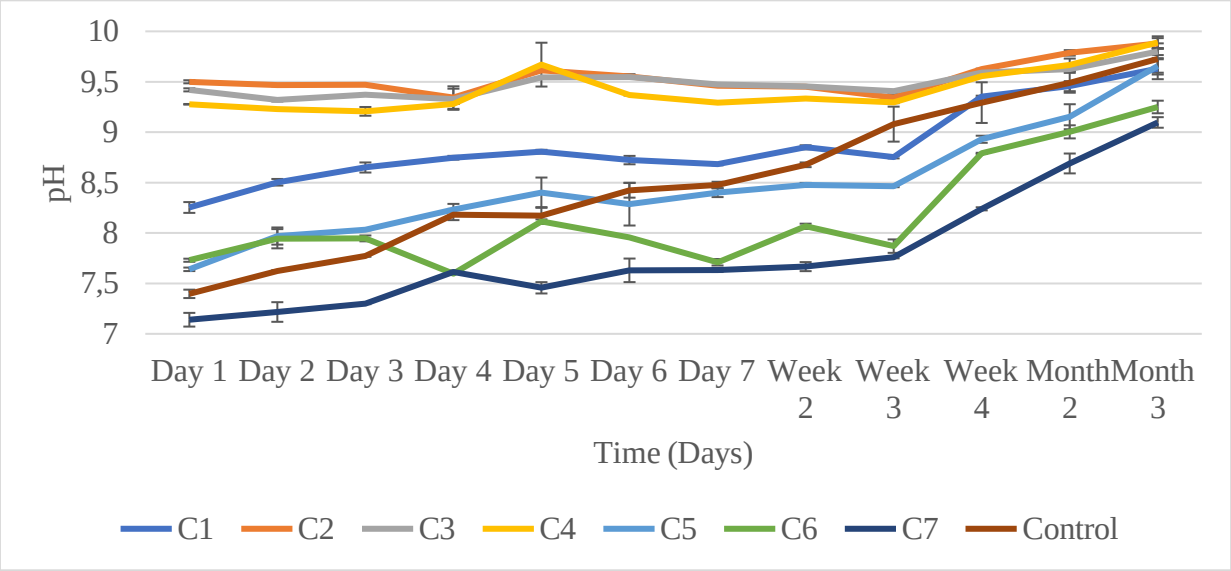

Figure 4.6: pH value cultured water samples. Whiskers reflect standard error.

4.2.2 The effect of electrical conductivity

There was variation in the electrical conductivity (EC) for control and treated samples during the study period (Figure 4.7). The EC for the control samples showed an upward increase, from (1084.7 µS/cm to 1603.7 µS/cm). The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.10) at Day 1 to Months 3**.** The electrical conductivity (EC) reflects the number of soluble salts in water. Conductivity reflects how many soluble salts there are in water.

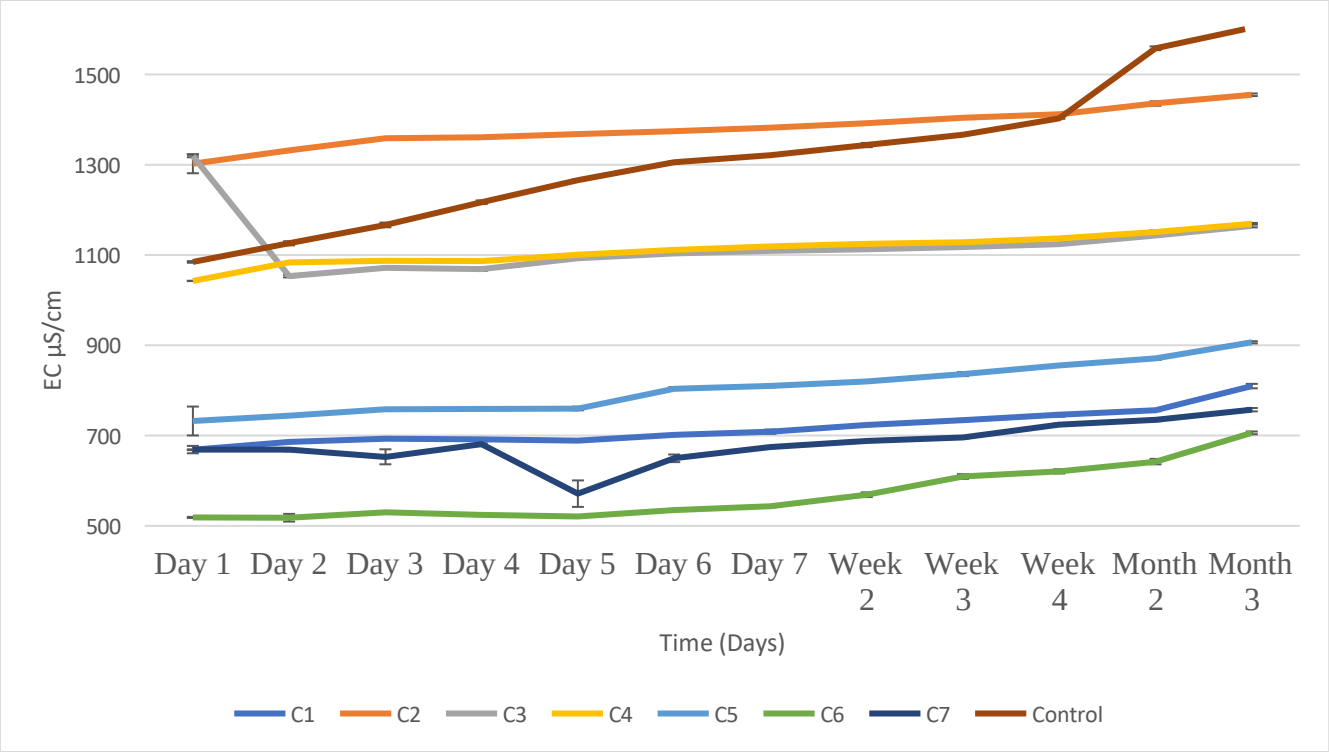

Figure 4.7: EC value cultured water samples. Whiskers reflect standard error.

4.2.3 The effect of total dissolved solids

There was variation in total dissolved solids (TDS) for control and treated samples during the study period (Figure 4.8). The TDS for the control samples showed an upward increase, from 1017.3 to 1403.7. The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.11) at day1 to month 3. The total dissolved solids (TDS) are a crucial parameter in water quality for drinking purposes and aquatic environments (Naubi et al., 2016). (Naubi et al., 2016). They give the water flavor while lowering its palatability. The mechanical abrasive impact of suspended particles can lead to biological imbalances in the aquatic environment (Munni et al., 2015). The water quality decreases as a result of high TDS loads.

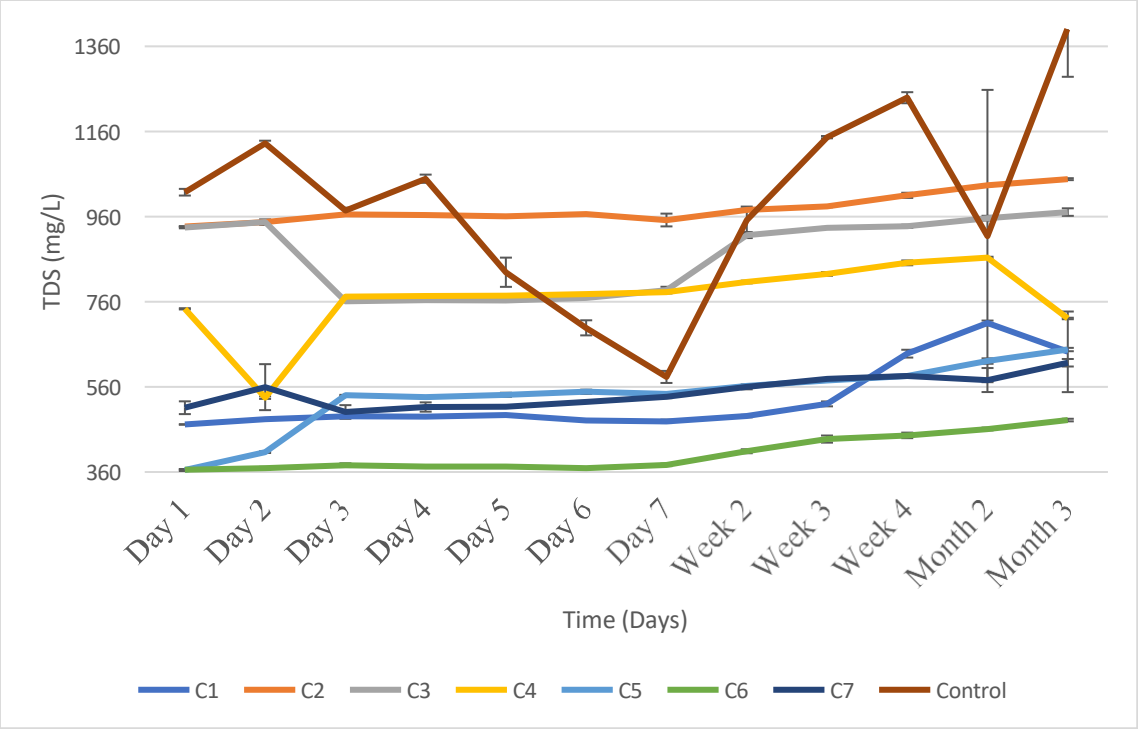

Figure 4.8: The effect of TDS.

4.2.4 The effect of temperature

There was variation in temperature for control and treated samples during the study period (Figure 4.9). The temperature for the control samples showed an upward increase, from 20.10 to 30.20. The temperature for modified clay (Coal) bricks showed the decrease and increase but consistent between 20 and 38°C**.** The ideal temperature range for freshwater aquaculture is between 25–40°C (Munni et al., 2015). Conclusion: All trials' temperatures were appropriate for aquatic species to survive. The single factor ANOVA showed significant differences ($p<0.05$) (Table A4.12).

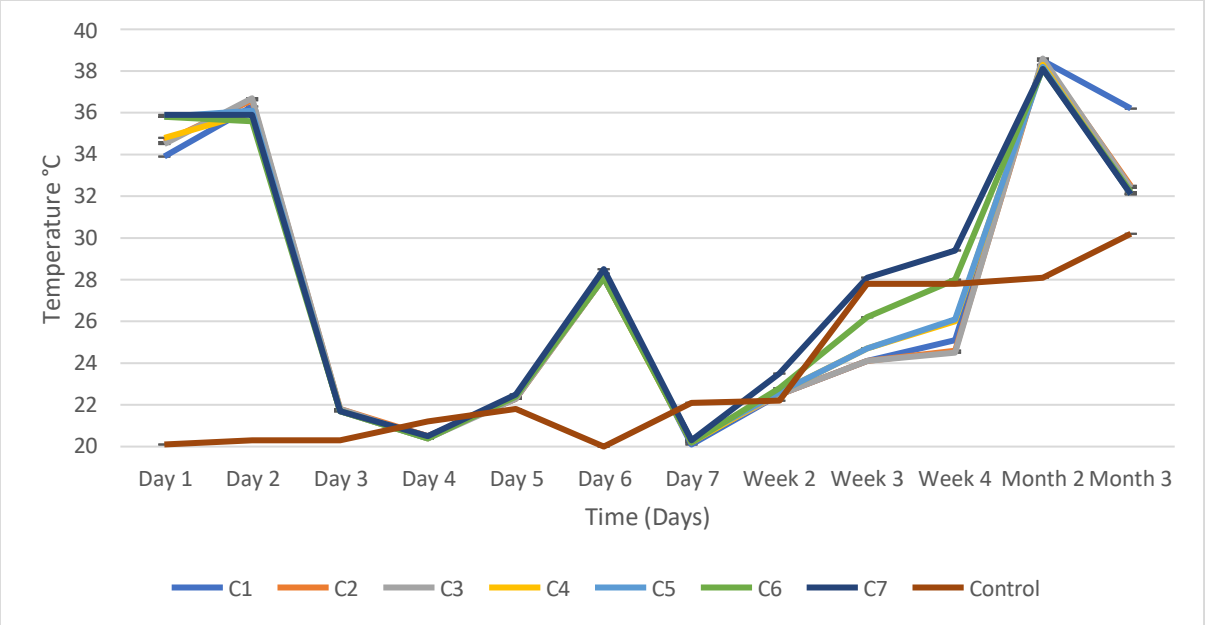

Figure 4.9: Temperature value cultured water samples. Whiskers reflect standard error.

4.2.5 The effect of Coal

During the study period, the growth of cyanobacteria in both control and treated samples increased (Figure 4.10). Cyanobacteria cells are significantly increased over a 24-hour period from day 0, 1, 2, 3, 4, 5, 6, and 7, week 2, week 3, week 4, month 2 and month 3. From day 1 to month 3, the single factor ANOVA revealed a significant difference between untreated samples C1, C2, C3, C4, C5, C6, and C7 (Table A4.13). From day 1 to month 3, the p value was less than 5% with a 95% confidence level (Table 4.14). The control experiment received no chemical treatment, and the algal blooms in those containers continued to grow. It was discovered that, in addition to nutrients in the growth media, the coal matrix also contributed nutritionally to the growth of cyanobacteria.

Table 4.14: p-values for modified clay (coal) samples.

Time (in days)	p-values
Day 1	0.011
Day 2	0.004
Day3	0.006
Day 4	0.003
Day 5	0.002
Day 6	0.023
Day 7	0.017
Week 2	0.004
Week 3	0.003
Week 4	0.006
Month 2	0.004
Month 3	0.004

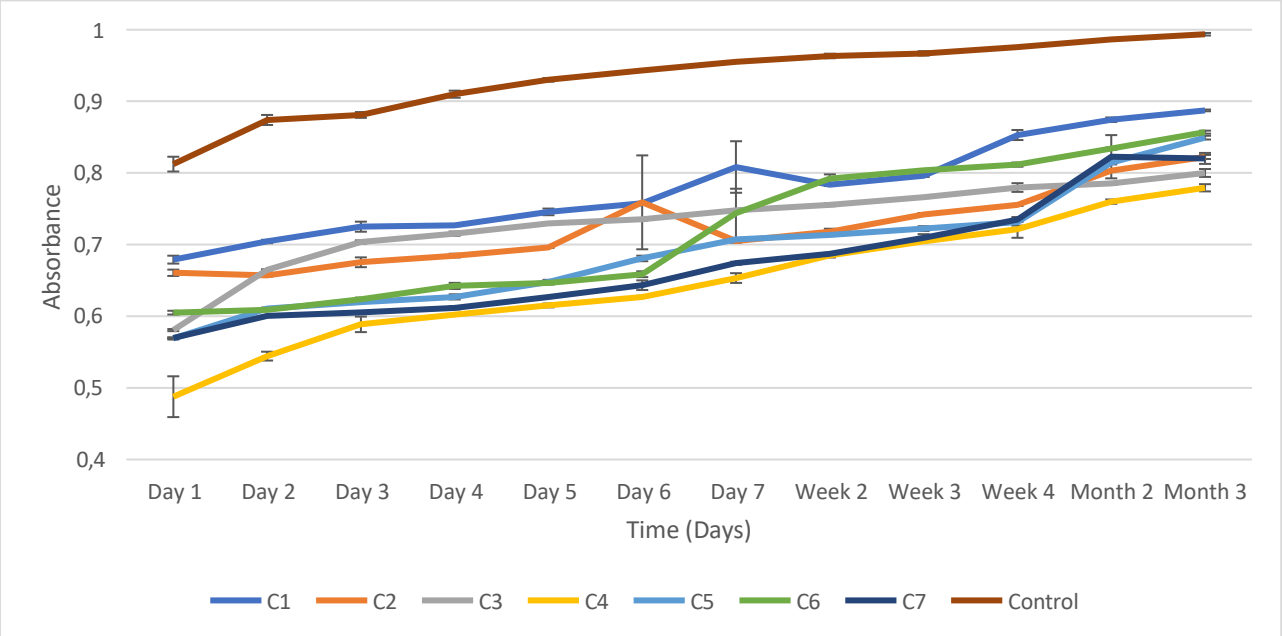

Figure 4.10: The inhibition of cyanobacteria growth treated with modified clay (Coal) brick.

4.3 Evaluation of modified clay (banana) bricks in inhibition of laboratory blue-green algae/cyanobacteria suspension

4.3.1 The effect of pH

There was variation in pH for control and treated samples during the study period (Figure 4.11). The alkaline pH for the control samples showed an upward increase, from 7.4 to 9.7. The alkaline pH for Coal and Banana bricks showed the decrease and increase but consistent between 7 and 7.5. This alkaline pH is expected since algal blooms in alkaline conditions (Vadlamani et al., 2017).

The single factor ANOVA showed significant differences ($p<0.05$) between the untreated samples and the control sample (Table A4.15) on day 7. In other days p was non-significant because $p>0.05$. A pH level greater than 7 indicates an increasing amount of alkalinity in the solutions. Notably, pH level influences other potential toxicants, such as heavy metal bioavailability.

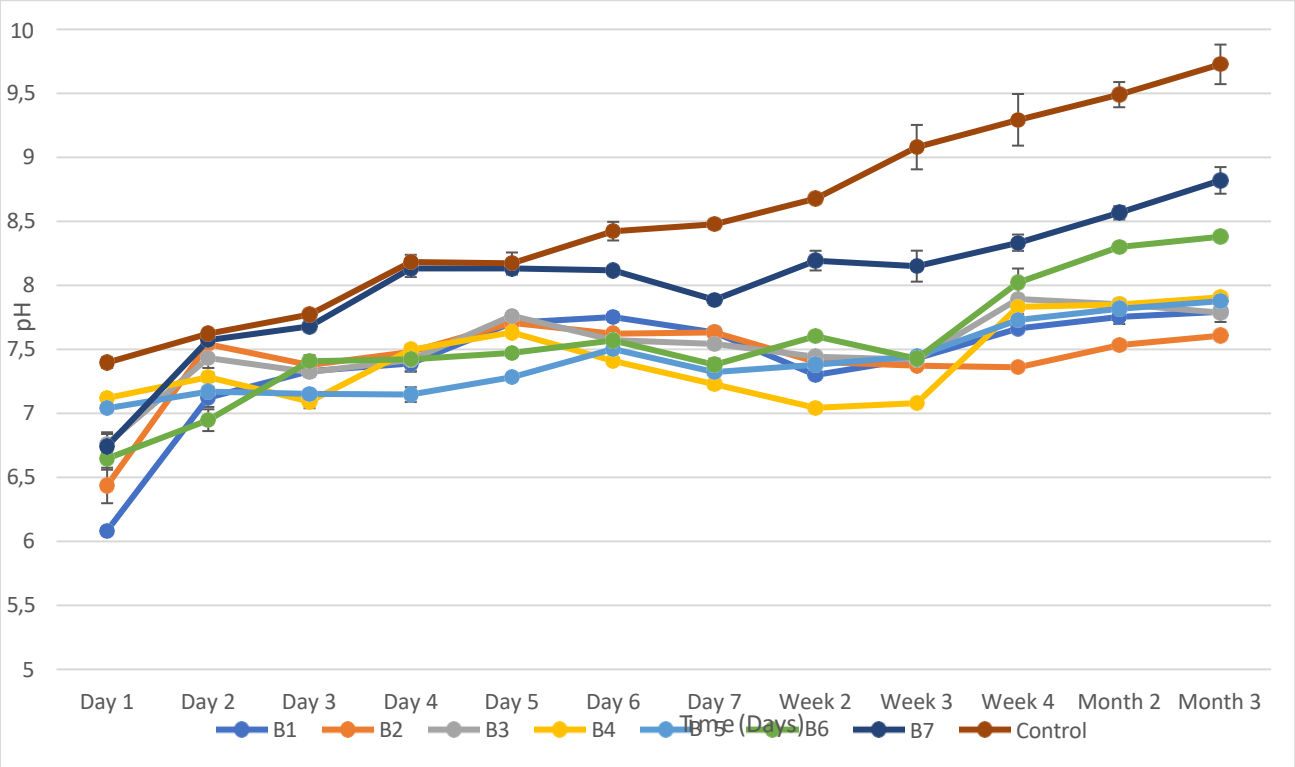

Figure 4.11: pH value cultured water samples. Whiskers reflect standard error.

4.3.2 The effect of electrical conductivity

There was variation in the electrical conductivity (EC) for control and treated samples during the study period (Figure 4.12). The EC for the control samples showed an upward increase, from (1084.7 µS/cm to 1603.7 µS/cm). The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.16) at Day 1 to Months 3**.** The electrical conductivity (EC) reflects the number of soluble salts in water. Conductivity reflects how many soluble salts there are in water.

It further displays the water's nutritional composition. In the control samples, high EC values (1084.7 S/cm to 1603.7 S/cm) have been noted (Figure 4.12). The BG 11 produced medium, which had a high concentration of salts according to the Kruger and Eloff (1977) preparation process, and the removal of salts from the clay matrix are likely to blame for the high values.

The single factor ANOVA revealed significant differences ($p>0.05$), indicating that it was not statistically significant. In general, the electrical conductivity profiles of the treated and control samples are similar. Electrical conductivity has no effect.

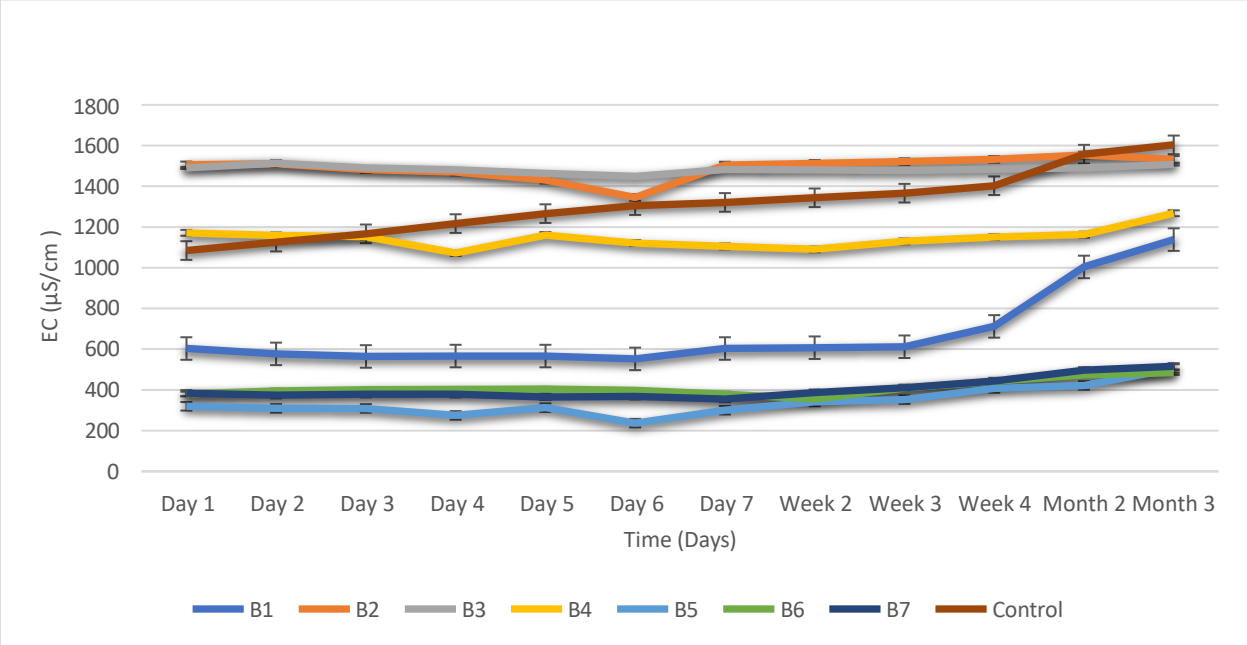

Figure 4.12: EC value cultured water samples. Whiskers reflect standard error.

4.3.3 The effect of total dissolved solids

There was variation in total dissolved solids (TDS) for control and treated samples during the study period (Figure 4.13). The TDS for the control samples showed an upward increase, from 1017.3 to 1403.7. The single factor ANOVA showed non-significant differences ($p>0.05$) between the treated samples and the control sample (Table A4.17) at day 1 to month 3. The TDS for banana bricks and control was non-significant, and the single factor ANOVA showed significant differences ($p>0.05$) (Table A4.15). Overall conclusion, the treated and control samples both have similar profiles with regard to total dissolved solids. There is no effect of total dissolved solids.

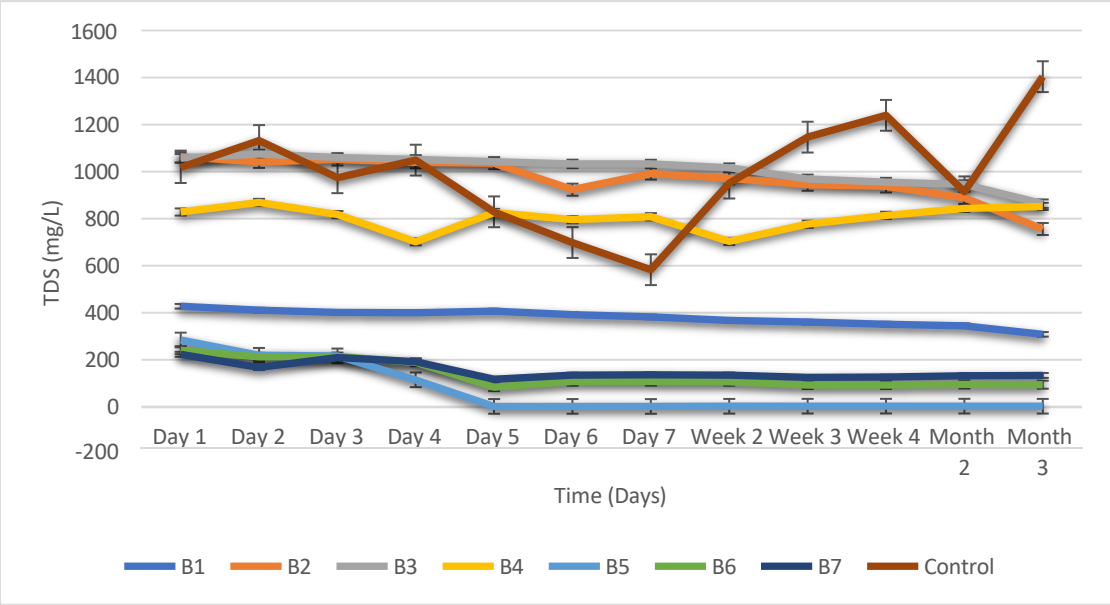

Figure 4.13: TDS value cultured water samples. Whiskers reflect standard error.

4.3.4 The effect of temperature

There was variation in temperature for control and treated samples during the study period (Figure 4.14). The temperature for the control samples showed an upward increase, from 20.10 ^{o}C to 30.20^{o}C. The modified clay (Banana) bricks' temperature showed variation but consistency between 20 and 38 ^{o}C. Temperatures between 25 and 40 °C are ideal for freshwater aquaculture (Munni et al., 2015). The single factor ANOVA revealed significant differences ($p<0.05$) in all samples, including treatment and control (Table A4.18). The temperature for all experiments was found to be suitable for aquatic organisms to survive on (Pack et al., 2014). In conclusion, the temperature profiles of the treated and control samples are similar. The temperature has no effect.

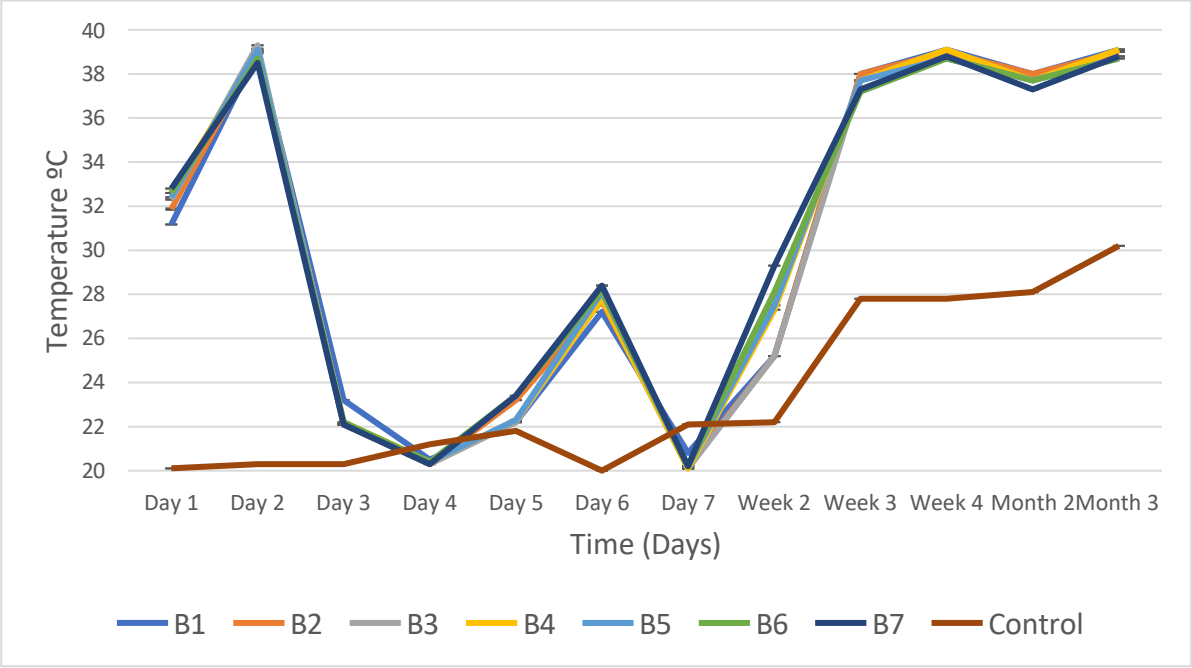

Figure 4.14: Temperature value cultured water samples. Whiskers reflect standard error.

4.3.5 The effect of banana material

There was variation in growth of cyanobacteria for both control and treated samples during the study period (Figure 4.15). The cyanobacteria cells are significantly decreasing for 24 hours test period from day 0, 1, 2, 3, 4, 5, 6 and 7, week 2, week 3, week 4, month 2 and month 3. The single factor ANOVA showed a significant difference between untreated samples B1, B2, B3, B4, B5, B6, B7 and control from day 1 to month 3 (Table A4.19). The p value was below 5% and is 95% confidence level from day 1 to month 3 (Table 4.20). Since no inhibitory substance was used in the control experiment, the algal blooms in those containers continued to grow unabatedly on the control samples. This was most likely caused by the container still receiving adequate light. and had nutrients to enable growth (Beyl, 2018). On the other hand, the modified clay (banana) bricks had various levels of banana content and these modified clay bricks did inhibit the growth of cyanobacteria.

Table 4.20: p-value for Banana samples

Time (days)	p-values
Day 1	0.017
Day 3	0.007
Day 4	0.012
Day 5	0.007
Day 6	0.009
Day 7	0.001
Week 2	0.003
Week 3	0.001
Week 4	0.015
Month 2	0.015
Month 3	0.001

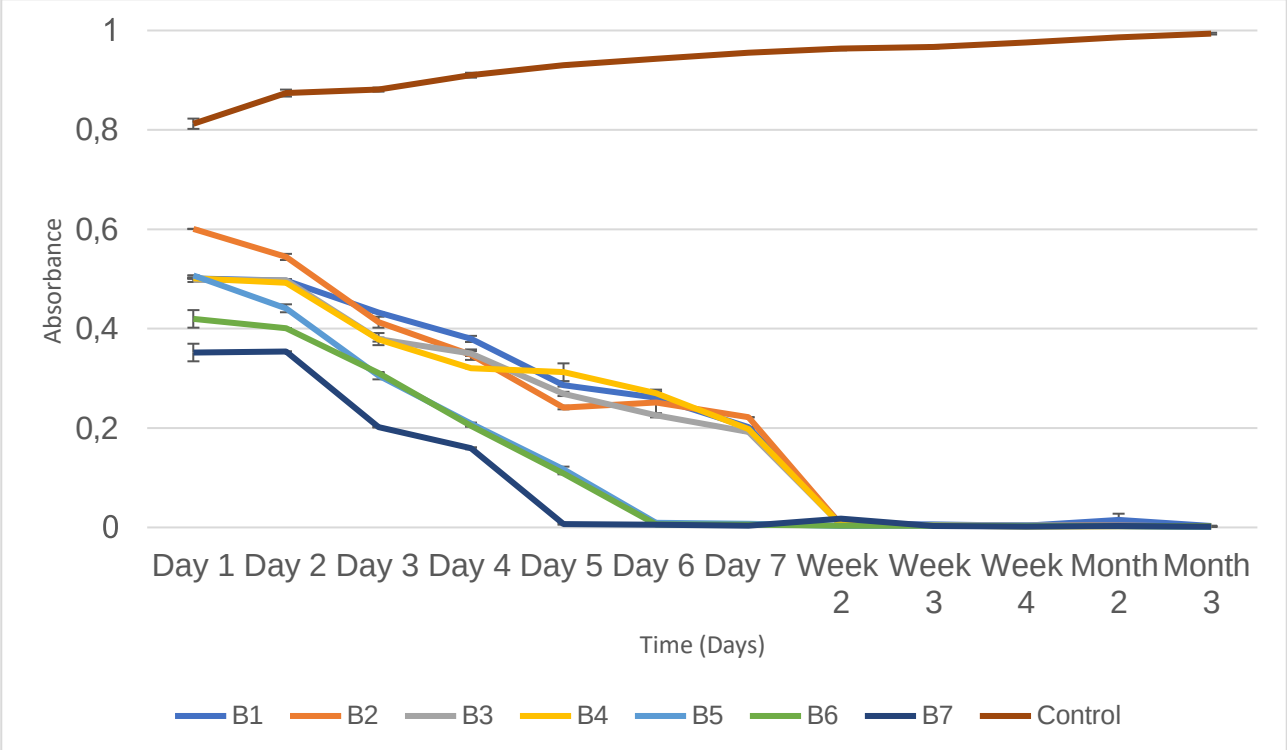

Figure 4.15: The inhibition of cyanobacteria growth treated with modified clay (Banana) bricks.

Overall, the treated and control samples had different profiles in terms of banana (potassium). Banana (potassium) influenced the growth of cyanobacteria. As a result, while this technology has the potential to be used to control harmful algal blooms, more research must be conducted using other potassium-containing materials.

4.3.6 Mineral composition of banana and how potassium inhibits the growth of cyanobacteria.

The mineral composition of banana peel was phosphorus, iron, calcium, magnesium, and sodium, zinc, copper, potassium, and manganese. Banana (matrix) did inhibit the growth of cyanobacteria because it consists of high levels of potassium (Jaishankar et al., 2014).

Potassium came from banana peels which were dried and made into powder and then added to clay material to form the brick. This brick was then sun-dried, and oven dried. The oven has high temperatures (180 ^{o}C) which ashes the banana matrix in the modified clay brick. The potassium in this modified clay brick is now available in the water body through dissolution.

The proposed mechanism of potassium in inhibiting the growth of cyanobacteria is as follows, according to Ni et al. (2023), algae develop, the photosynthetic system, antioxidant enzyme system, and cell membrane of algae cells Potassium involved in rapid extrusion of sodium from *Microcystis* cells leading to disturbance in ion balance and osmoticum which were primarily destroyed in order to prevent algae growth, according to an investigation on the inhibitory impact, the appropriate dosage for *Microcystis* aeruginosa inhibition rate was up to 95%, and the antioxidant enzymes in algal cells were gradually inactivated by the long-term action of Tea Polyphenols (TP) which consist of high potassium rate (Shukla &Rai, 2006).

There was an observation of 50% reduction in the 10-day yield of cultured *M. aeruginosa* in pond water supplemented with 1 and 3 mM Potassium salt (Parker et al., 1997). Allelochemicals, which contain potassium have the advantages of being environmentally safe and highly effective at inhibiting algal growth, have been an innovative and promising method of controlling algae blooms (Zhu et al., 2021).

4.2 Conclusion

The modified (coal and banana) bricks showed a gradual inhibition or gradual decrease in the growth of cyanobacteria from week 1 to month 3. Whereas the modified clay (coal) bricks did not inhibit blue-green Algae/Cyanobacteria during the same period. The modified clay (Banana) brick had an inhibitory effect on the growth of cyanobacteria during the same period. The inhibitory action may be due to presence of potassium in the banana material. As a result, while this technology has the potential to be used to control harmful algal blooms, more research will be conducted using other potassium-containing materials. The control experiment received no chemical treatment, and the algal blooms in those containers continued to grow. This was most likely due to the presence of light, adequate nutrients, and the absence of an inhibitory agent in the container.

CHAPTER 5: INVISTEGATION OF PHYSICAL CHARACTERISTIC OF BRICKS

Abstract

This chapter focus on investigating bricks in terms of their physical characteristics (water absorption, compressive strength, sound test, impact test, efflorescence, dimensional test tolerance and wrappage). Since none of the bricks' water absorption exceeded 20%, they can all be used for building because they won't weaken the overall structure of the brickwork by absorbing water from cement mortar, B5 did not qualify to be used for building because it had a 29.41% rate, which is more than the required 20%. The Control brick strength was hard to crush compared to the other bricks, the compressive strength was 22,85 N/mm^2 to crush the brick, followed by the C5 which consist of clay and coal and its compressive strength was 22.24 N/mm^2, the coal +Banana (CB5) compressive strength was 20,07 N/mm^2. The Banana brick (B5) had 11.96 N/mm^2 and it was easy to deform. The color changes after firing, before firing, the B5, B6 were Greyish to reddish while the bats from C4, C5, C6, C7, CB4, CB5, CB6 and CB7 were greyish to blackish due to the presence of Coal powder. Due to the strength of the bricks and the rate of material they are made of, CB4 and B4 shattered during the impact test, indicating that it is not recommended to use them for construction. Bricks used in the efflorescence test control and C4 were undamaged and could be used in construction. After being immersed in water for 24 hours, bricks were allowed to dry , and none of them displayed the surface-coating salts. When placed in the miniature bricking machine that was used for bricking, banana-containing bricks' width and breath were lowered due to the banana matrix's tendency to shrink when burned. The coal and banana bricks from CB1 to CB7 also showed a diversity of morphologies, some convex and others concave. The control and coal bricks did not shrink after heating, although some of them showed concavity and others convexity.

Keywords: Water Absorption, Strength of the brick, Color of the bricks, Impact test and Efflorescence.

5.1 Physical Test on Bricks

5.1.1 Water absorption

To find out how much moisture the brick absorb, a water absorption test was performed. The bricks should not be utilized for building if they absorb more than 20% of the weight of dry brick because this lowers the strength of the brickwork (Albitar et al.,2017). In this test control, five sun- dried and oven baked bricks from various samples were taken, their weights were recorded.

Formula

Water absorption=(W1-W)/WX100

Table 5.1: Water Absorption Rate

S	W1(g)	W(g)	%Water Absorption
B1	220.45	217.77	1.23
B2	193.49	190.82	1.40
B3	198.27	192.24	3.14
B4	169.81	155.03	9.53
B5	157.83	121.96	29.41
CB1	157.38	134.65	16.88
CB2	181.13	158.93	13.97
CB3	165.48	142.86	15.83
CB4	167.38	156.66	6.84
CB5	205.83	201.54	2.13
C1	228.93	225.95	1.32
C2	225.96	222.09	1.74
C3	233.30	229.58	1.62
C4	235.40	230.94	1.93
C5	230.83	226.72	1.81
C	210.28	203.57	3.29

Since none of the bricks' water absorption exceeded 20%, they can all be used for building because they won't weaken the overall structure of the brickwork by absorbing water from cement mortar. B5 did not qualify to be used for building because it had a 29.41% rate, which is more than the required 20%.

5.1.2 Compressive strength/ crushing strength.

Compressive strength refers to the ability of a certain material or structural element to withstand loads that reduce the size of that material, or structural element, when applied (Priyadarshini et al., 2021). A force was applied to the top and bottom of a test sample, until the sample fractures or is deformed. Brick is classified as first-class brick, , second, third, sun dried, and fly ash brick (Priyadarshini et al., 2021).

Compressive Strength of Brick	
Types of Brick	Strength
First Class Brick	105 kg/cm^2
Second Class Brick	70 kg/cm^2
Common Building Brick	35 kg/cm^2
Sun Dried Brick	15 - 25 kg/cm^2
Fly Ash Brick	90 - 100 kg/cm^2

Figure 5.1: Compressive strength of bricks (Priyadarshini et al., 2021).

5.1.3 The implications of load, pressure, and temperature

The bricks' colour and strength are the bricks' most important properties due to the common belief that red color is an indicator of a good indicator of good quality bricks, the color formed after firing process is an important quality indicator **(**Brencich et al., 2021**).** During the firing process the occurrence of high temperature the compressive strength and color of the brick changed. The load of the bricks depends on the material of the brick and the strength of the bricks, the pressure also depends on the strength of a brick. if the break is weak, less pressure will be applied to fracture a brick in (Table 5.2).

Compressive strength=Nmm^2 ,**1 kg/cm2 = 0.0981 N/mm^2**

Compressive=max.load at failure (in N)/Area of specimen (in mm^2)

Table 5.2: The load of samples, pressure, and temperature

Sample	Load	Pressure	Temperature
CB5	0.47	0.122	23.5
B5	0.57	0.251	22.5
C5	0.62	0.110	24.26
Control	0.64	0.501	25.25

The control brick strength was hard to crush compared to the other bricks, the compressive strength was 22,85 N/mm^2 to crush the brick, followed by the C5 which consist of clay and coal and its compressive strength was 22.24 N/mm^2, the coal +banana (CB5) compressive strength was 20,07 N/mm^2. The Banana brick (B5) had 11.96 N/mm^2 and was easy to deform (Table 5.3).

Table 5.3: Compressive Strength

Samples	Actual size	Load(T)	Compressive strength
C5	226.72 kg	0.110	22.24 N/mm^2
B5	121.96 kg	0.251	11.96 N/mm^2
CB5	204.54 kg	0.122	20.07 N/mm^2
Control	232.97 kg	0.501	22.85 N/mm^2

5.1.3 Color test

Clay brick that had been properly kilned (burnt) was crimson in hues throughout.. but they were black ones that are well kilned but change to black because they were consisted of coal powder. The firing temperature greatly impacts the color and shrinkage of clay bricks (Brencich et al., 2021**).** Figure 5.2 shows the color changes after firing. Before firing, the B5, B6 were Greyish to reddish while the bats from C4, C5, C6, C7, CB4, CB5, CB6 and CB7 were greyish to blackish due to the presence of coal powder. However, all the control, B4, B3, B2, B1, C1, C2, C3, CB1, CB2 and CB3 had a bright red color after firing and these could be attributed to the fact that all these bricks had high iron oxide content (Poornima et al., 2022). The bricks that contained lot of banana powder (B6, B7, CB6 and CB7) were burning and turning in black color and were not of good quality or strong.

Figure 5.2: Color of the bricks, **A**-firing of modified clay brick, **B**-overheated modified bricks

5.1.4 Impact test

Bricks were dropped onto the ground during this experiment from a height of one meter. The figure used control, B4, CB4, and C4 for the impact test. CB4 and B4 were broken based on the bricks' strength and the material rate they contain (Table 5.4), indicating that they are unsuitable for construction. The control and C4 bricks were not broken and can be used for building/construction (Thakur et al., 2022).

Table 5.4: Impact of the bricks.

Modified clay brick	Impact
C4	**
B4	*
CB4	*
Control	**

Key *broken, **not broken.

Figure 5.3: Impact test of the bricks **(A)** before the impact and **(B)** after the impact

5.1.5 Efflorescence

A fine, white, powdery coating of salts that are soluble in water is left behind on the surface of brickwork called efflorescence (Nhabih et al., 2020**).** Soluble salts should not be present in a good brick. In this experiment, bricks were submerged in water for 24 hours before being given time to completely dry off and no brick showed the white fine powdery coating of salts on the surface when dried (Figure 5.4).

Figure 5.4: Efflorescence of clay bricks, **A**-submerged bricks, **B**-exposed modified bricks

Table 5.5: Efflorescence Test.

Modified clay brick	Impact
C1	**
C7	**
B1	**
B7	*
CB1	**
CB7	*
Control	**

Key *efflorescence, **no efflorescence

5.1.6-Dimensional tolerance test

The brick's size and shape were examined using a test for dimension tolerance. Four bricks were placed in an arrangement along its length, width, and height for this test in (Figure 5.5). The dimensions were contrasted with one another and with the normative dimensions (Hjerm et al.,2020). Bricks that contain Banana shrink because of Banana matrix when burnt, the width and the Breath was reduced when placing it to the miniature bricking machine that was used for bricking.

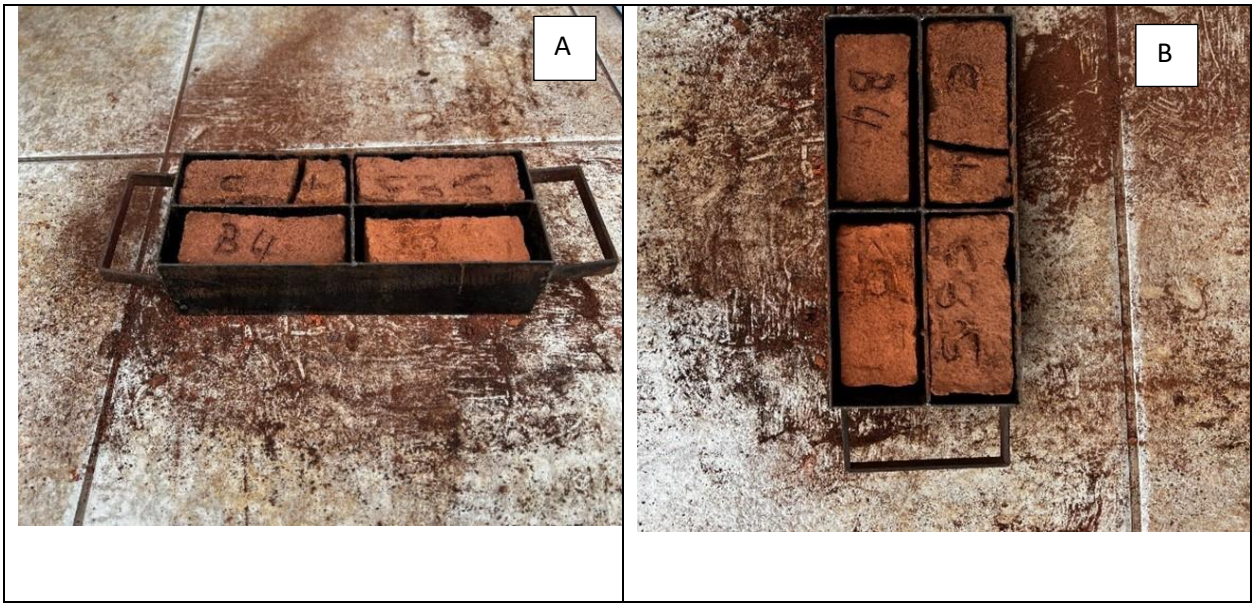

Figure 5.5: Size and shapes of the bricks. **A**-width of modified bricks, **B**-height, and length of the modified bricks.

5.1.7 Wrappage test

The results of a wrappage test revealed how level the brick surface was. Wrappage should be within acceptable bounds if the bricks are fired and cooled properly (Figure 5.6). Concave and convex wrappage tests are used. The morphologies of the modified clay (banana B1 to B7) bricks ranged from concave to convex, based on the proportion of bananas in the clay used to make them. After heating, some other bricks shrink, get smaller, and change shapes and sizes as a result of the heat. From CB1 to CB7, the coal and banana bricks also displayed a variety of shapes, with some being convex and others concave. After heating, the coal and control bricks did not contract, but some of them exhibited concavity and others convexity (Peng et al., 2021).

Figure 5.6: Wrappage test of the bricks. **A-**fired modified bricks**,B-**level of the modified bricks.

5.2 Conclusion

The bricks produced using conventional compaction techniques showed water absorption of less than 20%, all of the bricks can be used for construction because they won't weaken the overall structure of the brickwork by absorbing water, with the exception of B5, which did not qualify because its rate was higher than the required 20% at 29.41%. C5 (22.24 N/mm^2), B5 (11.96 N/mm^2), CB5 (20.07 N/mm^2), and control (28.85 N/mm^2) all have compressive strengths. The type of material used to make the bricks determines their strength. Examination revealed that the bricks' color had changed because of thermal stress high temperature. Due to the strength of the bricks and the rate of material they are made of, CB4 and B4 shattered during the impact test, indicating that it is not recommended to use them for construction. Bricks used in the efflorescence test control and C4 were undamaged and could be used in construction. After being immersed in water for 24 hours, bricks were allowed to dry , and none of them displayed the surface- coating salts. When placed in the miniature bricking machine that was used for bricking, banana- containing bricks' width and breath were lowered due to the banana matrix's tendency to shrink when burned. The coal and banana bricks from CB1 to CB7 also showed a diversity of morphologies, some convex and others concave. The control and coal bricks did not shrink after heating, although some of them showed concavity and others convexity. In future it is important to use a machine to produce the bricks since in this study the bricks were hand-made.

CHAPTER 6: THE LEVELS OF SELECTED METALS IN THE MODIFIED CLAY BRICKS

Abstract

This chapter focuses on analysing the metal content of the modified clays (with either banana biomass and coal and or with coal and or with banana biomass). In comparison to other bacteria, cyanobacteria have unusually high metal requirements for optimal growth This is partly because these bacteria use metal cofactors like cytochromes, plastocyanin, and chlorophyll rings in their oxygenic photosynthetic electron transfer mechanism. Given that cyanobacteria have greater metal requirements and are therefore more vulnerable to trace nutrient limitation, an adequate supply of trace metals is necessary to ensure optimal development, even though there is a large overall supply of metal, metal shortages frequently happen. Overall supply of metal, metal shortages frequently happen. The C5, B5, CB5, and control modified clay bricks were chosen because they were of good quality and contained moderate treatment for algae and cyanobacteria. The metal average Mg per mg of changed clay bricks was calculated based on an examination using inductively coupled plasma atomic emission spectroscopy (ICP-OES) and Microsoft Excel (2019)**.** The findings for potassium demonstrated strong support for the null hypothesis between the modified bricks, with p = 0.00 indicating a significant difference between the B5 and C5, CB5, and control. B5 demonstrated a significant potassium (K) metal content followed by CB5 and control had no content of potassium. The one-way ANOVA statistical analysis for B5, C5. CB5 and control p = 0.02 in Manganese (Mn), there was no difference, manganese level in control bricks was higher than in other modified bricks. The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.02, where there is a significant difference between these bricks, the CB5 modified brick demonstrated that it has a higher Sodium (Na) metal content than other bricks and that it also has a higher sodium metal content than other bricks. The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.04, where there is a significant difference between these bricks Nickel (Ni) metal content was higher in the control bricks than in the other changed bricks.

Keywords: Metal content, Modified clay Bricks, ICP-OES, ANOVA and Cyanobacteria

6.1 Quantification of heavy metals

The glass beakers were, washed with deionized water and then dried for about five minutes in an oven set to 150 ^{o}C. The four clay bricks (C5, B5, CB5, and Control) based on the clay bricks composition and ratio were selected for test, were first crushed in a jaw crusher, and then ground in a mill. Each milled sample was weighed at 500 g using a Radwag analytical balance and was added to the decomposition beakers (Kumar and Sinha, 2020). A few drops of deionized water, 45 ml of HCl, and 15 ml of HNO_3 (Nitric acid) were added for moisture (Lian. The beakers were then set on the hot plate for approximately 90 and 120 min, this is the prepared sample to decompose. After decomposition, the samples were left to cool down at room temperature. The prepared samples were then paper filtere, mixed with deionized water in a 100 ml volumetric flask, shaken, and allowed to settle for two hours.

The metal contents were analyzed by ICP-OES (Optima 8000, Perkin Elmer, Canada) after acid digestion. Leaching of heavy metals except that the brick pieces were acid-digested and then analyzed for major and trace metals. Few metals – K, Na, Mn, and Ni in the results which was replicated. The 5 standard metal solution, blank and four types of samples which is CB5, B5, C5 and control, were analyzed in (A4.21).

The output of ICP-OES was used to calculate mean metal content (mg per liter). The mean and confidence interval were calculated using the Microsoft Office excel (2019). The final metal content was express as mg per g as the following expression (1).

Metal concentration (mg per gram) = $\frac{x*V}{m}$ equation 1

Where x mg per L is average reading from the ICP-OES instrument, V is volume (L) 0.1 litre (100 ml volumetric flask where the acid digest was added) and m is mass weighed (g) of ground material was acid-digested.

6.2 The effect of metals on the growth of cyanobacteria

6.2.1 The role played metals in the growth of Cyanobacteria

The majority of organisms require the elements calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), and zinc (Zn) to function. Some species just need other elements as barium (Ba), cobalt (Co), nickel (Ni), strontium (Sr), and vanadium (V). Compared to other bacteria, cyanobacteria have unusually high metal requirements for optimal growth (Facey et al.,2019). This is partly because these bacteria use metal cofactors like cytochromes, plastocyanin, and chlorophyll rings in their oxygenic photosynthetic electron transfer mechanism. Given that cyanobacteria have greater metal requirements and are therefore more vulnerable to trace nutrient limitation, an adequate supply of trace metals is necessary to ensure optimal development, even though there is a large overall supply of metal, metal shortages frequently happen (Parsy et al., 2022).

The metal content of the modified clay (C5, B5, CB5) and control bricks were analysed (Table 6.1). Based on an examination using inductively coupled plasma atomic emission spectroscopy (ICP-OES) and Microsoft Excel (2019), the metal average mg per g of the bricks was calculated in (equation 1).

Table 6.1: p-value and metal average of modified clay bricks

Modified clay brick	Average mg/g			
	K	Mn	Na	Ni
B5	13.0	2.4	3.1	0.3
C5	8.2	2.9	3.1	0.3
CB5	12.4	1.7	16.6	1.682
Control	-0.0	3.5	2.9	10.6
P values	0.00	0.02	0.02	0.04

6.2.2 The statistical analysis of one-way ANOVA

The statistical analysis of one-way ANOVA was done to assess the significance and acceptability of the null hypothesis for the experiment between B5 and C5, CB5 and control for metal that were found in the bricks which were potassium, manganese, sodium and Nickel. A cyanobacteria growth curve graph was drawn based on the average of metal content in (Figure 6.1). The potassium data demonstrated strong agreement between the B5 and C5, CB5 and control where there was a significant difference between two variables and p = 0.00, the modified bricks. B5 showed high metal content of Potasium (K) then followed by CB5, C5 the control did not have potassium content at all. There was no difference between B5 and CB5 in terms of Manganese (Mn) content. Secondly, the one-way ANOVA statistical analysis for B5, C5. CB5 and control p = 0.02, where the distinction between these bricks was significant. Thus, manganese was present in different rate on clay bricks.

Control bricks was having high content of Manganese than other modified bricks. The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.02, where the distinction between these bricks is significant. Thus, sodium (Na**)** was present in different rate on clay bricks. CB5 modified brick showed that it consists of high metal content of sodium than other bricks. The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.04, where the distinction between these bricks is significant. Thus, Nickel (Ni**)** was present at a different rate in clay bricks and control showed higher metal content of Nickel than other modified bricks.

6.3 Conclusion

The results for potassium showed strong evidence against the modified bricks as a null hypothesis, with p = 0.00 suggesting a substantial difference between the B5, C5, CB5, and control. After B5, CB5 showed a substantial Potasium (K) metal level, whereas the control had negligible potassium content. The statistical one-way ANOVA analysis for B5, C5, and D5. In terms of manganese (Mn), there was no difference between CB5 and control at p = 0.02; the manganese level in control bricks was higher than that in other modified bricks.

The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.02, where there is a significance difference between these bricks, the CB5 modified brick demonstrated that it has a higher Sodium (Na) metal content than other bricks and that it also has a higher sodium metal content than other bricks. The one-way ANOVA statistical analysis for B5, C5, CB5 and control p = 0.04, where there is a significance difference between these bricks Nickel (Ni) metal content was higher in the control bricks than in the other changed bricks.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

It is clear from the study's findings that the defined goals were met and that the issues with algae/cyanobacteria on clay bricks were successfully resolved. The study's physiochemical parameters, in BG 11 media, the conditions including temperature, pH, TDS, EC, and dissolved solids were all favorable for blue-green algae growth and survival. Bricks with Banana powder, coal, coal + banana, and control were placed in containers and monitored for three months. During the monitoring period, the BG 11 media where the banana powder bricks were placed saw daily inhibiting the algae/cyanobacteria, Algae/Cyanobacteria in the containers were dying every day, but in the container containing coal bricks, they were surviving, the control with no inhibiting agent showed growth.

This study used a one-way ANOVA statistical method and identified banana as having a pure significant value. This was also viewed favorably because the treatment materials showed excellent inhibitory capacity during the trial period. The banana and coal samples and the control samples, on the other hand, the findings of the ANOVA analysis showed that from the first day of the experiment to the last day of the third month, demonstrated substantially different values of absorbance.

Although the absorbance for the treated (banana) samples was decreasing, the graph for the untreated and control samples was increasing when compared to control, other samples of coal, coal + Banana, and other samples. The absorbance indicated a substantial change from days 0 through 1, 3, 4, 5, 6, and 7 of the 24-hour test period, which drastically inhinbit the number of cyanobacteria cells. From day 1 through month 3, the single factor ANOVA revealed a significant difference between the treated samples B1, B2, B3, B4, B5, B6, B7, and the control. The following values were used to calculate the p value: 0.017, 0.007, 0.012, 0.007, 0.009, 0.001, 0.003, 0.001, 0.015, 0.015, and 0.001. which, from day 1 to month 3, was less than 5% and had a 95% confidence level. Day 2 $p>0.05$ indicates a single factor, which non-significant difference was revealed using ANOVA.

The simultaneous confidence level was controlled while comparing all group pairs using the turkey mini tab. This group has a small degree of separation, which is represented by letters, where a

single letter denotes a significant component that cannot be treated like other groups do who share letters.

For the 24-hour test period starting on days 0 through 1, 2, 3, 4, 5, and 7 and weeks 2 through 4, the absorbance drastically decreased for coal and banana bricks. From day 1 to week 4, the single factor ANOVA revealed a significant difference between the treated samples CB1, CB2, CB3, CB4, CB5, CB6, and the CB7. From day 1 to week 4, the p value ranged from 0.005 to 0.003, 0.005 to 0.003, 0.004 to 0.002, 0.011 to 0.017, 0.012 to
0.008, all of which were below the 5% threshold. From 2 and 3 month there was no significance difference.

While the algae kept growing, it was discovered that the absorbance on the untreated samples and control samples was rising, and the graph for these samples was ascending. A considerable growth in cyanobacteria cells was seen over a test period of 24 hours starting on days 0, 1, 2, 3, 4, 5, and 7. During weeks 2, 3, and 4, as well as months 2 and 3, the absorbance greatly varied. From day 1 to month 3, the single factor ANOVA revealed a significant difference between the untreated samples C1, C2, C3, C4, C5, C6, and the C7. From day 1 to month 3, the p value was 0.011, 0.004, 0.005, 0.003, 0.023, 0.018, 0.004, 0.003, 0.006, 0.004, and 0.004, less than 5% and within the 95% confidence interval.

According to this study, using modified clay (banana) brick was effectively inhibited the growth of algae and cyanobacterial species, within one week. The modified (coal + banana) brick had a gradual inhibition of up to three months. Based on the findings, the modified clay bricks had variable banana content. The major element in banana was potassium has been shown to have a high content, which is supported by ICP-OES results. Additionally, banana bricks were discovered to have a higher potassium concentration than other bricks when compared to other metals (Ni, Na, and Mn).

Clay bricks' physical characteristics, including their resistance to water absorption, were examined. The bricks produced using conventional compaction techniques showed water absorption of less than 20%, all of the bricks can be used for construction because they won't weaken the overall structure of the brickwork by absorbing water, except for B5, which did not qualify because its rate was higher than the required 20% at 29.41%.

C5 (22.24 N/mm^2), B5 (11.96 N/mm^2), CB5 (20.07 N/mm^2), and control (28.85 N/mm^2) all have compressive strengths. The type of material used to make the bricks determines their strength. Examination revealed that the bricks' color had changed because of thermal stress high temperature.

Due to the strength of the bricks and the rate of material they are made of, CB4 and B4 shattered during the impact test, indicating that it is not recommended to use them for construction. Bricks used in the efflorescence test control and C4 were undamaged and could be used in construction. After being immersed in water for 24 hours, bricks were allowed to dry fully, and none of them displayed the surface-coating salts. When placed in the miniature bricking machine that was used for bricking, banana-containing bricks' width and breath were lowered due to the banana matrix's tendency to shrink when burned. The coal and banana bricks from CB1 to CB7 also showed a diversity of morphologies, some convex and others concave. The control and coal bricks did not shrink after heating, although some of them showed concavity and others convexity.

7.2 Recommendations

According to the study's findings, it is strongly advised to use modified clay bricks B5 because it has a moderate rate of powder from Banana peels to prevent the growth of algae and cyanobacteria. The application of modified clay bricks B5 on clay bricks is said to be useful at inhibiting behavior because the banana raw material is available as the banana fruit trees are grown in Vhembe district. Further research is required to determine whether the modified clay brick B5 when used to build the pavement, during the rainy season would the brick surface withstand the rigous of human use.The modified clay bricks (banana) alone or (coal + banana) bricks may be used in the control of algae/cyanobacteria blooms in aqueous environment also. The use of modified clay brick B5 in inhibiting the growth of cyanobacteria, does this result in lysis of the cyanobacteria cells And or result in release of cyanotoxins, thus further research is required to determine this.

REFERENCES

Abubakar I, Birnin Yauri A.U, Faruq U.Z, Noma S.S and Sharif N. (2015). Characterization of Dabagi clay deposit for its ceramic potential. African Journal of Environmental science and Technology, 8(8), 455-459.

Ahmad Z.A, Bakar A, Hisham B, Johari I and Said S. (2017). Effects of the Firing Temperature on Microstructure and Physical Properties of Clay Bricks from Berdas (Malaysia): Science of Sintering, University of Sains Malaysia, Penang, 42 pp. 245-254.

Akintoye, O. A., Obi, C. N., Etim, O. A., Olorundami, T., Ukata, S. U., & Harrison, U. (2014). Seasonal variation in the physicochemical characteristics of surface water in Etche River, Niger Delta Area of Nigeria. Journal of Environmental Science, Toxicology and Food Technology, 8(7), 01-07.

Albitar, M., Ali, M. M., Visintin, P., & Drechsler, M. (2017). Durability evaluation of geopolymer and conventional concretes. Construction and Building Materials, 136, 374-385.

Anderson, C. R., Moore, S. K., Tomlinson, M. C., Silke, J., & Cusack, C. K. (2015). Living with harmful algal blooms in a changing world: strategies for modeling and mitigating their effects in coastal marine ecosystems. In Coastal and marine hazards, risks, and disasters (pp. 495-561).

Anyakora, S. V. (2022). evaluation of banana peel powder as natural coagulant for treatment of wastewater. nau department of civil engineering final year project & postgraduate portal.

Anyasi, T. A., Jideani, A. I., & Mchau, G. A. (2015). Morphological, physicochemical, and antioxidant profile of noncommercial banana cultivars. Food science & nutrition, 3(3), 221-232.

Asadi, A., Verma, A., Yang, K., & Mejabi, B. (2017). Wastewater treatment aeration process optimization: A data mining approach. Journal of environmental management, 203, 630-639.

Asenahabi, B. M. (2019). Basics of research design: A guide to selecting appropriate research design. International Journal of Contemporary Applied Research, 6(5), 76-89.

Ayandiran, T. A., Fawole, O. O., & Dahunsi, S. O. (2018). Water quality assessment of bitumen polluted Oluwa river, South-Western Nigeria. Water Resources and Industry, 19, 13-24.

Babisk, M. P., Amaral, L. F., da Silva Ribeiro, L., Vieira, C. M. F., do Prado, U. S., Gadioli, M. C. B., & da Costa Garcia Filho, F. (2020). Evaluation and application of sintered red mud and its incorporated clay ceramics as materials for building construction. Journal of Materials Research and Technology, 9(2), 2186-2195.

Baldwin, N. A., & Whitton, B. A. (1992). Cyanobacteria and eukaryotic algae in sports turf and amenity grasslands: a review. Journal of applied phycology, 4, 39-47.

Beyl, C. A. (2018). Getting started with tissue culture media preparation, sterile technique, and laboratory equipment. In Plant tissue culture concepts and laboratory exercises (pp. 21-38).

Bhattacharya, D., & Price, D. C. (2020). The algal tree of life from a genomics perspective. In Photosynthesis in algae: biochemical and physiological mechanisms (pp. 11-24). Springer, Cham.

Blankenship, R. E. (2021). Molecular mechanisms of photosynthesis. John Wiley & Sons.

Brencich, A., Lątka, D., Matysek, P., Orban, Z., & Sterpi, E. (2021). Compressive strength of solid clay brickwork of masonry bridges: Estimate through Schmidt Hammer tests. Construction and Building Materials, 306, 124494.

Brick Industry Association. (2016). Technical Notes on Brick Construction: Specifications for and Classification of Bricks. The Clay Brick Association, Reston,1-56.

Brynard, S. T. (2014). Educating Learners with Down Syndrome Successfully: A Narrative Journey. Mediterranean Journal of Social Sciences, 5(20), 1888.

Cao, S. C., Jang, J., Jung, J., Waite, W. F., Collett, T. S., & Kumar, P. (2019). 2D micromodel study of clogging behavior of fine-grained particles associated with gas hydrate production in NGHP-02 gas hydrate reservoir sediments. Marine and petroleum geology, 108, 714-730.

Carreira-Casais, A., Otero, P., Garcia-Perez, P., Garcia-Oliveira, P., Pereira, A. G., Carpena, M., & Prieto, M. A. (2021). Benefits and drawbacks of ultrasound-assisted extraction for the recovery of bioactive compounds from marine algae. International Journal of Environmental Research and Public Health, 18(17), 9153.

Charai, M., Sghiouri, H., Mezrhab, A., Karkri, M., & El Hammouti, K. (2020). Comparative study of a clay before and after fired brick-making process. Materials Today: Proceedings, 31, S103-S108.

Chen, Y. M., Gao, J. B., Yuan, Y. Q., Ma, J., & Yu, S. (2016). Relationship between heavy metal contents and clay mineral properties in surface sediments: Implications for metal pollution assessment. Continental Shelf Research, 124, 125-133.

Coletti, C., Cultrone, G., Maritan, L., & Mazzoli, C. (2016). How to face the new industrial challenge of compatible, sustainable brick production: Study of various types of commercially available bricks. Applied Clay Science, 124, 219-226.

Cultrone, G, Sebastián E, Elert K, De La Torre MJ, Cazalla O, Rodriguez-Navarro C (2015). Influence of mineralogy and firing temperature on the porosity of bricks. Journal of the European Ceramic Society 24(3), 547–564.

Dai, S., Finkelman, R. B., French, D., Hower, J. C., Graham, I. T., & Zhao, F. (2021). Modes of occurrence of elements in coal: A critical evaluation. Earth-Science Reviews, 222, 103815.

Delali, A. H. (2017). Durability of Locally Produced Burnt Clay Bricks, Ghana: Kwame Nkurmah University of Science and Technology, 1-30.

Dondi, M., Mazzanti, F., Principi, P., Raimondo, M., & Zanarini, G. (2016). Thermal conductivity of clay bricks. Journal of materials in civil engineering, 16(1), 8-14.

El-Sheekh, M. M., Abdeldaim, M. M., Gharib, S. M., & El-Ksassas, H. (2019). Green technology applications for algal bloom control. In Handbook of algal technologies and phytochemicals (pp. 13-21). CRC Press.

Facey, J. A., Apte, S. C., & Mitrovic, S. M. (2019). A review of the effect of trace metals on freshwater cyanobacterial growth and toxin production. Toxins, 11(11), 643.

Fernandes Lourenco, P.B, and Castro, F (2016). Ancient Clay Bricks: Manufacture and properties, 188-193.

Fritsch, F. E. (2016). The role of algal growth in the colonization of new ground and in the determination of scenery. Geographical. GeoConference, 367-374 (2017).

Ghadage, S. J., & Karande, V. C. (2019). The distribution of blue-green algae (Cyanobacteria) from the paddy fields of Patan and Karad tehsils of Satara District, Maharashtra, India. Journal of Threatened Taxa, 11(14), 14862-14869.

Ghernaout, D., Elboughdiri, N., Ghareba, S., & Salih, A. (2020). Coagulation Process for Removing Algae and Algal Organic Matter—An Overview. Open Access Library Journal, 7(4), 1-21.

Glibert, P. M. (2021). Tiny Phytoplankton: The Most Powerful Organisms of the Oceans. Frontiers for Young Minds, 9.

Graziani, L., Quagliarini, E., & D'Orazio, M. (2016). TiO2-treated different fired brick surfaces for biofouling prevention: Experimental and modelling results. Ceramics International, 42(3), 4002-4010.

Gumbo, J. R., & Cloete, T. E. (2011). Light and electron microscope assessment of the lytic activity of *Bacillus* on *Microcystis aeruginosa*. African Journal of Biotechnology, 10(41), 8054-8063.

Hassan, H. F., Hassan, U. F., Usher, O. A., Ibrahim, A. B., & Tabe, N. N. (2018). Exploring the potentials of Banana (*Musa Sapietum*) peels in feed formulation. International Journal of Advanced Research in Chemical Science, 5(5), 10-14.

Hentati, O., Abrantes, N., Caetano, A. L., Bouguerra, S., GonçaAlves, F., Römbke, J., & Pereira, R. (2015). Phosphogypsum as a soil fertilizer: ecotoxicity of amended soil and elutriates to bacteria, invertebrates, algae and plants. Journal of hazardous materials, 294, 80-89.

Hjerm, M., Eger, M. A., Bohman, A., & Fors Connolly, F. (2020). A new approach to the study of tolerance: Conceptualizing and measuring acceptance, respect, and appreciation of difference. Social Indicators Research, 147(3), 897-919.

Huertas, M.J., López-Maury, L., Giner-Lamia, J., Sánchez-Riego, A.M., & Florencio, F.J., (2014). 'Metals in Cyanobacteria: Analysis of the Copper, Nickel, Cobalt and Arsenic Homeostasis mechanism 45(4), 865–886.

Ibrahim, A. M. M. (2017). Harmful algal blooms and toxins'impact on the environment. Blue Biotechnology Journal, 2(2), 251.

Innocent, N.A (2018). college of science and technology school of engineering department of civil, environmental and geomatic engineering.

Iqbal, R., Tedjakusuma, T., & Dwinandha, D. (2020). Initial study of the Coix lachryma-jobi application in reducing algal growth in eutrophic lake. In E3S Web of Conferences (Vol. 148, p. 05009). EDP Sciences.

Jaishankar, M., Mathew, B. B., Shah, M. S., & Gowda, K. R. S. (2014). Biosorption of few heavy metal ions using agricultural wastes. Journal of Environment Pollution and Human Health, 2(1), 1-6.

Jayakumar, S. (2015). Studies on the Biodeterioration of Concrete Marine Algae (Doctoral dissertation, Department of Civil engineering, Pondicherry Engineering College).

Jin, X., Bi, L., Lyu, T., Chen, J., Zhang, H., & Pan, G. (2019). Amphoteric starch-based

bicomponent modified soil for mitigation of harmful algal blooms (HABs) with broad salinity tolerance: Flocculation, algal regrowth, and ecological safety. Water research, 165, 115005.

Jipanin, S. J., Shaleh, S. M., Lim, P. T., Leaw, C. P., & Mustapha, S. (2019, November). The monitoring of harmful algae blooms in Sabah, Malaysia. In Journal of Physics: Conference Series (Vol. 1358, No. 1, p. 012014).

Kassinger, R. (2019). Slime: How Algae Created Us, Plague Us, and Just Might Save Us. Houghton Mifflin Harcourt,10(3).

Kempster, P. L., Hattingh, W. H. J., & Van Vliet, H. R. (1980). Summarized water quality criteria (No. DWAFEC-TR--108). Department of Water Affairs.

Kochian, L. V., Piñeros, M. A., Liu, J., & Magalhaes, J. V. (2017). Plant adaptation to acid soils: the molecular basis for crop aluminum resistance. Annual Review of Plant Biology, 66, 571-598. Koroth S. (2017). Evaluation and improvement of frost durability of clay bricks. Natural library of Canada, Quebec, 12-29.

Kolodziejek, N., & Tey, L. S. (2016). Characteristics and Challenges of Brick Making Industry in Central Aceh, Silih Nara, Indonesia. Journal of Advanced Research Design, 18(1), 20-34.

Krüger, G. H. J., & Eloff, J. N. (1977). The influence of light intensity on the growth of different *Microcystis* isolates. Journal of the Limnological Society of southern Africa, 3(1), 21- 25.

Kumar, A., & Sinha, S. (2022). Performance of multiwalled carbon nanotube doped fly ash-based clay bricks. International Journal of Advanced Technology and Engineering Exploration, 9(89), 536.

Lian, X., Piao, S., Li, L. Z., Li, Y., Huntingford, C., Ciais, P., & McVicar, T. R. (2020). Summer soil drying exacerbated by earlier spring greening of northern vegetation. Science advances, 6(1), eaax0255.

Lin, C. (2018). Drinking water quality and human health: impact of harmful algae and water pipe

breaks.

Mani, D., Patil, D. J., Dayal, A. M., & Prasad, B. N. (2015). Thermal maturity, source rock potential and kinetics of hydrocarbon generation in Permian shales from the Damodar Valley basin, Eastern India. Marine and Petroleum Geology, 66, 1056-1072.

Maruyama, S., & Kim, E. (2020). Evolution of photosynthetic eukaryotes; current opinion, perplexity, and a new perspective. In Symbiosis: Cellular, Molecular, Medical and Evolutionary Aspects (pp. 337-351). Springer, Cham.

Matthijs, Hans CP, Daniel Jančula, Petra M. Visser, and Blahoslav Maršálek. "Existing and emerging cyanocidal compounds: new perspectives for cyanobacterial bloom mitigation." Aquatic ecology 50 (2016): 443-460.

Mesquita, E., Martini, R., Alves, A., Antunes, P., & Varum, H. (2018). Non-destructive characterization of ancient clay brick walls by indirect ultrasonic measurements. Journal of Building Engineering, 19, 172-180.

Mouiya, M., Bouazizi, A., Abourriche, A., Benhammou, A., El Hafiane, Y., Ouammou, M., ... & Hannache, H. (2019). Fabrication and characterization of a ceramic membrane from clay and banana peel powder: application to industrial wastewater treatment. Materials Chemistry and Physics, 227, 291-301.

Mueller, H. Maithy, S. Prajapati, S. Bhatta, A.D. and Shrestha, B.L. (2018). Green Brick Making Manual, Nepal: Hillside press, 1-34.

Munni, M., Fardus, Z., Mia, M., & Afrin, R. (2015). Assessment of Pond Water Quality for Fish Culture: A Case Study of Santosh Region in Tangail, Bangladesh. Journal of Environmental Science and Natural Resources ,6(2),157-162.

Munyai, L. F. (2019). Remote sensing of Harmful Algal Blooms (HABs) in water bodies of Vhembe district area, Limpopo province, South Africa (Doctoral dissertation).

Munyai, L. F. (2019). Remote sensing of Harmful Algal Blooms (HABs) in water bodies of Vhembe district area, Limpopo province, South Africa (Master dissertation), University of Venda.

Munyai, T. R., Sonqishe, T., & Gumbo, J. R. (2019). Algae colonisation of brick pavement at the University of Venda: A potential slippery hazard. Jàmbá: Journal of Disaster Risk Studies, 11(2).

Murray, H.H. (2015). Applied Clay Mineralogy Today and Tomorrow. Department of Geological Sciences. Bloomington: Indiana University, 39-48.

Murray, H.H. (2018). Applied Clay Mineralogy Today and Tomorrow. Department of Geological Sciences. Bloomington: Indiana University, 39-48.

Nagarajaiah, S. B., & Prakash, J. (2017). Chemical composition and antioxidant potential of peels from three varieties of banana. Asian Journal of Food and Agro-Industry, 4(1), 31-46.

Naubi, I., Zardari, N. H., Shirazi, S. M., Ibrahim, N. F. B., & Baloo, L. (2016). Effectiveness of Water Quality Index for Monitoring Malaysian River Water Quality. Polish Journal of Environmental Studies, 25(1).

Nhabih, H. T., Arat, K. K., & Haidi, A. S. (2020). Methods of processing efflorescence of clay Brick. Int J Scient Eng Sci, 3, 48-56.

Nkansah, M. A., Korankye, M., Darko, G., & Dodd, M. (2016). Heavy metal content and potential health risk of geophagic white clay from the Kumasi Metropolis in Ghana. Toxicology reports, 3, 644-651.

Özyiğitoğlu, G. Ç. (2020). Environmental Significance of Lichens and Biodeterioration. In Environmental Concerns and Sustainable Development, 247-277. Springer, Singapore.

Pack, E. C., Kim, C. H., Lee, S. H., Lim, C. H., Sung, D. G., Kim, M. H., & Kim, S. W. (2014). Effects of environmental temperature change on mercury absorption in aquatic organisms with respect to climate warming. Journal of Toxicology and Environmental Health, Part A, 77(22-24), 1477-1490.

Padhan, D., Rout, P. P., Kundu, R., Adhikary, S., & Padhi, P. P. (2021). Bioremediation of heavy metals and other toxic substances by microorganisms. Soil Bioremediation: An Approach Towards Sustainable Technology, 285-329.

Parker, D. L., Kumar, H. D., Rai, L. C., & Singh, J. B. (1997). Potassium salts inhibit growth of the cyanobacteria *Microcystis* spp. in pond water and defined media: implications for control of microcystin-producing aquatic blooms. Applied and Environmental Microbiology, 63(6), 2324-2329.

Parsy, A., Guyoneaud, R., Lot, M. C., Baldoni-Andrey, P., Périé, F., & Sambusiti, C. (2022). Impact of salinities, metals and organic compounds found in saline oil & gas produced water on microalgae and cyanobacteria. Ecotoxicology and Environmental Safety, 234, 113351.

Peng, Y., Peng, X., Yang, M., Shi, H., Wang, W., Tang, X., & Wu, Y. (2020). The performances of the baking-free bricks of non-sintered wrap-shell lightweight aggregates from dredged sediments. Construction and Building Materials, 238, 117587.

Perold, J. (2017). Ceramic Parameters in the Financial Evaluation of Brick Clay Deposits, With Reference to Two South African Examples., South Africa: University of Pretoria, 20-31.

Philpotts, A. R., & Ague, J. J. (2022). Principles of igneous and metamorphic petrology. Cambridge University Press.

Poornima, V., Venkatasubramani, R., Sreevidya, V., & Chandrasekar, P. (2022). Study on properties of bio-bricks. Materials Today: Proceedings, 49, 2103-2109.

Priyadarshini, M., Giri, J. P., & Patnaik, M. (2021). Variability in the compressive strength of non-conventional bricks containing agro and industrial waste. Case Studies in Construction Materials, 14, e00506.

Rakhimova, N. R. (2020). A review of calcined clays and ceramic wastes as sources for alkali-activated materials. Geosystem Engineering, 23(5), 287-298.

Ramanan, R., Kim, B. H., Cho, D. H., Oh, H. M., & Kim, H. S. (2016). Algae–bacteria interactions: evolution, ecology and emerging applications. Biotechnology advances, 34(1), 14-29.

Roark, A., Grossman, E. L., & Lebold, J. (2016). Low seasonality in central equatorial Pangea during a late Carboniferous highstand based on high-resolution isotopic records of brachiopod shells. Geological Society of America Bulletin, 128.

Roberts, V. A., Vigar, M., Backer, L., Veytsel, G. E., Hilborn, E. D., Hamelin, E. I., & Yoder, J. S. (2020). Surveillance for harmful algal bloom events and associated human and animal illnesses—One health harmful algal bloom system, United States, 2016–2018. Morbidity and Mortality Weekly Report, 69(50), 1889.

Rolls, R. J., Baldwin, D. S., Bond, N. R., Lester, R. E., Robson, B. J., Ryder, D. S., & Watson, G. A. (2017). A framework for evaluating food-web responses to hydrological manipulations in riverine systems. Journal of Environmental Management, 203, 136-150.

Rosli, N. R., Yusuf, S. M., Sauki, A., & Razali, W. M. R. W. (2019). Musa sapientum (Banana) peels as green corrosion inhibitor for mild steel. In Key Engineering Materials (Vol. 797, 230-239). Trans Tech Publications Ltd.

Rubidge B. (2015). Palaeontological desktop study of student residence development, Thohoyandou, Limpopo Province, Emnarentia, Johannesburg, 2-13.

Saad, A., & Atia, A. (2014). Review on freshwater blue-green algae (Cyanobacteria): occurrence, classification and toxicology. Biosci. Biotechnol. Res. Asia, 11(3), 1319-1325.

Šál,J., Nováková, P., Proceedings of 17th International Multidisciplinary Scientific Janatian, N., Olli, K., Cremona, F., Laas, A., & Nõges, P. (2020). Atmospheric stilling offsets the benefits from reduced nutrient loading in a large shallow lake. Limnology and Oceanography, 65(4), 717-731.

Sha, S., Rong, G., Chen, Z., Li, B., & Zhang, Z. (2020). Experimental evaluation of physical and mechanical properties of geothermal reservoir rock after different cooling treatments. Rock Mechanics and Rock Engineering, 53(11), 4967-4991.

Shen, X., Zhang, H., He, X., Shi, H., Stephan, C., Jiang, H., & Eichholz, T. (2019). Evaluating the treatment effectiveness of copper-based algaecides on toxic algae *Microcystis aeruginosa* using single cell-inductively coupled plasma-mass spectrometry. Analytical and bioanalytical chemistry, 411(21), 5531-5543.

Singh, K. (2016). Microbial and enzyme activities of saline and sodic soils. Land Degradation & Development, 27(3), 706-718.

Tang, G., Müller, M., Rios, A., & Sennrich, R. (2018). Why self-attention? a targeted evaluation of neural machine translation architectures. arXiv preprint arXiv:1808.08946.

Thakur, A., Senthil, K., & Singh, A. P. (2022). Evaluation of concrete bricks with crumb rubber and polypropylene fibres under impact loading. Construction and Building Materials, 315, 125752.

Thomas, L. (2012). Coal Geology, 2nd Edition. 2nd ed. Chennai: John Wiley & Sons, 137-151. Brozovsky Jiri. (2015). Determination of the Compressive Strength of Calcium Silicate Bricks by Combined Non-Destructive Method. The Scientific World Journal. Hindawi, Brno, 2014(829194) ,1-6.

Uddin, M. K. (2017). A review on the adsorption of heavy metals by clay minerals, with special focus on the past decade. Chemical Engineering Journal, 308, 438-462.

Vadlamani, A., Viamajala, S., Pendyala, B., & Varanasi, S. (2017). Cultivation of microalgae at extreme alkaline pH conditions: a novel approach for biofuel production. ACS Sustainable Chemistry & Engineering, 5(8), 7284-7294.

van der Boog, C. G., Dijkstra, H. A., Pietrzak, J. D., & Katsman, C. A. (2021). Double-diffusive mixing makes a small contribution to the global ocean circulation. Communications Earth & Environment, 2(1), 1-9.

Vu, H. T., Scarlett, C. J., & Vuong, Q. V. (2018). Phenolic compounds within banana peel and

their potential uses: A review. Journal of Functional Foods, 40, 238-248.

Wang, X., Cheng, H., Chai, P., Bian, J., Wang, X., Liu, Y., & Pan, Z. (2020). Pore characterization of different clay minerals and its impact on methane adsorption capacity. Energy & Fuels, 34(10), 12204-12214.

Yu, X., Chen, L., & Zhang, W. (2015). Chemicals to enhance microalgal growth and accumulation of high value bioproducts. Frontiers in microbiology, 6, 56.

Zhang, H., Li, J., Yang, X., Guo, S., Zhan, H., Zhang, Y., & Fang, Y. (2018). Influence of coal ash on potassium retention and ash melting characteristics during gasification of corn stalk coke. Bioresource technology, 270, 416-421.

Zheng, L., Wu, M., Cui, Y., Tian, L., Yang, P., Zhao, L., & Liu, J. (2022). What causes the great green tide disaster in the South Yellow Sea of China in 2021. Ecological Indicators, 140, 108988.

Zittelli, G. C., Mugnai, G., Milia, M., Cicchi, B., Benavides, A. S., Angioni, A., & Torzillo, G. (2022). Effects of blue, orange and white lights on growth, chlorophyll fluorescence, and phycocyanin production of Arthrospira platensis cultures. Algal Research, 61, 10258.

APPENDIX

Table A4.1: The variation of pH during 3-month study period (Coal and Banana)

	Timeframe

Treatment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	7.397	7.623	7.773^{b}	8.183	8.173	8.423	8.477^{a}	8.677^{a}	9.080	9.293	9.490	9.727
CB1	7.157	7.510	7.420^{c}	7.370	7.257	7.300	7.633^{c}	7.500^{cd}	7.610	7.807	8.293	7.993
CB2	7.653	7.913	8.010^{a}	7.880	8.047	8.017	7.907^{b}	8.103^{b}	8.040	8.003	8.290	7.777
CB3	7.547	7.600	7.263^{cd}	7.743	7.630	7.737	7.630^{c}	7.530^{c}	7.420	7.220	7.407	7.697
CB4	7.527	6.953	7.217^{d}	7.060	7.423	7.527	7.463^{cd}	7.427^{cd}	7.337	7.267	7.480	7.603
CB5	7.367	7.190	7.007^{e}	7.063	7.387	7.363	7.100^{e}	7.420^{de}	7.390	7.370	7.440	7.683
CB6	7.310	7.607	7.283^{cd}	7.220	7.407	7.383	7.273^{de}	7.487^{cd}	7.333	7.227	7.307	7.477
CB7	7.190	7.843	7.353^{cd}	8.183	7.450	7.337	7.340^{d}	7.317^{e}	7.310	7.173	7.310	7.627
SEM'	0.05008	0.05167	0.03910	0.05683	0.06745	0.05063	0.04003	0.02195	0.06350	0.07300	0.08912	0.08787
Significance	Ns	Ns	*	Ns	Ns	Ns	*	*	Ns	Ns	Ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, CB1: ###, CB2: ###, CB3: ### CB4: ###, CB5: ###, CB6: ###, CB7: ### and SEM: Standard Error Mean.

Table A4.2: ECS during 3-month study period.

Treatment	Timeframe											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	1084.7	1126.0	1166.7	1217.0	1266.0	1305.3	1321.0	1343.7	1366.3	1403.0	1558.0	1603.7
CB1	600.3	614.3	506.0	635.7	642.7	642.3	645.3	659.3	611.0	621.3	634.0	660.7
CB2	499.7	498.3	586.0	519.3	499.3	510.3	509.7	520.7	531.0	540.7	561.3	591.3
CB3	462.0	483.3	450.7	506.3	499.3	515.0	524.3	530.0	542.3	549.3	567.7	629.7
CB4	576.7	552.7	588.3	602.3	519.3	608.0	627.7	632.3	646.0	666.3	681.3	722.3
CB5	684.7	690.7	701.0	666.3	707.3	738.0	720.7	745.3	753.7	767.7	785.3	815.0
CB6	523.0	519.0	540.7	550.7	560.3	559.3	554.0	574.7	587.3	614.7	625.0	659.0
CB7	521.3	522.0	528.7	535.7	533.0	530.0	539.3	540.0	544.7	563.3	571.3	598.7
SEM	2.865	5.740	14.192	12.257	9.170	3.859	6.181	3.195	3.383	4.478	6.852	8.930
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, CB1: ###, CB2: ###, CB3: ### CB4: ###, CB5: ###, CB6: ###, CB7: ### and SEM: Standard Error Mean

Table A4.3: TDS during 3-month study period.

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	1017.3	1132.3	974.0	1049.0	829.3	698.7	583.3	951.3	1146.7	1239.3	914.3	1403.7
CB1	486.7	477.3	502.0	508.3	498.3	522.7	518.0	528.0	550.3	571.3	603.3	674.7
CB2	359.0	336.0	360.3	366.0	364.3	359.3	352.0	355.0	358.7	372.7	381.0	407.3
CB3	317.3	344.7	299.7	366.7	368.7	370.7	371.7	375.7	387.3	415.7	466.7	504.0
CB4	399.0	382.3	422.7	427.0	397.3	424.3	439.7	454.7	461.7	471.7	510.3	550.0
CB5	486.7	477.3	502.0	508.3	498.3	522.7	518.0	528.0	550.3	571.3	603.3	674.7
CB6	370.3	375.0	372.7	382.7	398.7	396.3	400.0	407.3	425.3	441.3	504.0	550.7
CB7	367.7	371.3	375.3	375.0	377.0	387.0	395.0	418.0	421.0	433.3	440.3	465.7
SEM	5.549	7.422	6.033	5.437	16.513	6.712	6.228	11.941	4.417	5.641	121.432	40.860
Significance	Ns	Ns	Ns	ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, CB1: ###, CB2: ###, CB3: ### CB4: ###, CB5: ###, CB6: ###, CB7: ### and SEM: Standard Error Mean.

Table A4.4: Temperature during 3-month study period.

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	20.10	20.30	20.30	21.20	21.80	20.00	22.10	22.20	27.80	27.80	28.10	30.20
CB1	33.20	37.90	22.00	20.50	22.30	28.40	20.10	25.10	35.20	37.90	38.20	27.70
CB2	33.30	37.80	22.00	20.50	22.30	28.20	20.30	26.20	33.20	37.80	38.90	33.40
CB3	33.30	38.10	22.00	20.30	22.30	28.00	20.30	26.30	36.20	37.80	39.20	38.20
CB4	33.40	38.30	21.90	20.40	22.30	28.10	20.20	27.30	36.50	37.70	39.20	38.20
CB5	33.20	37.90	21.90	20.20	22.30	28.80	20.10	28.50	35.00	37.70	39.20	38.20
CB6	33.50	37.50	21.90	20.20	22.30	28.10	20.00	36.10	34.10	37.60	39.10	38.00
CB7	34.20	37.60	21.90	20.20	22.40	28.40	20.00	33.10	36.00	37.30	38.60	37.40
SEM	0.020412	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Significance	*	**	**	**	**	**	**	**	**	**	**	**

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, CB1: ###, CB2: ###, CB3: ### CB4: ###, CB5: ###, CB6: ###, CB7: ### and SEM: Standard Error Mean

Table A4.7: Absorbance during 3-month study period.

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	0.81233^{a}	0.87400^{a}	0.88100^{a}	0.91000^{A}	0.93000^{a}	0.94300^{a}	0.95500^{a}	0.96333^{a}	0.96700^{a}	0.97567^{a}	0.98633	0.99367
CB1	0.77933^{b}	0.76000^{b}	0.72133^{b}	0.70467^{C}	0.68500^{b}	0.60233^{d}	0.58867^{b}	0.54433^{b}	0.48767^{b}	0.42467^{b}	0.35033	0.19433
CB2	0.70267^{c}	0.69467^{d}	0.67200^{c}	0.65200^{De}	0.63733^{c}	0.63167^{b}	0.61600^{b}	0.54700^{b}	0.51667^{b}	0.41767^{b}	0.35800	0.25833
CB3	0.76200^{b}	0.74233^{c}	0.73533^{b}	0.72633^{B}	0.69333^{b}	0.62833^{bc}	0.57967^{b}	0.54200^{b}	0.40333^{c}	0.41300^{b}	0.35100	0.23233

CB4	0.6820 0[c]	0.66333 [e]	0.6523 3[c]	0.64433 E	0.6316 7[c]	0.61700 [c]	0.5990 0[b]	0.5900 0[b]	0.4006 7[c]	0.3513 3[c]	0.2366 7	0.1956 7
CB5	0.5943 3[d]	0.58533 [f]	0.5756 7[d]	0.56500 F	0.5496 7[d]	0.51800 [e]	0.4960 0[c]	0.4006 7[c]	0.3120 0[d]	0.2063 3[d]	0.1853 3	0.2413 3
CB6	0.6856 7[c]	0.67867 [de]	0.6713 3[c]	0.66167 D	0.6473 3[c]	0.62533 [bc]	0.5953 3[b]	0.5136 7[b]	0.5003 3[b]	0.4066 7[b]	0.2531 3	0.2166 7
CB7	0.5830 0[d]	0.57500 [f]	0.5640 0[d]	0.54633 g	0.5313 3[d]	0.51500 [e]	0.5036 7[c]	0.3946 7[c]	0.2976 7[d]	0.1940 0[d]	0.2106 7	0.0226 7
SEM	0.0052 59	0.00330 2	0.0046 67	0.00341 4	0.0040 10	0.00238 3	0.0105 93	0.0168 98	0.0115 97	0.0076 24	0.0658 32	0.0641 90
Significance	**	**	**	**	**	**	*	*	*	**	Ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, CB1: ###, CB2: ###, CB3: ### CB4: ###, CB5: ###, CB6: ###, CB7: ### and SEM: Standard Error Mean.

Table A4.8: PH during 3-month study period (COAL)

Treatment	Timeframe											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	7.397	7.623	7.773[e]	8.183	8.173	8.423	8.477[d]	8.677	9.080	9.293	9.490	9.727
C1	8.253	8.503	8.650c	8.747	8.807	8.723	8.683[c]	8.850	8.753	9.353	9.457	9.630
C2	9.500	9.467	9.470[a]	9.343	9.613	9.553	9.460[a]	9.450	9.343	9.627	9.787	9.880
C3	9.420	9.320	9.373[a]	9.327	9.543	9.547	9.473[a]	9.453	9.407	9.590	9.627	9.800
C4t	9.277	9.230	9.207[b]	9.280	9.670	9.370	9.293[b]	9.333	9.297	9.557	9.667	9.890
C5	7.640	7.970	8.033[d]	8.233	8.400	8.287	8.400[d]	8.477	8.463	8.930	9.153	9.657
C6	7.730	7.943	7.947[d]	7.597	8.117	7.957	7.710[e]	8.067	7.870	8.790	9.003	9.250
C7	7.140	7.127	7.300[f]	7.613	7.457	7.630	7.633[e]	7.667	7.760	8.240	8.690	9.097
SEM	0.3582	0.0584 8	0.0264 3	0.0614 2	0.10040	0.09097	0.0240 4	0.0226 4	0.0675 7	0.0727 2	0.07624	0.08183
Significance	Ns	Ns	*	Ns	Ns	Ns	*	*	Ns	Ns	Ns	ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, C1: ###, C2: ###, C3: ### C4: ###, C5: ###, C6: ###, C7: ### and SEM: Standard Error Mean.

Table A4.10: ECS during 3-month study period.

Treatment	Timeframe											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	1084.7	1126.0	1166.7	1217.0	1266.0	1305.3	1321.0	1343.7	1366.3	1403.0	1558.0	1603.7
C1	668.7	685.7	693.0	691.7	689.0	701.3	708.7	723.3	734.0	746.0	756.0	809.7
C2	1302.3	1331.7	1358.7	1361.0	1368.0	1374.0	1382.0	1392.3	1404.0	1411.7	1435.701	1455.0
C3	1319.3	1053.3	1071.7	1068.7	1092.7	1103.3	1109.0	1112.7	1117.7	1124.3	1143.3	1164.7
C4	1042.7	1083.3	1087.0	1086.3	1100.7	1111.0	1119.3	1125.0	1128.3	1136.7	1151.3	1169.3
C5	732.3	744.0	758.0	758.7	760.0	804.0	810.0	820	836.3	855.3	871.0	906.7
C6	518.7	518.0	530.3	524.7	521.0	535.0	543.3	569.0	609.3	620.7	642.3	706.0
C7	669.0	668.7	653.0	681.3	571.3	649.7	674.3	688.0	696.0	724.3	734.7	757.3
SEM	13.927	3.871	6.196	2.327	10.597	3.704	2.528	3.044	2.998	2.850	3.871	3.096

Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, C1: ###, C2: ###, C3: ### C4: ###, C5: ###, C6: ###, C7: ### and SEM: Standard Error Mean.

Table A4.11: TDS during 3-month study period.

Treatment	Timeframe											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	1017.3	1132.3	974.0	1049.0	829.3	698.7	583.3	951.3	1146.7	1239.3	914.3	1403.7
C1	471.7	484.0	490.7	490.3	493.7	481.0	479.0	491.3	520.0	638.0	710.0	642.3
C2	936.7	947.0	965.3	963.3	960.3	965.7	952.0	976.0	984.0	1010.0	1033.3	1048.0
C3	934.7	947.0	761.0	763.7	763.0	769.0	787.3	916.7	933.7	937.3	956.3	970.7
C4	743.3	534.7	771.7	773.3	774.3	777.7	782.7	806.3	825.3	851.3	863.7	720.7
C5	364.7	406.7	540.3	535.7	541.3	548.3	543.3	562.0	575.0	585.3	620.7	647.7
C6	365.3	368.7	376.0	373.0	372.7	369.3	376.7	408.7	437.3	446.0	461.0	482.0
C7	511.0	559.3	501.0	512.7	513.7	524.7	537.0	560.0	579.0	585.3	576.0	616.7
SEM	6.138	19.440	6.443	5.335	12.311	6.686	8.115	12.103	12.311	6.933	12.868	52.945
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, C1: ###, C2: ###, C3: ### C4: ###, C5: ###, C6: ###, C7: ### and SEM: Standard Error Mean.

Table A4. 12: Temperature during 3-month study period.

Treatment	Timeframe											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	20.10	20.30	20.30	21.20	21.80	20.00	22.10	22.20	27.80	27.80	28.10	30.20

C1	33.90	36.30	21.70	20.50	22.30	28.30	20.10	22.50	24.10	25.10	38.50	36.20
C2	34.60	36.60	21.80	20.50	22.30	28.10	20.30	22.50	24.10	24.60	38.50	32.50
C3	34.80	36.70	21.80	20.40	22.30	28.10	20.30	22.50	24.10	24.50	38.60	32.40
C4	35.80	36.00	21.70	20.40	22.40	28.10	20.20	22.60	24.70	26.00	38.30	32.10
C5	35.80	36.10	21.70	20.40	22.40	28.10	20.30	22.60	24.70	26.10	38.20	32.10
C6	35.90	35.60	21.70	20.40	22.40	28.10	20.20	22.80	26.20	28.00	38.10	32.20
C7	35.90	35.90	21.70	20.50	22.50	28.50	20.30	23.50	28.10	29.40	38.10	32.10
SEM	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Significance	**	**	**	**	**	**	**	**	**	**	**	**

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, C1: ###, C2: ###, C3: ### C4: ###, C5: ###, C6: ###, C7: ### and SEM: Standard Error Mean.

Table A4.13: Absorbance during 3-month study period.

Treatment	**Timeframe**											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	0.8123^{a}	0.8740^{a}	0.8810^{a}	0.9100^{a}	0.9300^{a}	0.9430^{a}	0.9550^{a}	0.9633^{a}	0.9670^{a}	0.9757^{a}	0.9863^{a}	0.9937^{a}
C1	0.6790^{b}	0.7043^{b}	0.7250^{b}	0.7267^{b}	0.7457^{b}	0.7577^{b} C	0.8083^{b}	0.8873^{b}	0.7960^{b}	0.8530^{b}	0.8743^{b}	0.8873^{b}
C2	0.6607^{b}	0.6570^{c}	0.6753^{c}	0.6847^{c}	0.6960^{d}	0.7590^{b}	0.7050^{c} d	0.8223^{d}	0.7420^{d}	0.7553^{d} e	0.8033^{c} d	0.8223^{d}
C3	0.5807^{c}	0.6647^{c}	0.7037^{b}	0.7153^{b}	0.7297^{c}	0.7353^{b} Cd	0.7480^{b} c	0.8000^{c}	0.7660^{c}	0.7797^{d}	0.7853^{c} d	0.8000^{e}
C4	0.4877^{d}	0.5443^{e}	0.5887^{e}	0.6023^{f}	0.6150^{f}	0.6270^{d}	0.6533^{d}	0.7793^{e}	0.7047^{f}	0.7213^{f}	0.7600^{d}	0.7793^{f}
C5	0.5690^{c}	0.6107^{d}	0.6197^{d}	0.6270^{e}	0.6477^{e}	0.6807^{b} Cd	0.7073^{c} d	0.8493^{d}	0.7223^{e}	0.7313^{e} f	0.8143^{c}	0.8493^{c}
C6	0.6050^{c}	0.6090^{d}	0.6237^{d}	0.6423^{d}	0.6463^{e}	0.6587^{b} Cd	0.7437^{b} c	0.8570^{b}	0.8037^{b}	0.8117^{c}	0.8340^{b} c	0.8570^{c}
C7	0.5697^{c}	0.6003^{e}	0.6053^{d} E	0.6117^{f}	0.6270^{f}	0.6433^{c} D	0.6740^{c} d	0.8203^{e}	0.7097^{e} F	0.7350^{e} f	0.8227^{b} c	0.8203^{d} e
SEM	0.011064	0.003516	0.005542	0.003089	0.002486	0.023413	0.017799	0.004158	0.002664	0.005852	0.004158	0.004158
Significance	*	**	**	**	**	*	*	**	**	**	**	**

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, C1: ###, C2: ###, C3: ### C4: ###, C5: ###, C6: ###, C7: ### and SEM: Standard Error Mean.

Table A4.15: pH during 3-month study period (BANANA)

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	7.397	7.623	7.73	8.183	8.173	8.423	8.477[a]	8.677	9.080	9.293	9.490	8.820
B1	6.083	7.123	7.330	7.390	7.707	7.753	7.633[c]	7.300	7.430	7.663	7.753	7.607
B2	6.437	7.540	7.377	7.480	7.707	7.623	7.633[c]	7.403	7.373	7.360	7.533	7.787
B3	6.763	7.433	7.323	7.417	7.763	7.573	7.540[c]	7.443	7.420	7.893	7.853	7.907
B4	7.120	7.283	7.093	7.497	7.633	7.410	7.227[e]	7.043	7.080	7.833	7.850	7.877
B5	7.040	7.170	7.153	7.147	7.283	7.503	7.323[e]	7.380	7.447	7.730	7.817	8.380
B6	6.647	7.947	7.407	7.423	7.473	7.570	7.380[d]	7.603	7.427	8.023	8.300	8.820
B7	6.743	7.573	7.680	8.133	8.133	8.117	7.887[b]	8.193	8.150	8.333	8.567	9.727
SEM	0.07816	0.5362	0.3835	0.05683	0.3729	8.423	0.02633	0.3035	0.7539	0.08886	0.4915	0.07331
Significance	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, B1: ###, B2: ###, B3: ### B4: ###, B5: ###, B6: ###, B7: ### and SEM: Standard Error Mean.

Table A4.16: ECS during 3-month study period

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	1084.7	1126.0	1166.7	1217.0	1266.0	1305.3	1321.0	1343.7	1366.3	1403.0	1558.0	1603.7
B1	603.3	577.0	564.3	566.3	566.3	552.3	603.3	603.3	612.0	712.0	1004.0	1138.3

B2	1505.3	1511.3	1482.7	1470.0	1430.0	1345.3	1504.3	1512.7	1521.3	1532.7	1553.7	1532.3
B3	1490.3	1513.3	1490.3	1481.3	1463.0	1449.0	1483.0	1481.3	1478.0	1483.7	1490.7	1507.3
B4	1171.7	1158.0	1152.3	1072.7	1160.7	1121.3	1105.0	1090.3	1129.7	1150.7	1162.7	1267.7
B5	340.0	338.3	339.0	319.0	344.0	292.3	327.3	354.3	369.7	419.0	441.7	496.3
B6	382.3	381.0	386.3	388.0	386.7	378.0	363.3	383.3	410.0	440.3	487.0	504.0
B7	383.7	373.7	379.0	378.3	365.7	368.3	355.0	386.7	410.7	444.0	496.3	516.0
SEM	7.145	11.910	11.944	17.157	12.724	31.948	15.959	16.536	12.108	8.474	9.112	17.617
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, B1: ###, B2: ###, B3: ### B4: ###, B5: ###, B6: ###, B7: ### and SEM: Standard Error Mean

Table A4.17: Observed TDS over a 3-month period.

Treatment	**Timeframe**											
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Week 2**	**Week 3**	**Week 4**	**Month 2**	**Month 3**
Control	1017.3	1132.3	974.0	1049.0	829.3	698.7	583.3	951.3	1146.7	1239.3	914.3	1403.7
B1	428.0	411.7	401.3	400.7	407.7	392.0	382.7	368.3	360.7	352.0	345.3	308.7
B2	1063.7	1041.3	1051.7	1040.0	1036.0	923.3	992.0	971.3	944.3	937.0	889.0	756.3
B3	1056.7	1075.0	1060.0	1052.0	1042.3	1032.7	1032.3	1017.0	969.3	955.7	945.3	864.0
B4	828.3	869.0	817.3	702.0	826.3	795.7	808.3	703.7	776.7	814.3	844.0	852.3
B5	284.7	219.7	217.0	269.0	234.7	247.7	221.3	303.7	333.0	344.7	349.7	318.7
B6	261.3	275.3	280.7	275.3	221.7	283.3	284.3	282.3	244.3	245.0	250.0	248.0
B7	243.3	263.0	268.3	257.3	257.3	262.7	266.3	261.0	259.0	265.3	287.0	292.7
SEM	4.862	34.379	3.592	13.847	12.857	698.7	13.119	13.424	6.810	6.978	121.646	41.208
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, B1: ###, B2: ###, B3: ### B4: ###, B5: ###, B6: ###, B7: ### and SEM: Standard Error Mean.

Table A4.18: Temperature during 3-month study period.

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	20.10	20.30	20.30	21.20	21.80	20.00	22.10	22.20	27.80	27.80	28.10	30.20
B1	31.17	39.00	23.20	20.50	22.20	27.20	20.80	25.20	38.00	39.10	38.00	39.10
B2	31.87	39.03	22.10	20.30	23.20	27.70	20.20	25.20	38.00	39.00	38.00	39.00
B3	32.30	39.30	22.10	20.30	22.20	27.80	20.10	25.20	37.70	39.10	37.70	39.10
B4	32.60	39.00	22.20	20.40	22.30	27.80	20.10	27.30	37.70	39.10	37.70	39.10
B5	32.40	39.10	22.10	20.40	22.30	28.10	20.20	27.50	37.70	38.70	37.70	38.70
B6	32.60	38.70	22.20	20.40	23.40	28.20	20.20	28.10	37.20	38.70	37.70	38.70
B7	32.80	38.50	22.10	20.30	23.40	28.40	20.20	29.30	37.30	38.80	37.30	38.70
SEM	0.011785	0.042492	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Significance	*	*	**	**	**	**	**	**	**	**	**	**

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, B1: ###, B2: ###, B3: ### B4: ###, B5: ###, B6: ###, B7: ### and SEM: Standard Error Mean

Table A4.19: Observed Absorbance over a 3-month period.

Treatment	Timeframe											
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Week 2	Week 3	Week 4	Month 2	Month 3
Control	0.812333^{a}	0.874000	0.881000^{a}	0.910000^{a}	0.930000^{a}	0.943000^{a}	0.955000^{a}	0.963333^{a}	0.967000^{a}	0.975667^{a}	0.986333^{a}	0.993667^{a}
B1	0.501000^{cd}	0.496667	0.432333^{b}	0.379333^{b}	0.286333^{bc}	0.261000^{b}	0.202000^{c}	0.007000^{bc}	0.006000^{b}	0.003667^{b}	0.015333^{b}	0.003000^{b}
B2	0.600667^{b}	0.544333	0.413000^{b}	0.347667^{bc}	0.241333^{d}	0.251667^{b}	0.221667^{b}	0.005333^{bc}	0.005000^{b}	0.004000^{b}	0.003333^{b}	0.002000^{b}
B3	0.498000^{cd}	0.497667	0.379000^{b}	0.350000^{bc}	0.268667^{cd}	0.225667^{b}	0.192333^{d}	0.005333^{bc}	0.004667^{b}	0.003667^{b}	0.003333^{b}	0.002333^{b}
B4	0.501333^{cd}	0.492000	0.378000^{b}	0.320667^{c}	0.312333^{a}	0.270000^{b}	0.198000^{c}	0.005000^{bc}	0.003667^{b}	0.002333^{b}	0.002333^{b}	0.001667^{b}
B5	0.507000^{c}	0.441000	0.305333^{b}	0.209000^{d}	0.116667^{e}	0.009667^{c}	0.007333^{e}	0.002667^{c}	0.003333^{b}	0.004000^{b}	0.002333^{b}	0.001000^{b}
B6	0.419667^{de}	0.400667	0.311000^{b}	0.204667^{d}	0.108333^{e}	0.006000^{c}	0.005333^{e}	0.003333^{c}	0.003667^{b}	0.002333^{b}	0.002667^{b}	0.002333^{b}
B7	0.352000^{e}	0.354000	0.201667^{b}	0.159333^{d}	0.007000^{f}	0.005333^{c}	0.003667^{e}	0.018000^{b}	0.003000^{b}	0.001667^{b}	0.002667^{b}	0.001667^{b}
SEM	0.017220	0.496667	0.006680	0.011933	0.007059	0.009384	0.000882	0.002963	0.001161	0.015333	0.015333	0.000755
Significance	*	Ns	**	*	**	**	**	**	**	*	*	**

**: P <0.01; *: P <0.05; (ns) not significant: P >0.05. ab Column means with different superscripts differ significantly at P <0.05. Con: Control, B1: ###, B2: ###, B3: ### B4: ###, B5: ###, B6: ###, B7: ### and SEM: Standard Error Mean.

Table A4:20

Anova: Single Factor for Potasium (K)

replicates/sample ID	C5	B5	CB5	Control
1	41.01	62.00	62.9	0.001
2	41.30	61.16	62.0	0.001
3	41.76	69.30	62.3	0.002

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C5	3	43.51	14.50333	0.012233
B5	3	-14.685	-4.895	0.008937

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	564.443	1	564.443	53323.96	2.11E-09	7.708647
Within Groups	0.042341	4	0.010585			
Total	564.4853	5				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B5	3	-14.685	-4.895	0.008937
CB5	3	4.01	1.336667	95.72321

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	58.2505	1	58.2505	1.216948	0.331864	7.708647
Within Groups	191.4643	4	47.86607			
Total	249.7148	5				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C5	3	43.51	14.50333	0.012233
B5	3	-14.685	-4.895	0.008937
CB5	3	4.01	1.336667	95.72321
Control	3	-18.672	-6.224	0.001083

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	807.7818	3	269.2606	11.24902	0.003053	4.066181
Within Groups	191.4909	8	23.93636			
Total	999.2727	11				

Anova: Single Factor sodium (Na)

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C5	3	46.31	15.43667	0.084933
B5	3	4.645	1.548333	0.000158

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	289.3287	1	289.3287	6800.4	1.3E-07	7.708647
Within Groups	0.170183	4	0.042546			
Total	289.4989	5				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B5	3	4.645	1.548333	0.000158

CB5	3	19.948	6.649333	74.41133

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	39.0303	1	39.0303	1.04904	0.363626	7.708647
Within Groups	148.823	4	37.20574			
Total	187.8533	5				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C5	3	46.31	15.43667	0.084933
B5	3	4.645	1.548333	0.000158
CB5	3	19.948	6.649333	74.41133
Control	3	8.473	2.824333	0.00029

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	353.5897	3	117.8632	6.328507	0.016594	4.066181
Within Groups	148.9934	8	18.62418			
Total	502.5832	11				

replicates/sample

ID	**C5**	**B5**	**CB5**	**Control**
1	1.548	0.891	0.893	1.2
2	1.547	0.883	1.656	1.2
3	1.57	0.897	0.899	1.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
C5	3	4.665	1.555	0.000169
B5	3	2.671	0.890333	4.93E-05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.662673	1	0.662673	6070.284	1.63E-07	7.708647
Within Groups	0.000437	4	0.000109			
Total	0.663109	5				

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
B5	3	2.671	0.890333	4.93E-05
CB5	3	3.448	1.149333	0.192542

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.100622	1	0.100622	1.044921	0.36447	7.708647
Within Groups	0.385183	4	0.096296			
Total	0.485805	5				

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Varianc*
C5	3	4.665	1.555	0.000169
B5	3	2.671	0.890333	4.93E-05
CB5	3	3.448	1.149333	0.192542
Control	3	3.704	1.234667	3.43E-0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.676417	3	0.225472	4.677968	0.035993	4.066181
Within Groups	0.38559	8	0.048199			
Total	1.062007	11				

Table A:21 ICP-OES RESULTS

Method: Bronie Test Run Page 1 Date: 10/27/2022 1:39:39 PM

========== = **Analysis Begun**

Start Time: 10/27/2022 11:04:12 AM Plasma On Time: 10/27/2022 10:35:25 AM
Logged In Analyst: Administrator Technique: ICP Continuous
Spectrometer: Optima 8000 Autosampler: S10

Sample Information File: C:\Users\Public\PerkinElmer Syngistix\ICP\Data\Sample Information
Bronies Samples.sifx
Batch ID: Bronies Samples
Results Data Set: Bronies Results
Results Library: C:\Users\Public\PerkinElmer Syngistix\ICP\Data\Results\Results.mdb

========== = **Method Loaded**
Method Name: Bronie Test Run Method Last Saved: 10/27/2022 11:04:09 AM
IEC File: MSF File: Method Description:

========== =
Sequence No.: 1 Autosampler Location: 1
Sample ID: Blank Date Collected: 10/27/2022 11:04:13 AM
Analyst: Data Type: Original Initial Sample Wt: Initial Sample Vol:
Dilution: Sample Prep Vol: Wash Time:

----------**Replicate Data: Blank**

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc.	Units	Analysis Time
1	K 766.490	-2317.2	-2317.2	[0.00]	mg/L	11:05:48 AM
1	P 213.617	814.7	814.7	[0.00]	mg/L	11:06:07 AM
1	S 181.975	1087.9	1087.9	[0.00]	mg/L	11:06:38 AM
1	As 193.696	1033.3	1033.3	[0.00]	mg/L	11:07:15 AM
1	La 398.852	486.4	486.4	[0.00]	mg/L	11:07:54 AM
1	Li 670.784	22831.0	22831.0	[0.00]	mg/L	11:08:17 AM
1	Mn 257.610	17181.6	17181.6	[0.00]	mg/L	11:08:44 AM
1	Mo 202.031	2809.4	2809.4	[0.00]	mg/L	11:09:10 AM
1	Na 589.592	-11665.0	-11665.0	[0.00]	mg/L	11:09:50 AM
1	Ni 231.604	1484.9	1484.9	[0.00]	mg/L	11:10:17 AM
1	Sc 361.383	4526.8	4526.8	[0.00]	mg/L	11:10:45 AM
1	Ca 317.933	-131432.3	-131432.3	[0.00]	mg/L	11:11:08 AM
2	K 766.490	-2644.7	-2644.7	[0.00]	mg/L	11:05:53 AM
2	P 213.617	904.1	904.1	[0.00]	mg/L	11:06:17 AM
2	S 181.975	1091.0	1091.0	[0.00]	mg/L	11:06:50 AM
2	As 193.696	1065.7	1065.7	[0.00]	mg/L	11:07:27 AM
2	La 398.852	602.5	602.5	[0.00]	mg/L	11:08:01 AM
2	Li 670.784	23370.9	23370.9	[0.00]	mg/L	11:08:25 AM
2	Mn 257.610	17162.8	17162.8	[0.00]	mg/L	11:08:53 AM
2	Mo 202.031	2861.6	2861.6	[0.00]	mg/L	11:09:21 AM
2	Na 589.592	-12312.4	-12312.4	[0.00]	mg/L	11:09:58 AM
2	Ni 231.604	1375.7	1375.7	[0.00]	mg/L	11:10:26 AM
2	Sc 361.383	4451.8	4451.8	[0.00]	mg/L	11:10:52 AM
2	Ca 317.933	-131042.3	-131042.3	[0.00]	mg/L	11:11:15 AM
3	K 766.490	-1700.8	-1700.8	[0.00]	mg/L	11:05:58 AM
3	P 213.617	860.0	860.0	[0.00]	mg/L	11:06:26 AM
3	S 181.975	1090.5	1090.5	[0.00]	mg/L	11:07:01 AM
3	As 193.696	1093.3	1093.3	[0.00]	mg/L	11:07:38 AM
3	La 398.852	763.5	763.5	[0.00]	mg/L	11:08:08 AM
3	Li 670.784	23748.8	23748.8	[0.00]	mg/L	11:08:32 AM
3	Mn 257.610	17189.3	17189.3	[0.00]	mg/L	11:09:00 AM
3	Mo 202.031	2825.9	2825.9	[0.00]	mg/L	11:09:33 AM
3	Na 589.592	-12576.7	-12576.7	[0.00]	mg/L	11:10:05 AM
3	Ni 231.604	1365.2	1365.2	[0.00]	mg/L	11:10:35 AM
3	Sc 361.383	4395.6	4395.6	[0.00]	mg/L	11:10:59 AM
3	Ca 317.933	-130166.4	-130166.4	[0.00]	mg/L	11:11:20 AM

Mean Data: Blank

Analyte	Mean Corrected Intensity	Std.Dev.	RSD	Calib Conc.	Units
K 766.490	-2220.9	479.26	21.58%	[0.00]	mg/L
P 213.617	859.6	44.69	5.20%	[0.00]	mg/L

S 181.975	1089.8	1.68	0.15%	[0.00] mg/L
As 193.696	1064.1	30.06	2.82%	[0.00] mg/L
La 398.852	617.4	139.17	22.54%	[0.00] mg/L
Li 670.784	23316.9	461.24	1.98%	[0.00] mg/L
Mn 257.610	17177.9	13.62	0.08%	[0.00] mg/L
Mo 202.031	2832.3	26.67	0.94%	[0.00] mg/L
Na 589.592	-12184.7	469.07	3.85%	[0.00] mg/L
Ni 231.604	1408.6	66.27	4.70%	[0.00] mg/L
Sc 361.383	4458.1	65.83	1.48%	[0.00] mg/L
Ca 317.933	-130880.3	648.29	0.50%	[0.00] mg/L

==========

Sequence No.: 2 **Autosampler Location: 2**
Sample ID: Std 1 **Date Collected: 10/27/2022 11:12:06 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol:**
Dilution: **Sample Prep Vol:** **Wash Time:**

----------Replicate Data: Std 1

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc.	Units	Analysis Time	
1	K 766.490	115066.2	117287.1	[1]	mg/L	11:13:43 AM	
1	P 213.617	17864.3	17004.7	[1]	mg/L	11:13:59 AM	
1	S 181.975	1081.6	-8.2	[1]	mg/L	11:14:27 AM	
1	As 193.696	2512.8	1448.7	[0.2]	mg/L	11:15:05 AM	
1	La 398.852	459358.7	458741.3	[0.2]	mg/L	11:15:44 AM	
1	Li 670.784	947120.0	923803.1	[0.2]	mg/L	11:15:57 AM	
1	Mn 257.610	1290084.0	1272906.1	[0.2]	mg/L	11:16:08 AM	
1	Mo 202.031	16476.4	13644.1	[0.2]	mg/L	11:16:21 AM	
1	Na 589.592	47129.8	59314.5	[0.2]	mg/L	11:16:57 AM	
1	Ni 231.604	53782.3	52373.7	[0.2]	mg/L	11:17:23 AM	
1	Sc 361.383	2633885.8	2629427.8	[0.2]	mg/L	11:17:47 AM	
1	Ca 317.933	-119859.8	11020.5	[0.01]	mg/L	11:17:57 AM	
2	K 766.490	141681.9	143902.8	[1]	mg/L	11:13:47 AM	
2	P 213.617	17739.7	16880.1	[1]	mg/L	11:14:08 AM	
2	S 181.975	1088.8	-1.0	[1]	mg/L	11:14:40 AM	
2	As 193.696	2462.2	1398.1	[0.2]	mg/L	11:15:17 AM	
2	La 398.852	471292.6	470675.2	[0.2]	mg/L	11:15:48 AM	
2	Li 670.784	1132537.3	1109220.4	[0.2]	mg/L	11:16:00 AM	
2	Mn 257.610	1276154.6	1258976.7	[0.2]	mg/L	11:16:12 AM	
2	Mo 202.031	16569.7	13737.4	[0.2]	mg/L	11:16:32 AM	
2	Na 589.592	-75099.9	-62915.2	[0.2]	mg/L	11:17:06 AM	Saturated within auto integration window (code 4)
2	Ni 231.604	54169.4	52760.8	[0.2]	mg/L	11:17:31 AM	
2	Sc 361.383	2665729.4	2661271.4	[0.2]	mg/L	11:17:50 AM	
2	Ca 317.933	-119642.4	11237.9	[0.01]	mg/L	11:18:04 AM	
3	K 766.490	157068.9	159289.8	[1]	mg/L	11:13:51 AM	
3	P 213.617	17671.9	16812.3	[1]	mg/L	11:14:16 AM	
3	S 181.975	1082.8	-7.0	[1]	mg/L	11:14:52 AM	
3	As 193.696	2422.8	1358.7	[0.2]	mg/L	11:15:28 AM	
3	La 398.852	461077.2	460459.8	[0.2]	mg/L	11:15:51 AM	
3	Li 670.784	1241093.4	1217776.5	[0.2]	mg/L	11:16:02 AM	
3	Mn 257.610	1313426.7	1296248.8	[0.2]	mg/L	11:16:15 AM	
3	Mo 202.031	16467.1	13634.8	[0.2]	mg/L	11:16:41 AM	
3	Na 589.592	20027.2	32211.9	[0.2]	mg/L	11:17:12 AM	Saturated within auto integration window (code 4)
3	Ni 231.604	54425.4	53016.8	[0.2]	mg/L	11:17:38 AM	
3	Sc 361.383	2677625.0	2673167.0	[0.2]	mg/L	11:17:53 AM	
3	Ca 317.933	-119654.0	11226.3	[0.01]	mg/L	11:18:09 AM	

----------Mean Data: Std 1

Analyte	Mean Corrected Intensity	Std.Dev.	RSD	Calib Conc.	Units
K 766.490	140159.9	21250.00	15.16%	[1]	mg/L
P 213.617	16899.0	97.59	0.58%	[1]	mg/L
S 181.975	-5.4	3.87	71.47%	[1]	mg/L
Standard intensity and concentration values are not in the same order.					
As 193.696	1401.9	45.10	3.22%	[0.2]	mg/L
La 398.852	463292.1	6451.44	1.39%	[0.2]	mg/L
Li 670.784	1083600.0	148651.91	13.72%	[0.2]	mg/L
Mn 257.610	1276043.8	18833.12	1.48%	[0.2]	mg/L
Mo 202.031	13672.1	56.73	0.41%	[0.2]	mg/L
Na 589.592	9537.1	64192.18	673.08%	[0.2]	mg/L
Saturated within auto integration window (code 4)					
Ni 231.604	52717.1	323.77	0.61%	[0.2]	mg/L

Sc 361.383 2654622.0 22615.04 0.85% [0.2] mg/L
Ca 317.933 11161.6 122.34 1.10% [0.01] mg/L

==========

Sequence No.: 3 **Autosampler Location: 3**
Sample ID: Std 2 **Date Collected: 10/27/2022 11:18:54 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol: Dilution:** **Sample Prep Vol: Wash**
Time:

----------Replicate Data: Std 2

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Analysis Time						
1	K 766.490	2511882.9	2514103.8	[10] mg/L	11:20:31 AM						
1	P 213.617	151682.0	150822.4	[10] mg/L	11:20:46 AM						
1	S 181.975	1084.6	-5.2	[10] mg/L	11:21:09 AM	1	As 193.696	15099.5	14035.4	[2] mg/L	11:21:45 AM
1	La 398.852	4278414.3	4277796.9	[2] mg/L	11:22:19 AM						
1	Li 670.784	20656373.7	20633056.8	[2] mg/L	11:22:30 AM						
1	Mn 257.610	11574078.6	11556900.7	[2] mg/L	11:22:45 AM						
1	Mo 202.031	130925.4	128093.0	[2] mg/L	11:22:58 AM						
1	Na 589.592	1055459.2	1067643.9	[2] mg/L	11:23:25 AM						
1	Ni 231.604	474581.6	473173.0	[2] mg/L	11:23:37 AM						
1	Sc 361.383	24424284.3	24419826.3	[2] mg/L	11:23:50 AM						
1	Ca 317.933	-59733.9	71146.5	[0.1] mg/L	11:24:05 AM						
2	K 766.490	5035455.4	5037676.2	[10] mg/L	11:20:35 AM						
	Saturated within auto integration window (code 4)										
2	P 213.617	154038.3	153178.7	[10] mg/L	11:20:53 AM						
2	S 181.975	1090.4	0.6	[10] mg/L	11:21:21 AM						
2	As 193.696	14855.9	13791.8	[2] mg/L	11:21:56 AM						
2	La 398.852	4226149.3	4225531.9	[2] mg/L	11:22:22 AM						
2	Li 670.784	42220534.6	42197217.7	[2] mg/L	11:22:35 AM	Saturated within auto integration window (code 4)					
2	Mn 257.610	11404596.4	11387418.5	[2] mg/L	11:22:49 AM						
2	Mo 202.031	130566.9	127734.5	[2] mg/L	11:23:05 AM						
2	Na 589.592	1234797.8	1246982.5	[2] mg/L	11:23:28 AM	2	Ni 231.604	474613.2	473204.6	[2] mg/L	11:23:41 AM
2	Sc 361.383	24790642.9	24786184.8	[2] mg/L	11:23:55 AM						
2	Ca 317.933	-59778.2	71102.2	[0.1] mg/L	11:24:12 AM						
3	K 766.490	4808523.5	4810744.4	[10] mg/L	11:20:38 AM						
	Saturated within auto integration window (code 4)										
3	P 213.617	154580.8	153721.2	[10] mg/L	11:20:59 AM						
3	S 181.975	1086.1	-3.7	[10] mg/L	11:21:32 AM						
3	As 193.696	14902.2	13838.1	[2] mg/L	11:22:05 AM						
3	La 398.852	4184070.1	4183452.7	[2] mg/L	11:22:25 AM						
3	Li 670.784	40329325.7	40306008.8	[2] mg/L	11:22:38 AM	Saturated within auto integration window (code 4)					
3	Mn 257.610	11784723.6	11767545.7	[2] mg/L	11:22:53 AM						
3	Mo 202.031	131276.8	128444.5	[2] mg/L	11:23:12 AM						
3	Na 589.592	1351649.0	1363833.7	[2] mg/L	11:23:30 AM						
3	Ni 231.604	476347.4	474938.8	[2] mg/L	11:23:44 AM						
3	Sc 361.383	24839978.1	24835520.0	[2] mg/L	11:23:59 AM						
3	Ca 317.933	-59336.2	71544.1	[0.1] mg/L	11:24:17 AM						

----------Mean Data: Std 2

Analyte	Mean Corrected Intensity	Std.Dev.	RSD	Calib Conc. Units					
K 766.490	4120841.5	1396094.20	33.88%	[10] mg/L					
Saturated within auto integration window (code 4)									
P 213.617	152574.1	1541.04	1.01%	[10] mg/L	S 181.975	-2.8	3.01	109.15%	[10] mg/L
Standard intensity and concentration values are not in the same order.									
As 193.696	13888.4	129.37	0.93%	[2] mg/L					
La 398.852	4228927.1	47263.66	1.12%	[2] mg/L					
Li 670.784	34378761.1	11941627.1	34.74%	[2] mg/L					
Saturated within auto integration window (code 4)									
Mn 257.610	11570621.6	190434.73	1.65%	[2] mg/L					
Mo 202.031	128090.7	355.00	0.28%	[2] mg/L					
Na 589.592	1226153.4	149189.43	12.17%	[2] mg/L					
Ni 231.604	473772.1	1010.52	0.21%	[2] mg/L					
Sc 361.383	24680510.4	227102.72	0.92%	[2] mg/L					
Ca 317.933	71264.2	243.37	0.34%	[0.1] mg/L					

==========

Sequence No.: 4 **Autosampler Location: 4**

Sample ID: Std 3 **Date Collected: 10/27/2022 11:25:02 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol:**
Dilution: **Sample Prep Vol: Wash Time:**

----------**Replicate Data: Std 3**

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc.	Units	Analysis Time
1	K 766.490	12568825.8	12571046.6	[20]	mg/L	11:26:39 AM
1	P 213.617	328002.2	327142.6	[20]	mg/L	11:26:56 AM
1	S 181.975	1141.6	51.8	[20]	mg/L	11:27:10 AM
1	As 193.696	30960.6	29896.5	[4]	mg/L	11:27:47 AM
1	La 398.852	8960930.3	8960312.8	[4]	mg/L	11:28:18 AM
1	Li 670.784	92474826.3	92451509.4	[4]	mg/L	11:28:30 AM
1	Mn 257.610	24633635.0	24616457.1	[4]	mg/L	11:28:57 AM
1	Mo 202.031	278271.0	275438.7	[4]	mg/L	11:29:15 AM
1	Na 589.592	7821672.6	7833857.3	[4]	mg/L	11:29:35 AM
1	Ni 231.604	983996.4	982587.8	[4]	mg/L	11:29:48 AM
1	Sc 361.383	54787341.7	54782883.7	[4]	mg/L	11:29:59 AM
1	Ca 317.933	21132.2	152012.5	[0.2]	mg/L	11:30:24 AM
2	K 766.490	13578747.3	13580968.2	[20]	mg/L	11:26:44 AM
2	P 213.617	324883.2	324023.6	[20]	mg/L	11:27:00 AM
2	S 181.975	1120.7	30.9	[20]	mg/L	11:27:22 AM
2	As 193.696	30413.2	29349.1	[4]	mg/L	11:27:57 AM
2	La 398.852	8948401.5	8947784.1	[4]	mg/L	11:28:22 AM
2	Li 670.784	102197411	102174094	[4]	mg/L	11:28:39 AM
2	Mn 257.610	24609271.1	24592093.2	[4]	mg/L	11:29:03 AM
2	Mo 202.031	280619.0	277786.6	[4]	mg/L	11:29:20 AM
2	Na 589.592	8388850.5	8401035.2	[4]	mg/L	11:29:39 AM
2	Ni 231.604	978050.9	976642.3	[4]	mg/L	11:29:52 AM
2	Sc 361.383	54940761.2	54936303.2	[4]	mg/L	11:30:07 AM
2	Ca 317.933	20122.3	151002.6	[0.2]	mg/L	11:30:30 AM
3	K 766.490	14318170.5	14320391.4	[20]	mg/L	11:26:48 AM
3	P 213.617	332103.7	331244.2	[20]	mg/L	11:27:04 AM
3	S 181.975	1124.1	34.3	[20]	mg/L	11:27:33 AM
3	As 193.696	30785.9	29721.8	[4]	mg/L	11:28:06 AM
3	La 398.852	9114812.4	9114194.9	[4]	mg/L	11:28:25 AM
3	Li 670.784	107073404	107050087	[4]	mg/L	11:28:46 AM
3	Mn 257.610	24869391.2	24852213.3	[4]	mg/L	11:29:08 AM
3	Mo 202.031	276728.3	273896.0	[4]	mg/L	11:29:24 AM
3	Na 589.592	8769261.9	8781446.6	[4]	mg/L	11:29:41 AM
3	Ni 231.604	1008597.4	1007188.8	[4]	mg/L	11:29:54 AM
3	Sc 361.383	55094891.7	55090433.7	[4]	mg/L	11:30:15 AM
3	Ca 317.933	19182.8	150063.1	[0.2]	mg/L	11:30:35 AM

----------**Mean Data: Std 3**

Analyte	Mean Corrected Intensity	Std.Dev.	RSD	Calib Conc. Units
K 766.490	13490802.1	878151.02	6.51%	[20] mg/L
P 213.617	327470.1	3621.38	1.11%	[20] mg/L
S 181.975	39.0	11.17	28.63%	[20] mg/L

Standard intensity and concentration values are not in the same order.

As 193.696	29655.8	279.59	0.94%	[4] mg/L
La 398.852	9007430.6	92672.57	1.03%	[4] mg/L
Li 670.784	100558564	7432164.76	7.39%	[4] mg/L
Mn 257.610	24686921.2	143664.61	0.58%	[4] mg/L
Mo 202.031	275707.1	1959.18	0.71%	[4] mg/L
Na 589.592	8338779.7	476852.41	5.72%	[4] mg/L
Ni 231.604	988806.3	16194.89	1.64%	[4] mg/L
Sc 361.383	54936540.2	153775.13	0.28%	[4] mg/L
Ca 317.933	151026.1	974.92	0.65%	[0.2] mg/L

==========

Sequence No.: 5 **Autosampler Location: 5**
Sample ID: Std 4 **Date Collected: 10/27/2022 11:31:20 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol: Dilution:** **Sample Prep Vol: Wash Time:**

----------**Replicate Data: Std 4**

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc.	Units	Analysis Time
1	K 766.490	46466766.1	46468987.0	[40]	mg/L	11:32:58 AM

1 P 213.617 690318.9 689459.3 [40] mg/L 11:33:23 AM
1 S 181.975 1488.1 398.3 [40] mg/L 11:33:33 AM
1 As 193.696 65631.9 64567.8 [8] mg/L 11:34:07 AM
1 La 398.852 19501666.8 19501049.3 [8] mg/L 11:34:36 AM 1 Li 670.784 Saturated3 Saturated3 11:34:51 AM
Saturated in preshot (code 3)
1 Mn 257.610 53675705.4 53658527.6 [8] mg/L 11:35:17 AM
1 Mo 202.031 586890.1 584057.8 [8] mg/L 11:35:42 AM
1 Na 589.592 22172416.9 22184601.6 [8] mg/L 11:35:56 AM
1 Ni 231.604 2117411.5 2116002.9 [8] mg/L 11:36:16 AM
1 Sc 361.383 118305447 118300989 [8] mg/L 11:36:26 AM
Saturated within auto integration window (code 4)
1 Ca 317.933 183282.8 314163.2 [0.4] mg/L 11:36:51 AM
2 K 766.490 48174048.2 48176269.1 [40] mg/L 11:33:05 AM
2 P 213.617 694307.2 693447.7 [40] mg/L 11:33:25 AM
2 S 181.975 1420.3 330.5 [40] mg/L 11:33:45 AM
2 As 193.696 65418.9 64354.8 [8] mg/L 11:34:16 AM
2 La 398.852 19313304.2 19312686.8 [8] mg/L 11:34:41 AM
2 Li 670.784 50222177.4 50198860.5 [8] mg/L 11:34:58 AM
Saturated within survey window (code 5)
2 Mn 257.610 53189465.4 53172287.5 [8] mg/L 11:35:25 AM
2 Mo 202.031 576640.7 573808.4 [8] mg/L 11:35:45 AM
2 Na 589.592 29171019.0 29183203.7 [8] mg/L 11:36:03 AM
2 Ni 231.604 2101380.9 2099972.3 [8] mg/L 11:36:19 AM
2 Sc 361.383 117883742 117879284 [8] mg/L 11:36:35 AM
Saturated within auto integration window (code 4)
2 Ca 317.933 184819.7 315700.0 [0.4] mg/L 11:36:56 AM
3 K 766.490 48878999.2 48881220.1 [40] mg/L 11:33:12 AM
3 P 213.617 705471.8 704612.3 [40] mg/L 11:33:28 AM
3 S 181.975 1390.3 300.5 [40] mg/L 11:33:55 AM
3 As 193.696 64706.2 63642.1 [8] mg/L 11:34:23 AM
3 La 398.852 19044372.2 19043754.8 [8] mg/L 11:34:44 AM
3 Li 670.784 51608410.1 51585093.2 [8] mg/L 11:35:05 AM
Saturated within survey window (code 5)
3 Mn 257.610 53625055.4 53607877.5 [8] mg/L 11:35:33 AM
3 Mo 202.031 587275.1 584442.7 [8] mg/L 11:35:47 AM
3 Na 589.592 29375673.5 29387858.2 [8] mg/L 11:36:07 AM
3 Ni 231.604 2132700.2 2131291.6 [8] mg/L 11:36:21 AM
3 Sc 361.383 117282716 117278258 [8] mg/L 11:36:42 AM Saturated within auto integration window (code 4)
3 Ca 317.933 189668.0 320548.3 [0.4] mg/L 11:37:00 AM

----------**Mean Data: Std 4**

Analyte	Mean Corrected Intensity	Std.Dev.	RSD	Calib Conc. Units
K 766.490	47842158.7	1240338.42	2.59%	[40] mg/L
P 213.617	695839.7	7854.59	1.13%	[40] mg/L
S 181.975	343.1	50.11	14.61%	[40] mg/L

Standard intensity and concentration values are not in the same order.

As 193.696	64188.2	484.82	0.76%	[8] mg/L
La 398.852	19285830.3	229827.18	1.19%	[8] mg/L
Li 670.784	Saturated5			[8] mg/L
Mn 257.610	53479564.2	267311.79	0.50%	[8] mg/L
Mo 202.031	580769.6	6031.72	1.04%	[8] mg/L
Na 589.592	26918554.5	4101000.30	15.23%	[8] mg/L
Ni 231.604	2115755.6	15661.08	0.74%	[8] mg/L
Sc 361.383	117819510	513979.17	0.44%	[8] mg/L

Saturated within auto integration window (code 4)

Ca 317.933	316803.8	3332.63	1.05%	[0.4] mg/L

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Sequence No.: 6 **Autosampler Location: 6**
Sample ID: Std 5 **Date Collected: 10/27/2022 11:37:44 AM**
Analyst: **Data Type: Original Initial Sample Wt:** **Initial Sample Vol:**
Dilution: **Sample Prep Vol: Wash**
Time: ----------
----------**Replicate Data: Std 5**

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Analysis Time	
1	K 766.490	112718684	112720905	[80] mg/L	11:39:20 AM	Saturated within auto integration window (code 4)
1	P 213.617	1364487.8	1363628.2	[80] mg/L	11:39:48 AM	
1	S 181.975	3395.9	2306.1	[80] mg/L	11:39:58 AM	
1	As 193.696	125935.4	124871.3	[16] mg/L	11:40:29 AM	
1	La 398.852	37970421.8	37969804.4	[16] mg/L	11:40:55 AM	
1	Li 670.784	Saturated3	Saturated3		11:41:14 AM	Saturated in preshot (code 3)

1 Mn 257.610 104779212 104762034 [16] mg/L 11:41:41 AM Saturated within auto integration window (code 4)
1 Mo 202.031 1107859.8 1105027.5 [16] mg/L 11:42:07 AM
1 Na 589.592 63811656.7 63823841.3 [16] mg/L 11:42:21 AM
1 Ni 231.604 4063869.8 4062461.2 [16] mg/L 11:42:50 AM
1 Sc 361.383 Saturated3 Saturated3 11:43:01 AM Saturated in preshot (code 3)

1 Ca 317.933 502576.4 633456.7 [0.8] mg/L 11:43:25 AM

2 K 766.490 116976005 116978226 [80] mg/L 11:39:29 AM
Saturated within auto integration window (code 4)
2 P 213.617 1355061.7 1354202.1 [80] mg/L 11:39:51 AM
2 S 181.975 3085.2 1995.4 [80] mg/L 11:40:08 AM
2 As 193.696 126335.9 125271.8 [16] mg/L 11:40:37 AM
2 La 398.852 38001979.1 38001361.6 [16] mg/L 11:41:01 AM
2 Li 670.784 9913914.9 9890597.9 [16] mg/L 11:41:22 AM
Saturated within survey window (code 5)
2 Mn 257.610 103435283 103418105 [16] mg/L 11:41:49 AM Saturated within auto integration window (code 4)
2 Mo 202.031 1136897.3 1134065.0 [16] mg/L 11:42:11 AM
2 Na 589.592 74495368.2 74507552.8 [16] mg/L 11:42:31 AM
2 Ni 231.604 4140297.3 4138888.7 [16] mg/L 11:42:53 AM
2 Sc 361.383 73617280.2 73612822.1 [16] mg/L 11:43:08 AM
Saturated within auto integration window (code 4)

2 Ca 317.933 496394.4 627274.7 [0.8] mg/L 11:43:28 AM

3 K 766.490 118365766 118367987 [80] mg/L 11:39:36 AM
Saturated within auto integration window (code 4)
3 P 213.617 1382364.1 1381504.5 [80] mg/L 11:39:53 AM
3 S 181.975 2949.9 1860.1 [80] mg/L 11:40:18 AM
3 As 193.696 126399.8 125335.8 [16] mg/L 11:40:44 AM
3 La 398.852 38149681.2 38149063.8 [16] mg/L 11:41:07 AM
3 Li 670.784 9993849.3 9970532.4 [16] mg/L 11:41:29 AM
Saturated within survey window (code 5)
3 Mn 257.610 104236244 104219066 [16] mg/L 11:41:58 AM Saturated within auto integration window (code 4)
3 Mo 202.031 1101580.3 1098748.0 [16] mg/L 11:42:13 AM
3 Na 589.592 74073842.7 74086027.4 [16] mg/L 11:42:38 AM
3 Ni 231.604 4093813.3 4092404.7 [16] mg/L 11:42:56 AM
3 Sc 361.383 73069137.5 73064679.5 [16] mg/L 11:43:15 AM Saturated within auto integration window (code 4)
3 Ca 317.933 510742.0 641622.3 [0.8] mg/L 11:43:31 AM

Mean Data: Std 5

Analyte	Mean Intensity	Corrected Std.Dev.	RSD	Calib Conc. Units
K 766.490	116022373	2942384.14	2.54%	[80] mg/L
Saturated within auto integration window (code 4)				
P 213.617	1366444.9	13867.45	1.01%	[80] mg/L
S 181.975	2053.9	228.65	11.13%	[80] mg/L
Standard intensity and concentration values are not in the same order.				
As 193.696	125159.6	251.73	0.20%	[16] mg/L
La 398.852	38040076.6	95695.46	0.25%	[16] mg/L
Li 670.784	Saturated5			[16] mg/L
Mn 257.610	104133068	676079.14	0.65%	[16] mg/L
Saturated within auto integration window (code 4)				
Mo 202.031	1112613.5	18841.00	1.69%	[16] mg/L
Na 589.592	70805807.2	6050231.92	8.54%	[16] mg/L
Ni 231.604	4097918.2	38510.87	0.94%	[16] mg/L
Sc 361.383	Saturated4			[16] mg/L
Ca 317.933	634117.9	7196.63	1.13%	[0.8] mg/L

Calibration Summary

Analyte	Stds.	Equation	Intercept	Slope	Curvature	Corr. Coef. Reslope
K 766.490	5	Lin Thru 0	0.0	1354000	0.00000	0.988202
P 213.617	5	Lin Thru 0	0.0	17090	0.00000	0.999861
S 181.975	5	Lin Thru 0	0.0	21.03	0.00000	0.931020
As 193.696	5	Lin Thru 0	0.0	7831	0.00000	0.999800
La 398.852	5	Lin Thru 0	0.0	2375000	0.00000	0.999844
Li 670.784	3	Lin Thru 0	0.0	23510000	0.00000	0.990420
Mn 257.610	5	Lin Thru 0	0.0	6517000	0.00000	0.999797
Mo 202.031	5	Lin Thru 0	0.0	70020	0.00000	0.999806
Na 589.592	5	Lin Thru 0	0.0	4070000	0.00000	0.984764
Ni 231.604	5	Lin Thru 0	0.0	257000	0.00000	0.999846
Sc 361.383	4	Lin Thru 0	0.0	14420000	0.00000	0.999117
Ca 317.933	5	Lin Thru 0	0.0	789900	0.00000	0.999883

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Sequence No.: 7 **Autosampler Location: 9**

Sample ID: C5 **Date Collected: 10/27/2022 11:44:12 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol: Dilution:** **Sample Prep Vol: Wash**
Time:

----------Replicate Data: C5

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Sample Conc. Units	Analysis Time
1	K 766.490	55502125.3	55504346.2	41.01 mg/L	41.01 mg/L	5:02:27 AM
1	P 213.617	213984.9	213125.4	12.47 mg/L	12.47 mg/L	5:02:55 AM
1	S 181.975	1751.6	661.8	31.47 mg/L	31.47 mg/L	5:03:07 AM
1	As 193.696	-46127.4	-47191.4	-6.026 mg/L	-6.026 mg/L	5:03:38 AM
1	La 398.852	1177151.3	1176533.8	0.495 mg/L	0.495 mg/L	5:03:57 AM
1	Li 670.784	6816361.1	6793044.2	0.289 mg/L	0.289 mg/L	5:04:10 AM
1	Mn 257.610	94481478.7	94464300.8	14.49 mg/L	14.49 mg/L	5:04:21 AM
1	Mo 202.031	-358829.9	-361662.2	-5.165 mg/L	-5.165 mg/L	5:04:48 AM
1	Na 589.592	61475963.2	61488147.9	15.11 mg/L	15.11 mg/L	5:05:00 AM
1	Ni 231.604	399384.4	397975.8	1.548 mg/L	1.548 mg/L	5:05:27 AM
1	Sc 361.383	13012497.0	13008038.9	0.902 mg/L	0.902 mg/L	5:05:40 AM
1	Ca 317.933	Saturated3	Saturated3			5:05:53 AM

Saturated in preshot (code 3)

2	K 766.490	55901984.9	55904205.7	41.30 mg/L	41.30 mg/L	5:02:35 AM
2	P 213.617	217856.2	216996.6	12.70 mg/L	12.70 mg/L	5:02:58 AM
2	S 181.975	1676.8	587.0	27.91 mg/L	27.91 mg/L	5:03:17 AM
2	As 193.696	-45729.9	-46794.0	-5.976 mg/L	-5.976 mg/L	5:03:44 AM
2	La 398.852	1165675.2	1165057.8	0.491 mg/L	0.491 mg/L	5:04:01 AM
2	Li 670.784	6813419.5	6790102.6	0.289 mg/L	0.289 mg/L	5:04:12 AM
2	Mn 257.610	93888099.0	93870921.1	14.40 mg/L	14.40 mg/L	5:04:30 AM
2	Mo 202.031	-349341.1	-352173.4	-5.030 mg/L	-5.030 mg/L	5:04:50 AM
2	Na 589.592	63203636.0	63215820.7	15.53 mg/L	15.53 mg/L	5:05:09 AM
2	Ni 231.604	399005.8	397597.2	1.547 mg/L	1.547 mg/L	5:05:32 AM
2	Sc 361.383	13140613.8	13136155.7	0.911 mg/L	0.911 mg/L	5:05:45 AM
2	Ca 317.933	40335281.1	40466161.4	51.23 mg/L	51.23 mg/L	5:06:01 AM

Saturated within survey window (code 5)

3	K 766.490	56522269.5	56524490.3	41.76 mg/L	41.76 mg/L	5:02:43 AM	
3	P 213.617	215074.0	214214.5	12.54 mg/L	12.54 mg/L	5:03:01 AM	
3	S 181.975	1662.7	572.9	27.24 mg/L	27.24 mg/L	5:03:27 AM	
3	As 193.696	-46093.7	-47157.8	-6.022 mg/L	-6.022 mg/L	5:03:48 AM	
3	La 398.852	1171174.8	1170557.4	0.493 mg/L	0.493 mg/L	5:04:04 AM	
3	Li 670.784	6932894.9	6909578.0	0.294 mg/L	0.294 mg/L	5:04:15 AM	
3	Mn 257.610	95280030.4	95262852.5	14.62 mg/L	14.62 mg/L	5:04:38 AM	
3	Mo 202.031	-352209.0	-355041.3	-5.071 mg/L	-5.071 mg/L	5:04:52 AM	
3	Na 589.592	63767672.2	63779856.9	15.67 mg/L	15.67 mg/L	5:05:16 AM	
3	Ni 231.604	404957.3	403548.7	1.570 mg/L	1.570 mg/L	5:05:35 AM	
3	Sc 361.383	12867510.1	12863052.0	0.892 mg/L	0.892 mg/L	5:05:48 AM	
3	Ca 317.933	40354190.3	40485070.6	51.26 mg/L	51.26 mg/L	5:06:08 AM	Saturated within survey window (code 5)

----------**Mean Data: C5**

Analyte	Mean Corrected Intensity	Calib. Conc. Units	Std.Dev.	Sample Conc. Units	Std.Dev.	RSD
K 766.490	55977680.8	41.36 mg/L	0.380	41.36 mg/L	0.380	0.92%
P 213.617	214778.8	12.57 mg/L	0.117	12.57 mg/L	0.117	0.93%
S 181.975	607.2	28.87 mg/L	2.272	28.87 mg/L	2.272	7.87%
As 193.696	-47047.8	-6.008 mg/L	0.0281	-6.008 mg/L	0.0281	0.47%
La 398.852	1170716.3	0.493 mg/L	0.0024	0.493 mg/L	0.0024	0.49%
Li 670.784	6830908.3	0.291 mg/L	0.0029	0.291 mg/L	0.0029	1.00%
Mn 257.610	94532691.5	14.51 mg/L	0.107	14.51 mg/L	0.107	0.74%
Mo 202.031	-356292.3	-5.088 mg/L	0.0695	-5.088 mg/L	0.0695	1.37%
Na 589.592	62827941.8	15.44 mg/L	0.293	15.44 mg/L	0.293	1.90%
Ni 231.604	399707.2	1.555 mg/L	0.0130	1.555 mg/L	0.0130	0.83%
Sc 361.383	13002415.5	0.901 mg/L	0.0095	0.901 mg/L	0.0095	1.05%
Ca 317.933	Saturated5	51.24 mg/L	0.017	51.24 mg/L	0.017	0.03%

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Sequence No.: 8 **Autosampler Location: 10**
Sample ID: B5 **Date Collected: 10/27/2022 5:06:55 AM**
Analyst: **Data Type: Original Initial Sample Wt:** **Initial Sample Vol:**
Dilution: **Sample Prep Vol:** **Wash Time:**

----------**Replicate Data: CONTROL**

100

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Sample Conc. Units	Analysis Time	
1	K 766.490	Saturated3	Saturated3			5:08:31 AM	Saturated in preshot (code 3)
1	P 213.617	384409.2	383549.7	22.45 mg/L	22.45 mg/L	5:08:58 AM	
1	S 181.975	4097.5	3007.7	143.0 mg/L	143.0 mg/L	5:09:10 AM	

PM

1	As 193.696	-45361.5	-46425.6	-5.929 mg/L	-5.929 mg/L	5:09:37 AM	
1	La 398.852	1380874.8	1380257.4	0.581 mg/L	0.581 mg/L	5:09:55 AM	

1:39:40
PM

1	Li 670.784	7254065.7	7230748.8	0.308 mg/L	0.308 mg/L	5:10:07 AM
1	Mn 257.610	78920840.9	78903663.0	12.11 mg/L	12.11 mg/L	5:10:18 AM
1	Mo 202.031	-346401.3	-349233.6	-4.988 mg/L	-4.988 mg/L	5:10:46 AM
1	Na 589.592	63868577.7	63880762.4	15.69 mg/L	15.69 mg/L	5:10:59 AM
1	Ni 231.604	395930.5	394521.9	1.535 mg/L	1.535 mg/L	5:11:26 AM
1	Sc 361.383	12856621.8	12852163.7	0.891 mg/L	0.891 mg/L	5:11:39 AM
1	Ca 317.933	Saturated3	Saturated3			5:11:50 AM

Saturated in preshot (code 3)

2	K 766.490	93607754.9	93609975.8	69.16 mg/L	69.16 mg/L	5:08:39 AM	Saturated within auto integration window (code 4)
2	P 213.617	385973.2	385113.6	22.54 mg/L	22.54 mg/L	5:09:01 AM	
2	S 181.975	3947.3	2857.5	135.9 mg/L	135.9 mg/L	5:09:19 AM	
2	As 193.696	-44748.2	-45812.2	-5.850 mg/	-5.850 mg/L	5:09:42 AM	
2	La 398.852	1384795.3	1384177.9	0.583 mg/L	0.583 mg/L	5:09:59 AM	
2	Li 670.784	7244978.7	7221661.8	0.307 mg/L	0.307 mg/L	5:10:09 AM	
2	Mn 257.610	79283517.8	79266339.9	12.16 mg/L	12.16 mg/L	5:10:28 AM	
2	Mo 202.031	-340128.4	-342960.7	-4.898 mg/L	-4.898 mg/L	5:10:48 AM	
2	Na 589.592	63497112.2	63509296.9	15.60 mg/L	15.60 mg/L	5:11:07 AM	
2	Ni 231.604	399832.7	398424.1	1.550 mg/L	1.550 mg/L	5:11:30 AM	
2	Sc 361.383	12738004.3	12733546.2	0.883 mg/L	0.883 mg/L	5:11:42 AM	
2	Ca 317.933	52546771.0	52677651.3	66.69 mg/L	66.69 mg/L	5:12:00 AM	Saturated within survey window (code 5)
3	K 766.490	93804457.9	93806678.8	69.30 mg/L	69.30 mg/L	5:08:46 AM	Saturated within auto integration window (code 4)
3	P 213.617	383473.2	382613.7	22.39 mg/L	22.39 mg/L	5:09:04 AM	
3	S 181.975	3891.1	2801.3	133.2 mg/L	133.2 mg/L	5:09:27 AM	
3	As 193.696	-44475.9	-45540.0	-5.816 mg/L	-5.816 mg/L	5:09:47 AM	
3	La 398.852	1365333.2	1364715.8	0.575 mg/L	0.575 mg/L	5:10:01 AM	
3	Li 670.784	7069107.6	7045790.7	0.300 mg/L	0.300 mg/L	5:10:12 AM	
3	Mn 257.610	79038831.0	79021653.1	12.13 mg/L	12.13 mg/L	5:10:36 AM	
3	Mo 202.031	-333223.5	-336055.8	-4.799 mg/L	-4.799 mg/L	5:10:50 AM	
3	Na 589.592	63470130.1	63482314.8	15.60 mg/L	15.60 mg/L	5:11:14 AM	
3	Ni 231.604	402462.0	401053.4	1.560 mg/L	1.560 mg/L	5:11:33 AM	
3	Sc 361.383	12948303.3	12943845.3	0.897 mg/L	0.897 mg/L	5:11:45 AM	
3	Ca 317.933	52401822.2	52532702.5	66.51 mg/L	66.51 mg/L	5:12:07 AM	Saturated within survey window (code 5)

----------**Mean Data: B5**

Analyte	Mean Corrected Intensity	Calib. Conc. Units	Calib. Std.Dev.	Sample Conc. Units	Sample Std.Dev.	RSD
K 766.490	Saturated4	69.23 mg/L	0.103	69.23 mg/L	0.103	0.15%
P 213.617	383759.0	22.46 mg/L	0.074	22.46 mg/L	0.074	0.33%
S 181.975	2888.8	137.4 mg/L	5.08	137.4 mg/L	5.08	3.69%
As 193.696	-45926.0	-5.865 mg/L	0.0579	-5.865 mg/L	0.0579	0.99%
La 398.852	1376383.7	0.580 mg/L	0.0043	0.580 mg/L	0.0043	0.75%
Li 670.784	7166067.1	0.305 mg/L	0.0044	0.305 mg/L	0.0044	1.45%
Mn 257.610	79063885.3	12.13 mg/L	0.028	12.13 mg/L	0.028	0.23%
Mo 202.031	-342750.0	-4.895 mg/L	0.0941	-4.895 mg/L	0.0941	1.92%
Na 589.592	63624124.7	15.63 mg/L	0.055	15.63 mg/L	0.055	0.35%
Ni 231.604	397999.8	1.548 mg/L	0.0128	1.548 mg/L	0.0128	0.83%
Sc 361.383	12843185.1	0.890 mg/L	0.0073	0.890 mg/L	0.0073	0.82%

PM

Ca 317.933	Saturated5	66.60 mg/L	0.130	66.60 mg/L	0.130	0.19%

Method: Bronie Test Run Page 13 Date: 10/27/2022
1:39:40

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Sequence No.: 9 Autosampler Location: 11
Sample ID: STD 3 Date Collected: 10/27/2022 5:12:56 AM
Analyst: Data Type: Original Initial
Sample Wt: Initial Sample Vol: Dilution:
Sample Prep Vol: Wash Time:

----------Replicate Data: STD 3

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Sample Conc. Units	Analysis Time

Method: Bronie Test Run Page PM

1 K 766.490 30283767.9 30285988.8 22.38 mg/L 22.38 mg/L 5:14:32 AM
1 P 213.617 394386.7 393527.2 23.03 mg/L 23.03 mg/L 5:14:52 AM
1 S 181.975 3473.9 2384.1 113.4 mg/L 113.4 mg/L 5:15:04 AM
1 As 193.696 35411.4 34347.3 4.386 mg/L 4.386 mg/L 5:15:32 AM
1 La 398.852 10100516.0 10099898.5 4.253 mg/L 4.253 mg/L 5:16:01 AM
1 Li 670.784 Saturated3 Saturated3 5:16:14 AM
Saturated in preshot (code 3)
1 Mn 257.610 29833749.2 29816571.3 4.575 mg/L 4.575 mg/L 5:16:39 AM
1 Mo 202.031 325709.7 322877.4 4.611 mg/L 4.611 mg/L 5:16:59 AM
1 Na 589.592 14590480.3 14602665.0 3.588 mg/L 3.588 mg/L 5:17:16 AM
1 Ni 231.604 1189388.2 1187979.6 4.622 mg/L 4.622 mg/L 5:17:31 AM
1 Sc 361.383 61296276.7 61291818.6 4.249 mg/L 4.249 mg/L 5:17:42 AM
1 Ca 317.933 146365.9 277246.2 0.351 mg/L 0.351 mg/L 5:18:06 AM
2 K 766.490 29987378.2 29989599.1 22.16 mg/L 22.16 mg/L 5:14:38 AM
2 P 213.617 408552.4 407692.8 23.86 mg/L 23.86 mg/L 5:14:55 AM
2 S 181.975 3387.5 2297.7 109.3 mg/L 109.3 mg/L 5:15:14 AM
2 As 193.696 35713.4 34649.4 4.425 mg/L 4.425 mg/L 5:15:41 AM
2 La 398.852 9705633.5 9705016.1 4.087 mg/L 4.087 mg/L 5:16:04 AM
2 Li 670.784 122134762 122111445 5.193 mg/L 5.193 mg/L 5:16:21 AM
Saturated within auto integration window (code 4)
2 Mn 257.610 29452360.9 29435183.0 4.517 mg/L 4.517 mg/L 5:16:46 AM
2 Mo 202.031 328355.7 325523.3 4.649 mg/L 4.649 mg/L 5:17:03 AM
2 Na 589.592 14687463.4 14699648.1 3.611 mg/L 3.611 mg/L 5:17:20 AM
2 Ni 231.604 1195501.0 1194092.4 4.645 mg/L 4.645 mg/L 5:17:35 AM
2 Sc 361.383 61234578.8 61230120.8 4.245 mg/L 4.245 mg/L 5:17:50 AM
2 Ca 317.933 144467.5 275347.8 0.349 mg/L 0.349 mg/L 5:18:11 AM
3 K 766.490 30313394.7 30315615.6 22.40 mg/L 22.40 mg/L 5:14:43 AM
3 P 213.617 390596.6 389737.0 22.81 mg/L 22.81 mg/L 5:14:59 AM
3 S 181.975 3350.9 2261.1 107.5 mg/L 107.5 mg/L 5:15:22 AM
3 As 193.696 35851.8 34787.7 4.442 mg/L 4.442 mg/L 5:15:49 AM
3 La 398.852 9937148.9 9936531.4 4.184 mg/L 4.184 mg/L 5:16:07 AM
3 Li 670.784 123254668 123231351 5.241 mg/L 5.241 mg/L 5:16:28 AM Saturated within auto integration window (code 4)
3 Mn 257.610 29305327.3 29288149.4 4.494 mg/L 4.494 mg/L 5:16:52 AM
3 Mo 202.031 318869.2 316036.8 4.514 mg/L 4.514 mg/L 5:17:06 AM
3 Na 589.592 14660591.3 14672776.0 3.605 mg/L 3.605 mg/L 5:17:24 AM

3 Ni 231.604 1225239.9 1223831.3 4.761 mg/L 4.761 mg/L 5:17:37 AM
3 Sc 361.383 61498485.7 61494027.6 4.263 mg/L 4.263 mg/L 5:17:57 AM
3 Ca 317.933 140254.7 271135.0 0.343 mg/L 0.343 mg/L 5:18:14 AM

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--Mean Data: STD 3

Analyte	Mean Corrected Intensity	Calib. Conc. Units	Std.Dev.	Sample Conc. Units	Std.Dev.	RSD
K 766.490	30197067.8	22.31 mg/L	0.133	22.31 mg/L	0.133	0.60%
P 213.617	396985.7	23.24 mg/L	0.554	23.24 mg/L	0.554	2.38%
S 181.975	2314.3	110.0 mg/L	3.00	110.0 mg/L	3.00	2.73%
As 193.696	34594.8	4.418 mg/L	0.0288	4.418 mg/L	0.0288	0.65%
La 398.852	9913815.3	4.175 mg/L	0.0836	4.175 mg/L	0.0836	2.00%
Li 670.784	Saturated4	5.217 mg/L	0.0337	5.217 mg/L	0.0337	0.65%
Mn 257.610	29513301.2	4.529 mg/L	0.0418	4.529 mg/L	0.0418	0.92%
Mo 202.031	321479.2	4.591 mg/L	0.0699	4.591 mg/L	0.0699	1.52%
Na 589.592	14658363.0	3.601 mg/L	0.0123	3.601 mg/L	0.0123	0.34%
Ni 231.604	1201967.7	4.676 mg/L	0.0746	4.676 mg/L	0.0746	1.60%
Sc 361.383	61338655.7	4.253 mg/L	0.0096	4.253 mg/L	0.0096	0.23%
Ca 317.933	274576.4	0.348 mg/L	0.0040	0.348 mg/L	0.0040	1.14%

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Sequence No.: 10 **Autosampler Location: 12**
Sample ID: CONTROL **Date Collected: 10/27/2022 5:18:57 AM**
Analyst: **Data Type: Original Initial Sample Wt:**
Initial Sample Vol: Dilution: **Sample Prep Vol: Wash Time:**

---**Replicate Data: CONTROL**

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Sample Conc. Units	Analysis Time
1	K 766.490	Saturated3	Saturated3			5:20:33 AM
	Saturated in preshot (code 3)					
1	P 213.617	1031684.6	1030825.0	60.33 mg/L	60.33 mg/L	5:21:01

AM
1 S 181.975 3062.0 1972.2 93.78 mg/L 93.78 mg/L 5:21:10
AM
1 As 193.696 -77618.0 -78682.1 -10.05 mg/L -10.05 mg/L 5:21:46 AM
1 La 398.852 1274421.8 1273804.4 0.536 mg/L 0.536 mg/L 5:22:01 AM
Method: Bronie Test Run Page PM
1 Li 670.784 20291106.7 20267789.8 0.862 mg/L 0.862 mg/L 5:22:14
AM
1 Mn 257.610 115662616 115645438 17.74 mg/L 17.74 mg/L 5:22:28 AM
Saturated within auto integration window (code 4)
1 Mo 202.031 -435594.3 -438426.6 -6.261 mg/L -6.261 mg/L 5:22:55 AM
1 Na 589.592 Saturated3 Saturated3 5:23:07
AM
Saturated in preshot (code 3)
1 Ni 231.604 725085.0 723676.4 2.815 mg/L 2.815 mg/L 5:23:35
AM
1 Sc 361.383 17713452.5 17708994.4 1.228 mg/L 1.228 mg/L 5:23:45 AM
1 Ca 317.933 Saturated3 Saturated3 5:23:59 AM Saturated in preshot (code 3)
2 K 766.490 -52826275 -52824054 -39.03 mg/L -39.03 mg/L 5:20:41 AM Saturated within auto integration window (code 4)
2 P 213.617 1040004.3 1039144.7 60.82 mg/L 60.82 mg/L 5:21:03
AM
2 S 181.975 3029.0 1939.3 92.21 mg/L 92.21 mg/L 5:21:22
AM
2 As 193.696 -77144.1 -78208.2 -9.987 mg/L -9.987 mg/L 5:21:51 AM
2 La 398.852 1260148.3 1259530.9 0.530 mg/L 0.530 mg/L 5:22:05 AM
2 Li 670.784 20291250.1 20267933.2 0.862 mg/L 0.862 mg/L 5:22:18 AM
2 Mn 257.610 115356381 115339203 17.70 mg/L 17.70 mg/L 5:22:37 AM
Saturated within auto integration window (code 4)
2 Mo 202.031 -431124.6 -433956.9 -6.198 mg/L -6.198 mg/L 5:22:57 AM
2 Na 589.592 59962161.9 59974346.6 14.73 mg/L 14.73 mg/L 5:23:17 AM
Saturated within survey window (code 5)
2 Ni 231.604 732343.1 730934.5 2.844 mg/L 2.844 mg/L 5:23:38
AM
2 Sc 361.383 17876508.1 17872050.1 1.239 mg/L 1.239 mg/L 5:23:49 AM
2 Ca 317.933 46988026.5 47118906.8 59.65 mg/L 59.65 mg/L 5:24:07 AM Saturated within survey window (code 5)
3 K 766.490 -52922538 -52920317 -39.10 mg/L -39.10 mg/L 5:20:49 AM Saturated within auto integration window (code 4)
3 P 213.617 1039625.9 1038766.3 60.80 mg/L 60.80 mg/L 5:21:05 AM
3 S 181.975 3003.9 1914.1 91.02 mg/L 91.02 mg/L 5:21:33 AM
3 As 193.696 -77338.2 -78402.3 -10.01 mg/L -10.01 mg/L 5:21:54 AM
3 La 398.852 1263384.2 1262766.8 0.532 mg/L 0.532 mg/L 5:22:09 AM
3 Li 670.784 20330595.4 20307278.4 0.864 mg/L 0.864 mg/L 5:22:21
AM
3 Mn 257.610 115706361 115689183 17.75 mg/L 17.75 mg/L 5:22:45 AM
Saturated within auto integration window (code 4)
3 Mo 202.031 -432174.1 -435006.5 -6.213 mg/L -6.213 mg/L 5:22:59 AM
3 Na 589.592 59991280.9 60003465.6 14.74 mg/L 14.74 mg/L 5:23:24 AM

Saturated within survey window (code 5)
3 Ni 231.604 724709.9 723301.3 2.814 mg/L 2.814 mg/L 5:23:41 AM
3 Sc 361.383 17841324.8 17836866.8 1.237 mg/L 1.237 mg/L 5:23:53 AM
3 Ca 317.933 47255259.9 47386140.2 59.99 mg/L 59.99 mg/L 5:24:14 AM Saturated within survey window (code 5) ----------

----------Mean Data: CONTROL

Analyte	Mean Corrected Intensity	Calib. Conc. Units	Calib. Std.Dev.	Sample Conc. Units	Sample Std.Dev.	RSD
K 766.490	Saturated4	-39.06 mg/L	0.050	-39.06 mg/L	0.050	0.13%
P 213.617	1036245.3	60.65 mg/L	0.275	60.65 mg/L	0.275	0.45%
S 181.975	1941.8	92.33 mg/L	1.386	92.33 mg/L	1.386	1.50%
As 193.696	-78430.9	-10.02 mg/L	0.030	-10.02 mg/L	0.030	0.30%
La 398.852	1265367.3	0.533 mg/L	0.0032	0.533 mg/L	0.0032	0.59%
Li 670.784	20281000.5	0.863 mg/L	0.0010	0.863 mg/L	0.0010	0.11%
Mn 257.610	115557941	17.73 mg/L	0.029	17.73 mg/L	0.029	0.17%
Saturated within auto integration window (code 4)						
Mo 202.031	-435796.6	-6.224 mg/L	0.0334	-6.224 mg/L	0.0334	0.54%
Na 589.592	Saturated5	14.74 mg/L	0.005	14.74 mg/L	0.005	0.03%
Ni 231.604	725970.8	2.824 mg/L	0.0167	2.824 mg/L	0.0167	0.59%
Sc 361.383	17805970.4	1.234 mg/L	0.0059	1.234 mg/L	0.0059	0.48%
Ca 317.933	Saturated5	59.82 mg/L	0.239	59.82 mg/L	0.239	0.40%

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Sequence No.: 11 **Autosampler Location: 13**
Sample ID: CB5 **Date Collected: 10/27/2022 5:25:02 AM**
Analyst: **Data Type: Original Initial**
Sample Wt: **Initial Sample Vol:**
Dilution: **Sample Prep Vol: Wash Time:**

----------Replicate Data: CB5

Repl#	Analyte	Net Intensity	Corrected Intensity	Calib. Conc. Units	Sample Conc. Units	Analysis Time
1	K 766.490	85168567.8	85170788.7	62.92 mg/L	62.92 mg/L	5:26:38 AM
1	P 213.617	269161.7	268302.1	15.70 mg/L	15.70 mg/L	5:27:07
1	S 181.975	15723.9	14634.1	695.8 mg/L	695.8 mg/L	5:27:19 AM
1	As 193.696	-45158.2	-46222.3	-5.903 mg/L	-5.903 mg/L	5:27:45 AM
1	La 398.852	1489884.2	1489266.7	0.627 mg/L	0.627 mg/L	5:28:03 AM
1	Li 670.784	13814867.1	13791550.2	0.587 mg/L	0.587 mg/L	5:28:14 AM

1 Mn 257.610 82948384.2 82931206.3 12.72 mg/L 12.72 mg/L 5:28:27 AM

Method: Bronie Test Run Page PM

1 Mo 202.031 -301223.5 -304055.8 -4.342 mg/L -4.342 mg/L 5:28:53 AM
1 Na 589.592 67575471.1 67587655.8 16.61 mg/L 16.61 mg/L 5:29:07 AM
1 Ni 231.604 427129.7 425721.1 1.656 mg/L 1.656 mg/L 5:29:34 AM
1 Sc 361.383 12882322.8 12877864.8 0.893 mg/L 0.893 mg/L 5:29:47 AM
1 Ca 317.933 Saturated3 Saturated3 5:30:00 AM Saturated in preshot (code 3)
2 K 766.490 84634537.1 84636758.0 62.53 mg/L 62.53 mg/L 5:26:47 AM
2 P 213.617 265444.4 264584.8 15.49 mg/L 15.49 mg/L 5:27:10 AM
2 S 181.975 15508.3 14418.5 685.6 mg/L 685.6 mg/L 5:27:28 AM
2 As 193.696 -44309.6 -45373.7 -5.794 mg/L -5.794 mg/L 5:27:50 AM
2 La 398.852 1506281.1 1505663.6 0.634 mg/L 0.634 mg/L 5:28:06 AM
2 Li 670.784 13817658.7 13794341.8 0.587 mg/L 0.587 mg/L 5:28:17 AM
2 Mn 257.610 82360822.6 82343644.7 12.63 mg/L 12.63 mg/L 5:28:35 AM
2 Mo 202.031 -298514.9 -301347.2 -4.304 mg/L -4.304 mg/L 5:28:57 AM
2 Na 589.592 67305200.0 67317384.7 16.54 mg/L 16.54 mg/L 5:29:15 AM
2 Ni 231.604 431213.0 429804.4 .672 mg/L 1.672 mg/L 5:29:39 AM
2 Sc 361.383 12968030.0 12963571.9 0.899 mg/L 0.899 mg/L 5:29:51 AM
2 Ca 317.933 67522210.5 67653090.8 85.65 mg/L 85.65 mg/L 5:30:08 AM Saturated within survey window (code 5)
3 K 766.490 84369018.8 84371239.6 62.33 mg/L 62.33 mg/L 5:26:55 AM
3 P 213.617 275960.5 275100.9 16.10 mg/L 16.10 mg/L 5:27:13 AM
3 S 181.975 15480.5 14390.7 684.3 mg/L 684.3 mg/L 5:27:35 AM
3 As 193.696 -44398.7 -45462.8 -5.806 mg/L -5.806 mg/L 5:27:54 AM
3 La 398.852 1498817.7 1498200.2 0.631 mg/L 0.631 mg/L 5:28:09 AM
3 Li 670.784 13895529.3 13872212.4 0.590 mg/L 0.590 mg/L 5:28:20 AM
3 Mn 257.610 82414256.2 82397078.3 12.64 mg/L 12.64 mg/L 5:28:44 AM
3 Mo 202.031 -297018.0 -299850.3 -4.282 mg/L -4.282 mg/L 5:28:59 AM
3 Na 589.592 67543972.8 67556157.5 16.60 mg/L 16.60 mg/L 5:29:23 AM
3 Ni 231.604 433649.9 432241.3 1.682 mg/L 1.682 mg/L 5:29:41 AM
3 Sc 361.383 12966822.4 12962364.3 0.899 mg/L 0.899 mg/L 5:29:54 AM
3 Ca 317.933 67100964.2 67231844.5 85.12 mg/L 85.12 mg/L 5:30:15 AM Saturated within survey window (code 5)

Mean Data: CB5

Analyte	Mean Corrected Intensity	Calib. Conc. Units	Calib. Std.Dev.	Sample Conc. Units	Sample Std.Dev.	RSD
K 766.490	84726262.1	62.59 mg/L	0.301	62.59 mg/L	0.301	0.48%
P 213.617	269329.3	15.76 mg/L	0.312	15.76 mg/L	0.312	

1.98%
S 181.975 14481.1 688.6 mg/L 6.33 688.6 mg/L 6.33
0.92%
As 193.696 -45686.3 -5.834 mg/L 0.0596 -5.834 mg/L 0.0596
1.02%
La 398.852 1497710.2 0.631 mg/L 0.0035 0.631 mg/L 0.0035
0.55%
Li 670.784 13819368.2 0.588 mg/L 0.0019 0.588 mg/L 0.0019
0.33%
Mn 257.610 82557309.8 12.67 mg/L 0.050 12.67 mg/L 0.050
0.39%
Mo 202.031 -301751.1 -4.309 mg/L 0.0304 -4.309 mg/L 0.0304 0.71%
Na 589.592 67487066.0 16.58 mg/L 0.036 16.58 mg/L 0.036
0.22%
Ni 231.604 429255.6 1.670 mg/L 0.0128 1.670 mg/L 0.0128
0.77%
Sc 361.383 12934600.3 0.897 mg/L 0.0034 0.897 mg/L 0.0034
0.38%
Ca 317.933 Saturated5 85.39 mg/L 0.377 85.39 mg/L 0.377
0.44%

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Analysis Begun
Start Time: Plasma On Time:
Logged In Analyst: Administrator Technique: ICP Continuous
Spectrometer: Optima 8000, S/N N/A (Offline) Autosampler: Not Applicable

Sample Information File: C:\Users\Public\PerkinElmer Syngistix\ICP\Data\Sample Information
Bronies
Samples.sifx
Batch ID: Bronies
Samples
Results Data Set:
Results Library: