ANALYSIS OF NAGONGERA TOWN COUNCIL WATER AND SOIL FOR MICROPLASTIC CONTAMINATION

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BU/UP/2021/1755

A RESEACH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF CHEMISTRY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE EDUCATION DEGREE OF BUSITEMA UNIVERSITY

SEPTEMBER 2024

DECLARATION

I Ssemugenyi Edison declare that this research project report entitled "analysis of Nagongera town council water and soil for microplastic contamination" is my own piece of work written with my sound knowledge and in a right state of mind. I acknowledge the received guidance and support from internet, my supervisors and colleagues but the research work, data analysis, and writing of this report are entirely my own efforts. I have properly cited and referenced all sources of information used in this research, and I have not engaged in any form of academic dishonesty or plagiarism.

………………………… Date: 22/08/2024

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This research project work has been submitted to the department of chemistry with approval of research project supervisor.

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ACKNOWLEDGEMENT

I would also like to thank my parents; Ms. Nampijja Peninnah, Ms. Mukankaka Elivania, Mr. Ssekate Amos and others who empowered me both financially and emotionally during the research process.

I would like to highly thank my supervisor Mr. Musagala Peter who has rendered his time and efforts to offer guidance and supervision to me during the research process.

I would also like to thank the lab technician madam Amado Mary for providing the necessary support during my practical sessions.

I would like to thank Dr. Kigozi Moses who transported my samples to main campus for FT-IR analysis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Microplastics are small fragments of plastics of size less than 5 mm. They generally breakdown from plastic materials such as polyethylene, polystyrene, polypropylene, and others due to different factors like abrasion, high temperatures and high pressure. Microplastics have detrimental effects when humans are exposed to them, these include; breast cancer, prostate cancer, organ dysfunctioning, inflammation, miscarriage and others.

This research was aimed at analyzing and comparing the level of microplastic contamination in the different water sources utilized by the residents of Nagongera town council and the different soil samples of Nagongera town council. Therefore, it could serve to sensitize the residents about the dangers of improper disposal of plastic wastes and also recommend on the best water sources suitable for human consumption that is those with the least level of microplastic contamination. The analysis of microplastics was done using FT-IR spectroscopy where the spectra were compared with the standard spectra of microplastics.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Microplastics are fragments of any type of plastic less than 5 mm found in water sources and on land. Based on the latest global estimate of microplastics, there are 93–236 thousand tons of microplastics floating on the ocean surface, which corresponds to 51 trillion particles. 79% of global plastic waste is stacked in landfills, which makes soil a large microplastic sink too. (Jassim, 2023)

In Uganda, microplastic contamination is highest around; sites in vicinity of fish landing and recreation centers, places in urban centers, sites in vicinity of river inflows. The average occurrence of microplastics ranges in 2834-329167 particles/km^2 with the highest in places in vicinity of fish landing sites and the least in cites in vicinity of river inflows.

The largest proportion (36%) of microplastic count in Uganda were of the size less than 1 mm which possess a threat to water quality of the lake. Analysis of the chemical composition of microplastics indicated dominance by the low-density polymers; polyethylene and polypropylene across the microplastic types. Microplastics are derived from the degradation of large plastic debris implying that microplastic contamination is due to improper plastic waste management.(Egessa et al., 2020)

Microplastics once inhaled or ingested, they get into the body system where they act as endocrine disrupting chemicals (EDCs) hence causing cancers such as thyroid, breast, prostate, brain cancer and others.(Lisbeth et al., 2015)

According to Uganda Cancer Institute (UCI), 125 males and 135 females per 100,000 in Central Uganda have cancer while 47 males and 54 females per 100,000 in Eastern Uganda have cancer. About 33,000 Ugandans are diagnosed with cancer every year of which only 7400 make it for care at UCI.

1.2 Statement of the problem

In Nagongera Town council, plastic wastes are not properly managed since they are littered almost everywhere. These plastics degrade into microplastics over time and they are washed off by wind and surface runoff into the water sources. Microplastics are major endocrine disrupting chemicals (EDCs) which lead to cancer. Therefore, this research is aimed at promoting awareness about the adverse effects of microplastic contamination and to find possible ways to minimize microplastic contamination in order to curb the problem of cancer.

1.3 Objectives of the Study

The overall objective of the study was to investigate the level of microplastic contamination in Nagongera town council water and soil.

The overall object will be achieved by the following specific objectives

- To determine the variation in microplastic contamination of soils from different origins using FT-IR spectroscopy.
- To analyze and compare the level of microplastic contamination of the various sources of water in Nagongera Town Council using the FT-IR technology.

- To ascertain the likely causes of microplastic contamination in different locations basing on the analysis results.

1.4 Justification of the Study

Microplastics are of concern because of their widespread presence in the water sources, soils and other locations and the potential physical and toxicological risks they pose to organisms. Microplastics pose significant risks to the ecosystem and human health, necessitating accurate detection for a comprehensive understanding of their distribution and impact. The riskiest problem microplastics are linked to is reduction in the fertility rate of organisms which highly affects the ecosystem. This research will enlighten the public about the dangers of exposure to microplastics such as causing cancer, organ dysfunctioning, weight gain, insulin resistance and so many others.

1.5 Literature Review

1.5.1 Introduction

Microplastics are fragments of any type of plastics less than 5 mm. Plastics are polymer products consisting of a wide range of synthetic or semi-synthetic organic and inorganic compounds (Saminathan et al., 2014).

They are substantially made from petrochemical materials extracted from coal, oil, and natural gas. Microplastics can be categorized based on their chemical composition for example; polyethylene (PE), polyvinyl chloride (PVC), polyurethane (PUR), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyester and others. The other category is based on the intention behind their manufacture, and they can be classified into primary and secondary microplastics. Primary microplastics are intentionally manufactured and added to consumer and commercial products like cosmetics, personal care products, pharmaceuticals, detergents, and insecticides while secondary microplastics on the other hand, are unintentionally formed by the breakdown of larger plastic materials through physical, chemical, or biological processes, such as fishing gear, plastic bottles, plastic bags, and plastic food containers(Osman et al., 2023).

Due to their wide range of physical and chemical properties, durability and relatively low cost, plastics are considered ideal materials with an extensive variety of applications by many industries. For example, the manufacturing industry uses million tons of plastics per year to produce textile fibers; while the food industries use plastics for packaging products, enabling to reduce food wastage and transportation costs. The economic advantages generated by plastics has caused this industry to grow steadily over the last decades, where world plastic production increased from 1.5 million tons in 1950 to 380 million tons in 2016.(Ariza-tarazona et al., 2023)

Despite the benefits of plastics to the economy and the daily life of the population, these tend to accumulate in the environment due to their durability and lack of biodegradation. These main intrinsic factors, in addition to their inadequate disposition, are the primary reasons why plastic waste has become a pollution problem of global scale. Initial concerns about contamination by plastics were that 79% of all plastics were being dropped to landfills or illegal dumping sites.(Ariza-tarazona et al., 2023)

Due to different physical and climate factors such as abrasion, high temperatures, rainfall and others, plastics breakdown to give smaller particles continuously which gives rise to the so called microplastics that are less than 5mm. these plastic debris are transported to water sources such as lakes, rivers, seas, oceans, wells and others by surface runoff, wind, humans and animals. Well as some water is packaged in plastic bottles, transported using plastic pipes thus promoting microplastic contamination(Jenkins et al., 2022).

Microplastics prove much more challenging to remove due to their small sizes, which are often too small to spot or grab in moving water and can remain active marine contaminants for up to 450 years. The small particles of microplastics serve as carriers for bacteria and persistent organic pollutants, which are toxic organic compounds that take years to degrade. Moreover, they consist of chemical materials that are hazardous to human and animal health in high concentrations. The humans ingest microplastics by eating marine animals that have consumed the material or through drinking water or breathing air. Therefore, it is very important to have idea and information about microplastics and how to avoid or eliminate their effect on our life(Jassim, 2023).

1.5.2 Sources of microplastics

There are different sources of microplastics; the majority of microplastics come from household activity with a percentage of 77% and 23% from industrial application(Jassim, 2023). Microplastic sources are classified into two; land-based and ocean/marine-based sources.

Land-based sources are responsible for 80–90% of microplastics in water bodies. These sources include plastic bags, bottles, personal care products, construction materials, and clothing. Plastic incinerators, which generate bottom ash that contains microplastics, are also a land-based source of these particles. Construction materials, household products, packaging items, food and drink packaging waste, and waste generated from shipbuilding are some of the most significant sources of larger plastic objects on land. Sewage sludge and industrial activities, particularly those using granules and small resin pellets, are other probable sources of microplastic discharge into the aquatic environment. In addition to medicines and construction materials, certain cosmetics and personal care products are also considered potential sources of plastic pollution, as they may contain microplastics used as drug carriers or as ingredients. Face washes, hand soaps, hand gels, laundry detergents, washing powder, toothpaste, facial creams, mascaras, lipsticks, sunblock, and shower gels are some of the common examples of such products. Many synthetic fibers, such as polyester, nylon, and acrylics, have been found to shed of clothing and discharge with the stream wastewater into water bodies. Tire wear and tear of cars greatly release microplastics into the environment. Single-use products made of polymeric plastics, such as drinking bottles, straws, cutlery, coffee cups, and bags, have been identified as a significant source of plastic pollution in the environment. Furthermore, the excessive use of single-use face masks made of plastic polymers, such as polyesters and polypropylenes, during the coronavirus disease 2019 (COVID-19) has significantly increased microplastic waste.(Osman et al., 2023)

Ocean/marine- based sources contribute to 10-20% microplastics discharged in the aquatic environment. The sources include seaside tourism, commercial fishing, marine vessels, and offshore industries. Discarded or lost fishing gear, such as plastic monofilament lines and nylon nets, are a significant source of microplastics that can float at different depths in the ocean. Over 600,000 tonnes of fishing gear are thrown away in the ocean each year, contributing to the problem. Shipping microplastic waste, commonly released from shipping and naval vessels, also adds to the problem. Moreover, a massive quantity of plastic waste from offshore industries, such as petrochemicals, is being released into marine ecosystems. While the contribution of ocean-based sources to microplastic pollution is not as high as land-based sources, it is still significant.(Osman et al., 2023)

How microplastics get into the water sources:

Plastic waste gets into water sources by; direct littering and later fragmentation, wastewater effluent, surface runoff (e.g. from roads and agricultural land) into soils, lakes and rivers, transportation by wind, maritime activities – i.e. fishing and shipping – caused by lost fishing gear, cargo and other litter (UK, n.d.).

1.5.3 Exposure routes

There are three routes through which humans can be exposed to microplastics i.e. the oral (drinks & food), respiratory (inhalation) and the dermal route (skin);

Gastrointestinal Tract; the primary plastic entry point into the human system is the gastrointestinal tract. Involuntary plastic ingestion by humans may happen via the food chain with consumption of contaminated food and drinks. Contamination may occur also through the migration of microplastic particles from the packaging materials into food products. Also, microplastic particles are present in widespread marine products, including fish, mussels, lobsters, oysters, sea cucumbers, and scallops. Micro- and nano-plastic fibers are also present in other foods, including beer, honey, table salt, and sugar. It is identified that a median of 20 microplastic particles per 10g of human stool samples, which confirms their involuntary ingestion. Based on animal models, plastic particles in certain size fractions (0.1 and 150 µm) can move across the mammalian gut into the lymphatic system via endocytosis using M cells of Peyer's patches.(Baj et al., 2022)

Respiratory System; another entry point of plastics into the human body is via the respiratory system. The sources of airborne microplastic include synthetic fabrics from clothing, rubber tire erosion, household objects, building materials, landfills, abrasive powders and 3D printing. According to (Dris, Rachid (Universite Paris-Est et al., 2017), up to 33% of household dust fallout is microplastic with polypropylene being predominant, and cellulose. High microplastic concentrations indoors may be explained both by examining numerous sources of plastic, including household objects and synthetic textiles, and the mechanisms involved in their dispersion, such as ventilation rate, airflow, room partition, as well as climatic conditions. In the lungs, a very thin tissue barrier, smaller than 1 µm, separates the lumen of the alveoli from the bloodstream. Nanosized particles bear the potential to penetrate the capillary blood system and be distributed throughout the human body. Vitro studies have shown that nanoplastic particles are absorbed by alveolar epithelial cells.(Baj et al., 2022)

Skin; the last route of exposure of plastics into the human body is through the skin. Skin constitutes the outer shell of the body that protects the body against heat, light, injury, and infection. Skin can come into contact with microplastic particles, especially when cosmetic products containing microplastics are used. The stratum corneum of the skin is a solid barrier composed of corneocytes, surrounded by hydrophilic lipids that prevents penetration of hydrophobic agents; hence, significant absorption of nanoplastic particles through the skin is not expected. According to the studies conducted on a porcine skin tissue model, the polystyrene particles with diameters of 20–200nm were unable to penetrate below the stratum corneum into deeper layers of the skin. However recent cancer studies have shown the ability of nanoplastics to penetrate the skin. There are some additional factors that may increase the nano-permeability of the stratum corneum; According to (Mortensen et al., 2008), exposure to UV radiation disrupts the expression of tight junction-related proteins (zonula occludens-1, claudin-1, and occludin), which increases the skin penetration of nanoparticles (carboxylated quantum dots) in mice models. In addition, certain ingredients of skin lotions (e.g., urea, glycerol, and α-hydroxyl acids) enhance the penetration of nanoparticles into the skin.(Baj et al., 2022)

1.5.4 Chemical composition of microplastics

Microplastics consist of carbon and hydrogen atoms bound together in polymer chains. Other chemicals, such as phthalates, polybrominated diphenyl ethers (PBDEs) and tetrabromobisphenol A (TBBPA) are typically also present in microplastics, and many of these chemical additives leach out of the plastics after entering the environment. [Britanicca]

Polymers are the macro components of plastics. They are the result of polymerization reactions occurring between single units called monomers. Polymers can be made of just one type of monomer (homopolymers) or from a mixture of monomers (copolymers). The most widely used commercial polymers are: polypropylene (PP), polyethylene (PE), high-density polyethylene (HDPE), low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE), polyvinyl chloride (PVC), polyurethane (PU), polyethylene terephthalate (PET), polystyrene (PS), expanded polystyrene (EPS), extruded polystyrene (XPS), polycarbonate (PC), epoxy resin, acrylic, acrylonitrile butadiene styrene (ABS), polyamides (PA)(nylon), polyester (PEST), polyvinylidene chloride (PVDC)(Saran), poly methyl methacrylate (PMMA), poly aryl sulfone (PSU), polyacrylonitrile (PAN), polyvinyl alcohol (PVA) and polytetrafluoroethylene (PTFE, Teflon), Polymers are not considered to be toxic per se; they are generally considered biologically inert, largely because of their size. Their monomeric units, however, may be toxic. Polymerization reactions generally require the use of initiators, solvents and catalysts. These substances are typically added in concentrations below 2 percent of the polymer weight and should ordinarily not remain in the final products(Lithner et al., 2011). When they persist in the final product they are considered impurities and need to be assessed for their toxicological properties.

Monomers are the building blocks of polymers, and they react with each other to form macromolecular chains. They can make up 4–100 percent of the final polymer by weight (Lithner et al., 2011). As indicated above, some monomers can be toxic. Therefore, although the polymers are generally too large to interact with tissue and result in adverse effects, an excessive amount of residual reactive monomers in the polymer may cause concern. (Lithner et al., 2011) developed a hazard ranking of plastic polymers based on the toxicity of each of their components. According to that ranking, the most hazardous plastic polymer monomers for human health are vinyl chloride (in PVC), epichlorohydrin (in epoxy), acrylonitrile (in ABS), methylenedianiline (in epoxy), 1,3-butadiene, propylene oxide, ethylene oxide (in some PU) and acrylamide, in ascending order. Some of the most relevant monomers with potential adverse effects are described next.

1.5.4.1 Styrene

The chemical formula for styrene is C_8H_8 but its structural formula is $C_6H_5CH{=}CH_2$. It contains a vinyl group as a substituent therefore it's a member of the vinyls-organic compounds[britannica]. Polystyrene is an addition polymer that results when styrene monomers polymerize. In polymerization, the carbon-carbon pie bond of the vinyl group is broken and a new carbon-carbon sigma bond is formed, attaching to the carbon of another styrene monomer to the chain.[wikipedia]

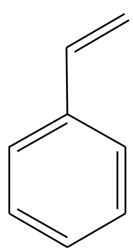


Fig 1: Styrene

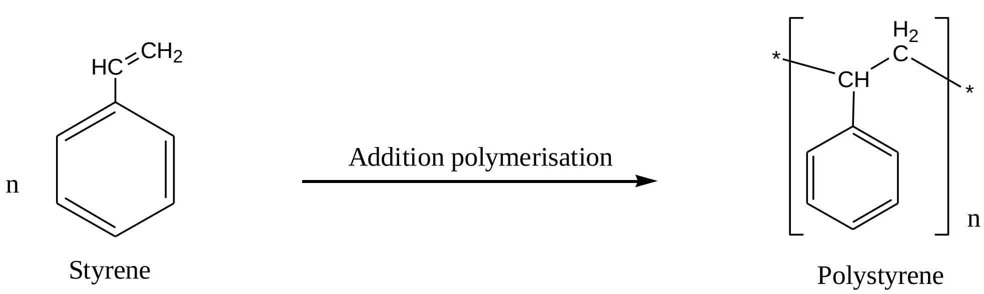
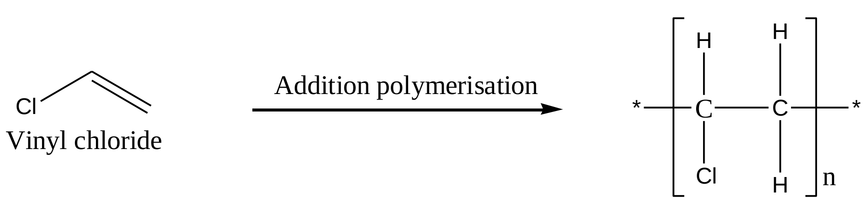


Fig 2: Polystyrene

Styrene is the main component of polystyrene (PS) and can make up to 100 percent of the polymer by weight. Some studies have investigated the adverse effects of exposure to styrene microparticles, such as the induction of immunological alterations at the cellular level (Hwang et al., 2020). The majority of studies investigating styrene toxicity in humans focused on the effects on workers exposed through inhalation, a pathway which could allegedly cause inflammation and impair the functions of the respiratory tract (Meyer et al., 2018). Moreover, the concentration of styrene in the blood of workers of both sexes from 17 different places was suggested as being positively related to serum prolactin levels (Luderer et al., 2011). Exposure through styrene-contaminated water caused subjective symptoms related to irritation of the respiratory tract and abdominal pain.(Gamarro, Garrido & Costanzo, 2022)

1.5.4.2 Vinyl chloride

Vinyl chloride [CH_2=CHCl] is the main component of PVC and accounts for up to 100 percent of this polymer. This molecule is reported to be mutagenic, may have consequences on reproduction and is considered as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC, 2008). Its adverse effects are attributed to the interaction of the parent compound or derived metabolites with neural membranes or other targets in the human body. Metabolites are generally believed to be easily excreted in the urine following a two-phase detoxification pathway. However, the intermediate metabolites from the phase I detoxification step, namely chloroethylene oxide and chloroacetaldehyde, can interact with DNA to form adducts (Brandt-Ruaf et al., 2012). Acute toxicity mainly involves oxidative reactions such as lipid peroxidation, while chronic exposure can result in alterations of the connective tissue of the fingers and their bones (acro-osteolysis), liver cancer (angiosarcoma) and hepatotoxicity.



Polyvinyl chloride

Fig 3: Polyvinyl chloride

1.5.4.3 Bisphenol A

Bisphenol A (BPA) is an aromatic chemical belonging to the group of bisphenol compounds and is used as a monomer in the production of polycarbonate plastics (circa 50 percent of the polymer by weight) and epoxy resins (up to 67 percent by weight) (Lithner et al., 2011).

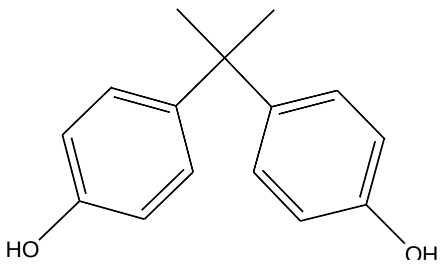


Fig 4: Bisphenol A

It is classified as a xenoestrogenic endocrine disruptive chemical (EDC) and is known to induce alterations and adverse effects on human cells even at low doses (Benachour & Aris, 2009). (Li et al., 2010) observed a dose-dependent increase in sexual dysfunction in workers from BPA and epoxy resin manufacturers. The use of this chemical in commercial products and in food-contact materials is strictly regulated by international authorities such as the European Commission, The Food and Drugs Authority of the United States (FDA), the Food and Agriculture Organization of the United Nations (FAO), and the World Health Organization of the United Nations (WHO) have also provided guidance through risk assessment exercises (WHO, 2010). In the European Union this compound can be used in food-contact materials and in food can coatings, and the specific migration limit (SML) into food in contact with these materials has been set at 0.05 mg/kg of food. In 2015, the EFSA derived a temporary tolerable daily intake (TDI) of 4 µg per kilogram of body weight/day (EFSA, 2015), and in 2021 EFSA proposed to lower the TDI to 0.04 ng per kilogram of body weight/day (EFSA, 2021). In addition to its use as a monomer in water pipes and metal cans, BPA is also used as an additive during the manufacture of PP, PVC and PE (Rani et al., 2015).

1.5.4.4 Ethylene

Ethylene is a gaseous hydrocarbon with a chemical formula C_2H_4 and is commonly produced by cracking of ethane. Its structural formula is CH_2=CH_2. Under the influence polymerization catalysts, the double bond can be broken and the resultant extra single bond used to link to a carbon atom in another ethylene molecule. Thus, made into the repeating unit of a large, polymeric molecule called polyethylene (polythene). Polyethylene is the most widely used plastic because it's cheap, non-conductor of electricity, resistant to solvents and dilute acids, easy to process for injection molding and others. However, polyethylene is not environmental friendly since it's not biodegradable.

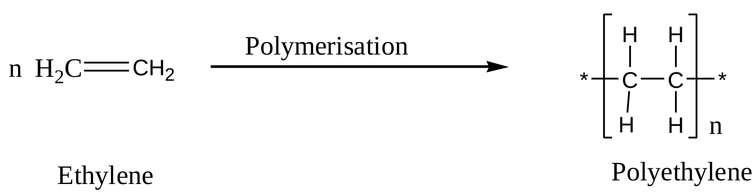


Fig 5: Polyethylene

1.5.5 Effects of microplastics

The results of cellular and animal experiments have shown that microplastics can affect various systems in the human body, including the digestive, respiratory, endocrine, reproductive and immune systems (Lithner et al., 2011).

The digestive system is affected when microplastics are ingested, and physical irritation of the gastrointestinal tract may eventually cause inflammation, resulting in various gastrointestinal symptoms. Microplastics may cause changes in the intestinal microbiome, resulting in an imbalance between beneficial and harmful bacteria, which can lead to various gastrointestinal symptoms such as abdominal pain, bloating, and changes in bowel habits (Lithner et al., 2011).

Still on digestion, microplastics can cause chemical toxicity, which involves the absorption and accumulation of environmental toxins such as heavy metals and polycyclic aromatic hydrocarbons (PAHs). These toxic substances can enter the body through the gastrointestinal tract when microplastics are ingested orally, leading to various gastrointestinal symptoms such as nausea, vomiting, and abdominal pain (Jassim, 2023).

Regarding the respiratory system, microplastics may cause oxidative stress in the airways and lungs when inhaled, leading to respiratory symptoms such as coughing, sneezing, and shortness of breath due to inflammation and damage, as well as fatigue and dizziness due to a low blood oxygen concentration. Recent study showed that micro-sized plastics were associated with mitochondrial damage in human respiratory cells (Osman et al., 2023).

Microplastics can act as carriers of other environmental toxins such as PS, and exposure to high concentrations of PS are detrimental to human lung cells, increasing the risk of chronic obstructive pulmonary disease (Jassim, 2023).

Microplastics interfere with the production, release, transport, metabolism and elimination of hormones, which can cause endocrine disruption and lead to various endocrine, developmental, and reproductive disorders (i.e. infertility, miscarriage and other congenital malformations) (Osman et al., 2023).

Microplastics can act as a medium for environmental toxic substances such as bisphenol A, which are absorbed into the body and cause various diseases of the endocrine system and reproductive system (Osman et al., 2023).

Accumulated exposure to microplastics induces chronic inflammation and homeostasis changes in animal experiments, and a study on human lung cells showed that microplastics can activate innate immunity by regulating the expression of genes and proteins involved in the immune response (Jassim, 2023).

1.5.5.1 Microplastics as cancer agents

Microplastics are considered to be endocrine- disrupting chemicals; which are exogeneous chemicals that may interfere with the actions of hormones in our bodies. Exogeneous means that they come from outside the body.

The endocrine disrupting chemicals present in microplastics include; Bisphenol A, Polychlorinated biphenyls, Phthalates (such as BBP, DBP, DEHP, etc.) and others. Some of the cancers linked to microplastics include; breast cancer, prostate cancer, uterine cancer, ovarian cancer, testicular cancer, and thyroid cancer.

There are different mechanisms in which endocrine disruptors could cause an effect in our body:

Receptor agonist; in this method, the chemical may mimic the effect of a natural hormone in a body (such as estrogen or thyroid hormones) by directly binding to the receptor.

Receptor antagonist; Instead of binding to the receptor for a hormone and mimicking its actions, the chemical may bind to the receptor so that the natural hormone cannot.

Receptor expression; the chemical may alter the expression (number of receptors) present for natural hormones. For example, BPA appears to affect the expression of estrogen receptors in the brain.

Signal transduction; there are many signaling pathways involved in the endocrine system. A chemical may act by interfering with or disrupting a wide variety of signaling pathways in the body involving hormones.

Epigenic alterations; Non-genetic changes that affect the way the DNA is read may result, and this has been seen with ovarian cancer cells in the laboratory.

Hormone synthesis; the production of hormones in the body could be affected in many ways, leading to an increase or decrease of many hormones.

Hormone transport

Blood levels of hormones.

Breakdown of hormones in the body (and removal from the body); A chemical may affect the metabolism of the hormone in the liver so that either a hormone is not broken down as fast as usual, or is broken down more rapidly.

Proliferation/ differentiation/ apopto.

Among females, Breast cancer (the most common) is caused by the abnormal regulation of cell proliferation and migration (caused by chemicals in microplastics), contributing to tissue invasion and metastasis formation. On the other hand, among males, prostate cancer (the most common) has been investigated and correlated with important signaling pathways (mostly P13K/Akt pathway-related-involved in proliferation, invasion, migration and cell survival.

When Polyvinyl chloride (PVC) is burned, it produces another extremely potent class of carcinogens called dioxins, which are breast carcinogens.

Microplastics, when consumed by humans, due to their small size, they have a high ratio of surface area to volume. Materials with a high surface area are highly cytotoxic to cells and tissue and can damage deoxyribonucleic acid (DNA) inside the cells. These mutations occur due to deoxyribonucleic acid damage that can lead to cancer. Microplastics in water tend to absorb hydrophobic organic pollutants from water which are carcinogenic, and long-term exposure can cause deoxyribonucleic acid mutations that contribute to cancer formation. In addition, heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), and lead (Pb) used in the production of plastics are carcinogenic, according to the International Agency for Research on Cancer (IARC).(Osman et al., 2023)

1.5.6 Remediation to microplastic pollution

Use of biodegradable plastics; they are known as bioplastics and have offered a promising solution for replacing conventional plastics in various applications. These plastics have already been used in food and pharmaceutical packaging materials, such as polyhydroxy alkanoates, and in agriculture and horticulture as mulching films for soil and crop protection.(Osman et al., 2023)

(Jassim, 2023) points out the following remediations;

Reusing and recycling plastic products is a highly effective strategy for managing microplastic contamination, reducing use of single-use plastics, and supporting legislation to curb plastic production and management.

He also emphasizes participation in a beach or river cleanup, avoiding products containing microbeads, sensitization against use of plastics and bottled water, and buying non-synthetic eco-friendly clothes.

He further encourages use of air dry, but not use of dryers, use of public transport and favor rail infrastructure, reduce meat and fish consumption, and using paper bags instead of plastic bags.

1.5.7 Microplastic analysis

Microplastics are analyzed using Fourier Transform Infrared spectroscopy which identifies microplastic particles via their vibration spectra, which are unique for every polymer type, and can be introduced into microscopic setups, which allows chemical imaging. By integrating the advantages of digital imaging with the attributes of spectroscopic measurements, chemical imaging enables the measurement of microplastic particle numbers, sizes as well as polymer identification simultaneously, which is advantageous over other analytical methods. The FTIR uses interferometry to record information about a material placed in the IR beam.

Samples are therefore prepared, and fed into the FTIR spectrophotometer where the IR beam passes through the samples and then produces IR spectra that are used to identify the number and types of microplastics present in the samples. The spectra given are compared to the standard microplastic spectra in order to find out the types of microplastics present while the number of microplastics is identified by considering the prominence of the peaks.

CHAPTER TWO

EXPERIMENTAL

2.1 Apparatus

The FT-IR imaging was done by JASCO 6600 FTIR microscope equipped with a liquid nitrogen cooled 64 × 64 detector elements focal plane array detector (FPA) with a 15 × IR objective.

Soil samples were sieved using a 500 mm metal sieve. Glass apparatus were used instead of plastic apparatus to avoid secondary contamination that may lead to increment in the microplastic levels in the samples.

Weighing was done on AX523 OHAUS analytical balance (OHAUS Corporation, USA)

Drying was done in a MEMMERT drying oven programmable via AtmoControl software (models with TwinDisplay)

2.2 Materials

The two soil samples (10 g each); one was got from the town center around the Nagongera central market and the other was got from the campus garden around next to the Math block

The four water samples (100ml each); first was got from R. Nagongera, the second was got from the pond opposite Comrades resort, the third was got from Mahanga borehole and the fourth was got from the tap.

Saturated Zinc Chloride solution; (prepared by dissolving a little $ZnCl_2$ at a time in 200ml of distilled water until no more $ZnCl_2$ can dissolve, then filter off the excess $ZnCl_2$) that will be mixed with the samples so as to separate off the microplastics. Microplastics will float while other materials will sink since microplastics have less density.

The removal of the natural organic materials was done using 30% solution of Hydrogen peroxide which is commercially marketed as 100V hydrogen peroxide.

2.3 Methodology

Microplastics were analyzed and identified using the Fourier Transform Infrared (FTIR) Spectroscopy. FTIR is a form of vibrational spectroscopy that identifies organic or inorganic materials by measuring the absorption of infrared radiation. When a molecule is excited into a higher vibrational state by absorbed IR radiation, the wavelength absorbed is a function of the energy difference between the at-rest and excited vibrational state. It also matches the molecular components and structures therefore it aids in identification of functional groups present in the sample (Mohamed et al., 2017)

When infrared radiation is passed through a sample, some radiation is absorbed by the sample and some passes through (is transmitted). The resulting signal at the detector is a spectrum representing a molecular 'fingerprint' of the sample. The usefulness of infrared spectroscopy arises because different chemical structures (molecules) produce different spectral fingerprints. The Fourier Transform converts the detector output to an interpretable spectrum. It generates spectra with patterns that provide structural insights. (Scientific, n.d.)

2.3.1 Procedure

2.3.1.1 Extraction of the microplastics

The soil samples were dried at 60 °C and afterwards screened over a 500 mm metal sieve as suggested by (Hidalgo-Ruz et al., 2012). The material passing through the sieve will be homogenized and analyzed.

For the extraction of microplastics, 10 g of each soil sample were treated with 30ml of 30% hydrogen peroxide overnight to remove natural organic materials. Microplastic particles were then extracted via density separation using saturated zinc chloride solution in a 100-ml glass beaker. After stirring the samples were treated in an ultrasonic bath for 15min and the beakers were kept covered overnight for the sedimentation of sand particles. Potential microplastic particles accumulated at the surface of the zinc chloride solution and were sampled off with a syringe for further analysis.

For water samples, they had to undergo pre-treatment, depending on the contamination from the source; Environmental samples like river water and pond water were screened in order to remove large suspended debris. The samples were passed through the digestion and density separation processes in order to sample off the suspected microplastics to be taken for FT-IR analysis. (Olesen et al., n.d.)

2.3.1.2 FPA- based micro FT-IR spectroscopy

FTIR spectra of particles were recorded using a JASCO 6600 FTIR spectrometer equipped with a liquid nitrogen cooled 64 × 64 detector elements focal plane array detector (FPA) with a 15 × IR objective. IR spectra were recorded in transmission mode as spectra in the range 3850 – 900 cm^{-1} with a resolution of 4 cm^{-1} and a 6 mm aperture.

2.3.2 Treatment of results (Coates, 2000)

The spectrophotometer (JASCO 6600 FTIR) gave spectra that I compared with the following data.

Type of bond stretching	**Wavenumber (cm^{-1})**	**Type of microplastic suspected**
C-H in -CH2- C-H in phenyl	2935-2915 3130-3070	PS, PVC, PE PS
C-C	1350-1000	PS, PVC, PE
C-Cl	800-700	PVC
Aromatic ring Monosubstituted ring	1615-1580 770-730	PS PS

Table 1: PS – Polystyrene, PVC – Polyvinyl chloride, PE – Polyethylene

In addition, the standard spectra for the different microplastic types will be used as references to verify the presence of microplastics;

Basing on absorption:

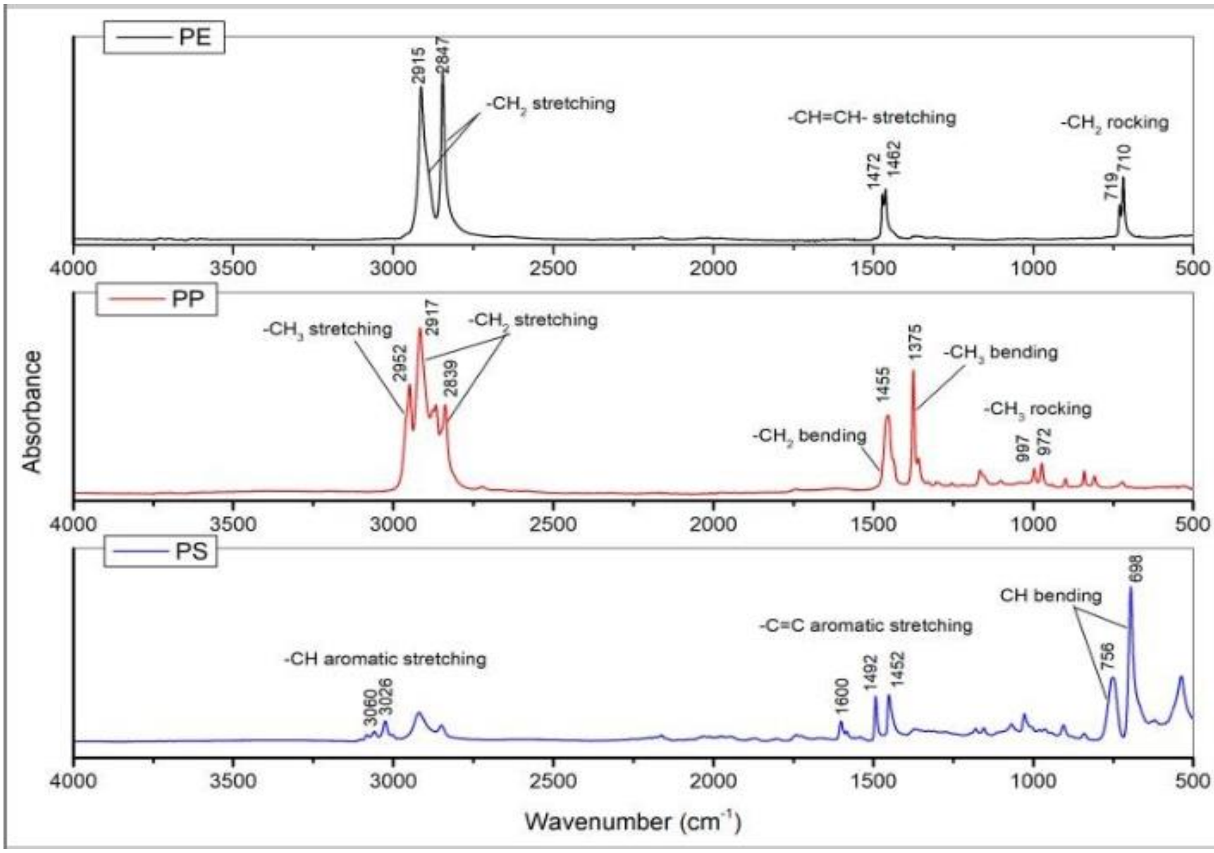


Fig 6: FT-IR absorption spectra for common microplastics

Basing on transmittance:

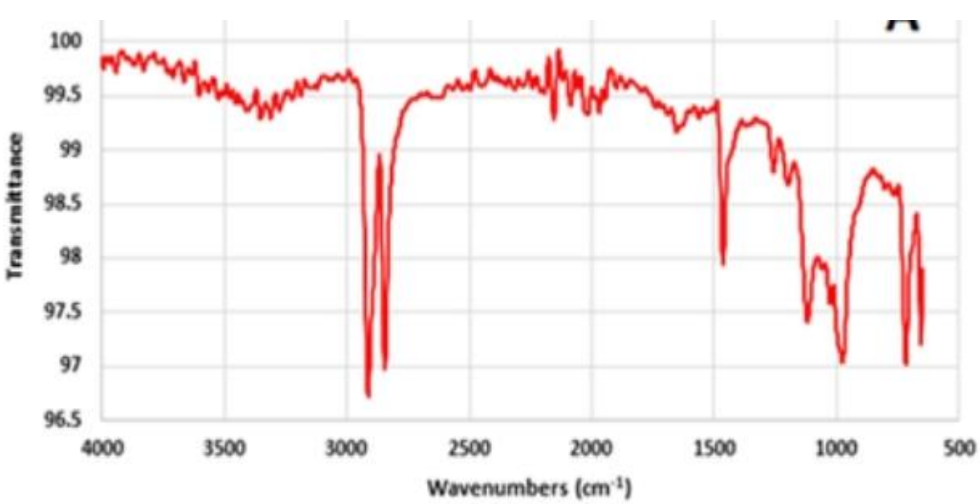


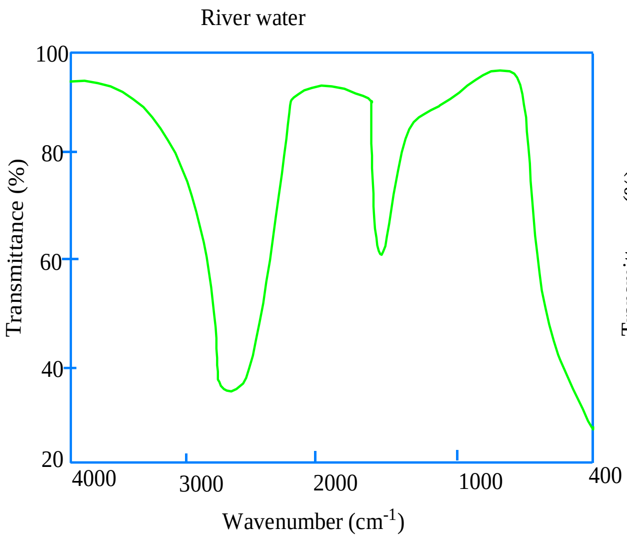
Fig 7: Standard FT-IR transmission spectra for microplastics

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 RESULTS

For **water samples**;



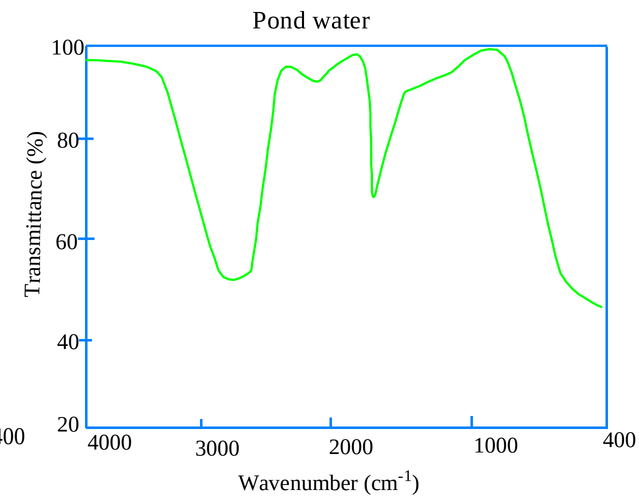
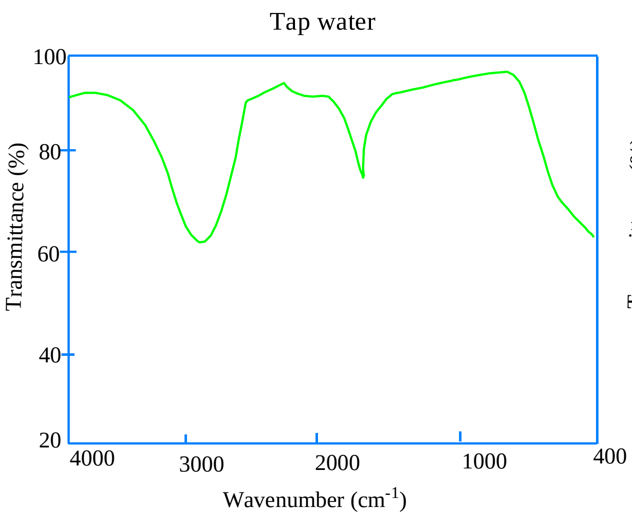


Fig 8: River water spectrum

Fig 9: Pond water spectrum



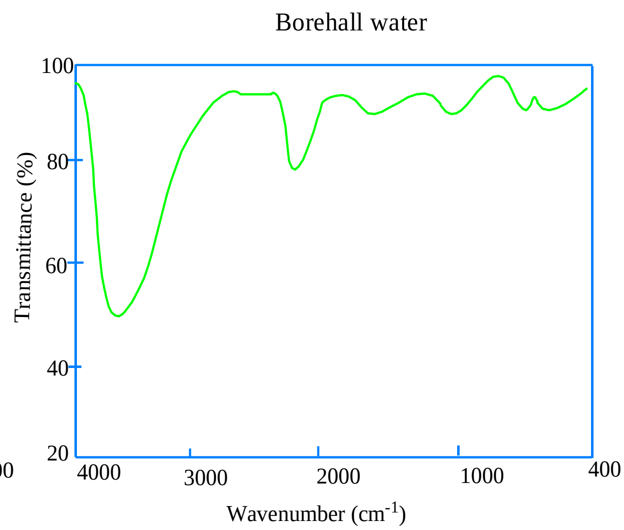
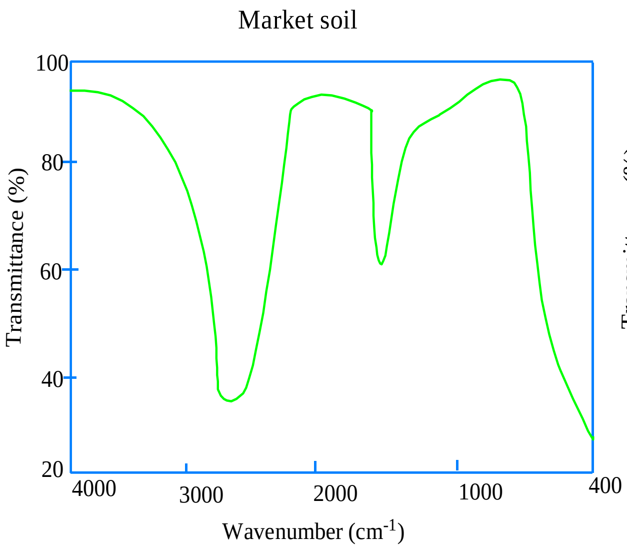


Fig 10: Tap water spectrum

Fig 11: Borehole water spectrum

Soil samples:



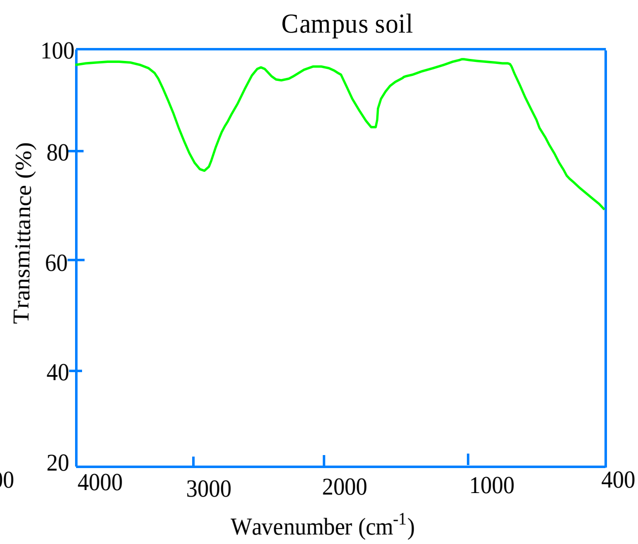


Fig 12: Market soil spectrum

Fig 13: Campus soil spectrum

3.2 DISCUSSION OF RESULTS:

Basing on the standard spectra, a sample containing microplastics has peaks at wavenumber of around 2800 cm^{-1}, 1500 cm^{-1} and 500 cm^{-1}. These peaks depict the low levels of transmittance of infrared radiations at those wavenumbers, in other words, there is a high level of absorption of infrared radiations at those wavenumbers.

The prominence of the peaks depict the number of absorbing particles (microplastics) present, that is; the higher the peaks the more the the number of absorbing microplastics.

By comparison with the standard spectra, river water, pond water, and tap water contain microplastics whereas borehole water does not have since its spectrum peaks donot comform to those of microplastics. River water has the highest number of microplastics followed by pond water then tap water basing on the prominence of the peaks. Therefore the order of contamination is River water > Pond water > Tap water > Borehole water.

The order is so because the river collects water in form of surface runoff from different places that are contaminated with microplastics hence the highest level of contamination. Ponds also collect water in form of surface runoff which comes along with microplastics hence a relatively higher level of contamination. Tap water is also contaminated by microplastics since its transported using plastic pipes which continuously wear and tear to give microplastics hence the low level of contamination observed. Borehole water was observed not to have microplastics, this may be due to the fact that it is drawn from deep down below the earth’s surface, a depth which microplastics cannot be leached to.

Both soil samples contain microplastics basing on the analysis, the Nagongera market soil had the highest level of microplastics contamination since it had more prominent peaks compared to those of the campus garden soil. Therefore the level of contamination is in the order; Nagongera market soil > Campus garden soil.

The order is so because Nagongera market is exposed to different types of plastics such as polythene bags, plastic bottles and others that always breakdown to give microplastics hence the higher level of microplastics contamination. While the campus garden soil is expose to a few plastics such as plastic bottles hence a relatively less level of microplastic contamination.

It is observed that the river water, pond water, tap water, market soil and campus soil samples are dominated by polyethylene (PE) and polystyrene (PS) since their spectra are seen to have three peaks around 2800 cm^{-1}, 1500 cm^{-1} and 600 cm^{-1}. While Borehole water is observed to contain more of polypropylene (PP) since its spectrum shows two peaks around 2800 cm^{-1} and 1500 cm^{-1}.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

It was observed that the order of contamination of water samples was River water > Pond water > Tap water > Borehole water and that of soil samples was Nagongera market soil > Campus garden soil.

In conclusion therefore, there is need for the government to regulate the usage of plastic materials which are the major sources of microplastics for example abolishing the use of polyethene bags which are highly littered everywhere.

The government should also extend tap water and borehole water to rural areas in order to minimize on the usage of river and pond water which has been observed to be highly contaminated by microplastics.

4.2 RECOMMENDATIONS

I recommend that people should use water with less or no microplastic contamination such as borehole water and tap water in order to avoid the health complications associated with microplastic exposure such as cancer, organ dysfunctioning and many others.

I recommend that more research should be done using other methods for example using UV-Vis-MS analysis for microplastics. This will help to draw correlation between different result sets hence generalizing and coming up with more credible results.

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