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Review

The contribution of Indigenous Knowledge Systems (IKS) on food security in Mbokomu ward, Kilimanjaro Region, Tanzania

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This paper focuses on the contribution of Indigenous Knowledge Systems (IKS) on food security in Mbokomu ward. The main objective of this paper is to ascertain the use and application of IKS on food security and document methods used in food preservation. Various ethnic groups have different methods of preserving food and use it during the food shortage. Thus, people in Mbokomu ward used several methods in preserving food items and ensure food security throughout the year. The research used different methods in collecting information regarding the application of IKS on food security such as key informants interviews, focus group discussions and observations methods. Secondary information was collected to get familiarisation with the IKS while primary information was collected in the field to ascertain the role of IKS on food security. Purposive sampling technique was used to select community leaders and clan elders who had indepth knowledge of traditional practices used in preserving food crops. People have used traditional systems in preserving food items, drying on the sun, using medicinal plants, using fire and smoke. The findings showed that people have used different systems like hanging maize to dry on trees or hanging meat on the roof close to kitchen to dry slowly with fire or smoke and peeled bananas dried on the sun and kept in the house roof for many years without being damaged. The study recommends that, there is a need to document all IKS knowledge used in preserving food. The IKS is preserved in the elders' memory, thus, serious effort and regulation must be made to document IKS before elders with IKS knowledge passed away or died.

Key words: Food security, Indigenous Knowledge Systems (IKS), Chagga, food preservation.

INTRODUCTION

Since time immemorial, indigenous knowledge systems (IKSs) was used in Africa and the rest of the world for various purposes depending on the needs of the society (Chiwanza, Musingafi and Mupa, 2013). Indigenous knowledge system is drawing attention of many researchers, higher learning institutions, governments

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and Non-Governmental Institutions (NGOs). However, IKS has gained popularity over the last 15 years (Nawe and Hambati, 2013). The current interest on indigenous knowledge has been motivated by an appreciation of its importance in contributing to sustainable livelihood systems (Liwenga and Lyimo, 2006). Indigenous knowledge system is applicable and used at the local level by communities as basis for decisions pertaining to food security, human and animal health, education, natural resources management and other vital resources (Gorjestani, 2000).

The development of most African countries has been based on knowledge generated in laboratories, research stations and universities.

The World Intelectual Property Organisation has recognised the application of traditional knowledge and appraised of local systems of innovation and intellectual property (Eyzaguirre, 2001). This observation helps to protect the local systems against new innovations. Research anchors IKSs as an integral part of food security, promotion and utilisation of local production systems.

Several innovations related to food consumption, preparation and preservation have been developed. Some of the innovations are, preserving food in the refrigerator or using pesticides. The aim of this manuscript is to ascertain the use and application of IKS on food security and document the methods used.

This paper starts with the definitions of key concepts used in this study which include indigenous knowledge systems, culture and food security. It further presents a historical background of the Chagga ethnic group in Mbokomu ward and provides the justification for carrying out this study. The paper also gives a brief review of related literature, presentation of the findings, discussions and finally, conclusion and recommendations.

Definition of concepts

Indigenous Knowledge Systems

Indigenous Knowledge Systems can be called IKS, local knowledge; others indigenous knowledge while others prefer trditional knowledge. According to Nuffic and UNESCO/MOST (2001), the definition of indigenous knowledge differ depending on the case at hand and even on the specific aspect authors would like to emphasise. Indigenous knowledge is refers to the knowledge identified by ethnic group.

Indigenous knowledge is the local knowledge which is unique to a defined culture or society or ethnic group. IKS refer to the complex set of knowledge and technologies existing and developed by communities, residing in a defined geographical location. Thus, it is knowledge held by local people, outside the formal scientific domain.

Food security

There are several definitions of food security. Food security means, families or communities both in rural and urban areas which are able to produce food, preserve and store it for future use (Khumbane, 2004). Food security exists when all people, at all times, have access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 2003). However, food security implies a situation where all people at all times have access to nutritionally adequate food and safe water (Chirimuuta and Mapolisa, 2011).

The World Food Summit of 1996 viewed food security in the context of access to safe and nutritious food (Chirimuuta and Mapolisa, 2011). All in all, there are four factors which determine food security; availability of food, access to food, stability of supply and utilisation of dietary food. Thus, a household is considered to be food secure when its occupants do not live in hunger or fear of starvation.

Culture

Everything humans perceive, know, think, value and feel is learned through participating in a cultural system. It is a pattern of responses discovered, developed or invented during the group's history of handling problems which arise from interactions among its members, and between them and their environment. These responses are considered as the correct way to perceive, feel, think, and act, and are passed on to the new members through immersion and teaching. Culture determines what is acceptable or unacceptable, important or unimportant, right or wrong, workable or unworkable. It encompasses all learned and shared, explicit or tacit, assumptions, beliefs, knowledge, norms, and values, as well as attitudes, behaviour, dress, and language. Culture is important in shaping society, thus culture can influence IKS.

The significance of IKS and food security

According to the Tanzania National Bureau of Statistics (TNBS) (2012) 48% of Tanzania’s population of 45 million people is unable to meet basic food and non-food needs. The high poverty level is attributed to income inequality and a relatively low rate of economic growth in rural areas (TNBS, 2002, 2005a). Tanzania’s economy depends heavily on agriculture (farming and livestock keeping). Agriculture accounts for 45% of GDP and 60% of export earnings. It also provides livelihoods for about 82% of the population (TNBS, 2005b).

Ethnic groups have different methods of producing, preserving food and use it during the food shortage or drought seasons. This article is desigend to document and ascertain different methods used by Chagga people of Mbokomu ward in Kilimanjaro Region to grow and preserve food for the future use. There is a claim that, Chagga people had different methods of preserving food items and use them during food shortages or drought seasons. Despite this claim, there is no document available in explaining the role of indigenous knowledge system on food security in Tanzania.

The general objective of this article is to examine the contribution of Indigenous Knowledge Systems on food security in Mbokomu ward. Specifically, this article dwells on exploring the potential contribution of indigenous knowledge systems on food security; document methods used on food preservation and suggest measures in addressing the threat to IKS. People in Mbokomu Ward have a rich history of IKS on different areas including food security. This IKS will disappear if not pro-actively conserved, documented and promoted.

Literature review and theory implications

Indigenous Knowledge System: An overview

IKSs are primarily based on local experience of the specific society which have evolved over time and transmitted from generation to generation by word of mouth or by practice (Das-Gupta, 2012). Knowledge is a philosophical term and can be conceptualised as a set of various facts and information traits. Knowledge is categorised into two types which are scientific and indigenous. Scientifically proven knowledge is the scientific knowledge, whereas knowledge of the indigenous peoples' is indigenous knowledge (IK). IKS is the actual knowledge of a given population that reflects the experiences based on traditions (Das-Gupta, 2010).

Indigenous knowledge is the local knowledge that is unique to a given culture or society. Culture aids in moulding indigenous knowledge of a particular society. IKS have survived since time immemorial (Mapara, 2009) and have originated locally and naturally (Altieri, 1995). Mapara (2009) pointed out that, IKS is a body or bodies of knowledge of the indigenous people of a particular geographical area that have survived for a very long time. IKSs are the adhesive that binds society as they constitute communicative processes through which knowledge is transimitted, preserved and acquired by man.

Theory implications in IKS

Knowledge and technology are not static. Ancestors used crude methods of farming, traditional medicines, eating-raw and uncooked food and wild fruits. The ealier people lived by eating wild food gatherd from the forest. They were eating raw-food and uncooked food because they had no knowledge of making fire. As time elapsed things changed and people discovered fire used to cook their food and started living in one place for a long time, they stoped nomadic life, and practised sedentary life due to population increase.

Population growth stimulated environmental change and the food produced traditionally became insuffient. According to Thomas Malthus in the 18th century, population is increasing at geometric progression while the supply of food expands at arithmetic progression. The main assumption is that technology is constant and fixed. Boserup (1971), gives some criticism by arguing that population pressure stimulates technological change especially in agricultural sector. Unlike Malthus's theory of population growth, Boserup theory considers demographic pressures as the cause of positive change in land-use and agricultural development. This article shows the relationship between increased population and agricultural intensification which appears to be complex one due to presence of a number of other factors, influencing the performance of a particular farming system leading to food insecurity. The increase in population has influenced societies to switch on to science and technology and leave indigenous knowledge systems. Now people are eating hybrid crops or genetic modified crops.

IKS and food security in Tanzania

The study by Kikula and Mwalyosi (1994) found that before colonialism, in Tanzania there were sound conservation and management measures, which were built in the indigenous agricultural practices that were quite effective. Toima (1997) in Monduli District, found that, the practices of IKS were intended to improve land resources and agricultrual production, and in the long run improve the quality of life. The Maasai and Barbaig societies practiced IKS on livestock keeping, milking, preserving milk and meat for future use.

There are several traditional management measures of resources. Some of the traditional measures include: the *Ngoro* (Matengo pit) system in Mbinga, the *Ukara* mixed farming system in Ukerewe, *Iraqwi* intensive farming in Mbulu, *Ufipa* mound cultivation system in Rukwa, and the mixed farming and zero/stall grazing of the Chagga (Kerario, 1996; Kikula and Mwalyosi, 1994; Nawe and Hambati, 2013). These systems were practised among the crop cultivators and mixed farmers. All these systems aimed at improving environment and food security. Other practices include the *Ngitiri* (*ngitiri is a sukuma word denoting the tradition of setting aside pasture for use in drought periods*) system in Shinyanga, Mwanza and

Tabora Regions that involved traditional rotations of grazing, and the *Ndobindo* or *Mbugha* in Singida to avoid or control overgrazing.

The traditional knowledge of pastoralists and farmers has enabled people to survive in difficult times and often changing environments throughout history. Despite its potential, indigenous knowledge is often unrecognised by development initiatives, leading to household food insecurity amongst groups. Access to adequate food is a basic human right and is catalysit to the realisation of all other rights (FAO, 1998).

The twentieth century witnessed exciting initiatives in revitalising technologies owned by local resource users in developing countries. It is obvious that, IK is a knowledge held by local people, outside the formal scientific domain. According to WCED, indigenous communities are "repositories of accumulated traditional knowledge and experience, after known as Traditional Environment Knowledge Systems (TEKS), which large societies could learn from managing complex ecological system" (WCED, 1987). Before the invention of science and technologies of preserving food, different societies had their own means of preserving food. Traditional methods used in preserving food will be covered in this article.

Importance of Indigenous Knowledge System in food security

IKS have several benefits including maintaining nature and palatability of food. IKS act as a community's armour against environmental shocks and manifests community's resourcefulness (Madebwe et al., 2005). It can be used in alleviating poverty as it is locally manageable and does not require confiscated technology. Indigenous knowledge can increase and enhance livelihood options, revitalise agriculture, increase food security, improve health and promote sense of cultural pride within the community (Madebwe et al., 2005). Indigenous knowledge helps the communities to cope with periodic food shortages by, utilising the traditional know in preserving food and increase food production which then ensure food security for all people.

Marginalisation of the IKS has resulted in rapid loss of traditional seed varieties best suited to the prevailing agro-economic conditions. The introduction of hybrid seeds which produce more crops has influenced people to abandon traditional seeds, yet these were drought resistant and more nutritious than the modern ones. The introduction of new seed varieties has led to the cultivation of unsuitable crops for marginal farming areas (Winniefridah and Mukoni, 2013). Traditional ways of seed selection and preservation are no longer a priority after years of dependence on commercially produced high yielding varieties.

Several studies have been undertaken on modern methods of processing to improve acceptance and utilisation of overall food security (Winniefridah and Mukoni, 2013). Traditional methods of production, processing, preservation and storage have been ignored in most societies.

The ignoring of the IKS have led to dissapearing of knowledge of preserving food in different parts of the world. Now people are producing genetic modified crops which have negative impacts on human body. Refrigerator, pest-cides and insectcides are the most used for preserving and storing food. Very few societies are are using traditional methods of preserving and keeping food.

Threats to Indigenous Knowledge Systems

Everything has merits and demerits. For this, IK is threatned by several factors. Mapara (2009) pointed out that indigenous knowledge is mostly stored in people's minds and passed on through generations by word of mouth rather than written form. IKS is vulnerable to change and disappear if no efforts are made to keep and preserve it.

There are number of factors contributing to the loss of Indigenous Knowledge System. For example, development process, rural-urban migration and change of population structure, epidemics, displacement or war, contributes to loss of indigenous knowledge. Innovation and technology also contribute to dissapearing of IKS. Indigenous knowledge is under threat from modern technology because even in remote areas the power that push global or just non-local content such as radio and television broadcasting and advertising among others, are much stronger than pulling local content. There is a need to protect indigenous traditional knowledge systems by any cost as it is a simple, affordablr and does not need heavy investment.

Madebwe et al. (2005) noted that marginalisation of IKS has resulted in rapid loss of traditional seed varieties best suited to the prevailing agro-economic conditions of specific regions. It has also led to the cultivation of unsuitable crops for marginal farming areas (Winniefridah and Mukoni, 2013).

Traditional ways of seed selection (Excerpt 1) and preservation are not considered as a priority after years of dependence on commercially produced high yielding varieties.

Traditional methods of production, processing, preservation and storage have been ignored. Millennium Development Goals (MDG) 2014 cites that maize is the staple food in Zimbabweas; hunger is commonly associated with its shortage in the country. The same is applicable to Tanzania, where maize is the most popular crop grown in Tanzania which is grounded into flour used to prepare thick porridge (*madidaluji)* and *ugali*.

Excerpt 1. Seeds selection for planting in the next season

“Traditionally, people in Mbokomu ward had their own knowledge and system of selecting and preserving seeds to be planted next season. They used to select the big and nice looking seeds of maize and beans, to list some, for planting or grown next seasons. The seed selection was done by the elders (mother/father/grandparents) soon after harvesting period.The selected seeds were dried either on the sun, hanging on the roof close to the fire or kitchen to dry slowly. These seeds stayed for long time without being damaged and they used no chemicals of any kind to preserve them. These seeds were resistant to drought, diseases and grow a little bit longer compared to hybrid seeds which grow for a few months. Now, this system of identifying and preserving seeds is no longer in use as people prefer buying seeds from the shops. Sometimes, people are late in planting seeds as most seeds are brought in the shops late, after planting seasons”. Said a farmer in Tema village.

The study area and research methodology

This study was undertaken in Mbokomu Ward, in Kilimanjaro Region of Tanzania. Mbokomu ward is located in Moshi Rural district. The ward consists of three villages, namely Tema, Korini-Juu and Korini-Chini. This study was carried out in all these three villages. Mbokomu ward is among the wards making Moshi-Rural district. The ward is boarded by Moshi Urban in the south, Tela village in the East and Uru in the west, in the north is boarded by Government Forest known as Kisao Forest (part of West Kilimanjaro Forest). The ward is located in the highlands of Kilimanjaro region. The Chagga is the dominant ethnic group in the Mbokomu ward.

Agriculture is the major economic activity in the ward. Agricultural economic activities in the Mbokomu ward comprise crop cultivation and limited livestock keeping mostly undertaken by small-holder peasant farmers. Farmers have been living in the area since in late 18th century. The kinds of food crops grown in the ward are: maize, beans, pulses, cowpeas, pigeon peas, sweet potatoes, cassava, finger millet, plantain (banana), yams, fruits and vegetables. Arabica coffee type is the major cash crop in the ward. There are two types of coffee which are Arabica and Robusta. Arabica is the type of coffee growing in Mbokomu Ward. The area has very feritile volcanic soil which support farming of different crops. In lowland areas where Korini-Kusini village is situated maize, beans and finger millet are the important sources of income.

People in Mbokomu ward keep small number of small stock like cattle, goats, sheep, pigs, chicken, ducks, rabbit and guinea fowls. Zero grazing is practised in these areas due to the nature of the land which is characterised by highland and steep slopes. Steep slopes hinder animal free grazing nature and lack of free land for grazing. Livestock production is done only on a small scale and which does not contribute much to the rural economy.

Livestock are kept to provide manure, eggs and milk. Pigs are kept for sale to provide income, but the number of people keeping pigs is very low, very few people are keeping pigs, despite the fact that not all are muslims. Moreover, it should be borne in mind that there are some christian sects whose members do not keep piglets. Other economic activities include handcrafts (toiloring and carpentry), small scale businesses and local brew preparation. Few people are civil servants because there are few employment sectors in Mbokomu ward such as secondary schools, primary schools and two disepensaries. Most employees in these institutions are from other wards, very few people in this ward have required qulaifications to be employed in these sectors.

Different sources and methods were used in collecting information regarding the application of IKS on food security. Secondary information was collected to get some familiarisation and food security at local, regional and global level. Secondary information was also obtained from books, journals, newspaper reports and internet resources. Primary information was collected to ascertain the role of IKS on food security. Since the study focused on IKS the target respondents were aged people, thus, key informants interviews, focus group discussions and direct observation were used in data collection. Purposive sampling was used to select community leaders and clan elders who are believed to have indepth knowledge of traditional practices used in production and preservation of food.

Presentation of findings and discussions

The historical investigation showed that life of people passed through different ages from stone age, iron age to scietific age including agrarian revolution and industrial revolution (science and technology age). Rural people applied wide range of indigenous knowledge techniques including land management, forest conservation, water mangement and food preservation etc. Over centuries several ethnic groups including Chagga people in Mbokomu ward have developed a useful indigenous knowledge system of natural resources and preservation of food for future use. The findings show that, in the development process, the technology of preserving and storing food items was changing as time passed away. IKS is bequethed from one people to another as pointed out by an old woman aged 94 years old, living in Mbokomu Ward, Tema village.

Her comment was:

"IKS is a traditional knowledge inherited from one generation to another, from our ancestors. People were taught by imitating or copying from others. IKS was used in different areas including forest conservation, irrigation, farming and food preservation. People used different methods of storing food iterms for the future use."

Ethnic groups have traditional methods of keeping and preserving food for use in time of shortage and drought seasons. Ethnic groups were prepared in advance for difficult seasons, preserving enough food to use incase of food shortage. Studies showed that several technologies were used in preserving food which include Scientific Knowledge System and Indigenous Knowledge System ((Das Gupta, 2012; Nawe and Hambati, 2013). People have different methods of producing and preserving food. Some of the traditional methods used in the preservation of food items include drying grains in the sun, using smoke, keeping food items on the roof of their houses, hanging maize and banana to dry slowly on the trees and roof. The other method used in preserving food include hanging meat on the roof close to the kitchen to dry slowly by heat and smoke from the fire.

Food is the main source of energy in human body. People are supposed to eat a balanced diet which contain protein, carbonhydrates and vitamins; without which the human body becomes weak and susceptible to diseases. The availabilty of food is determined by the ability of the society to access, afford and to produce enough food to use, and other for the next season. The remaining food should be properly preserved and stored for future use; these processes ensured food security in the family and society at large. Farrington and Martin (1988) observed that, throughout human history, human survival has depended on seizure of whatever survival potential is available in the surrounding. Meeting livelihood needs including food needs has not always been an easy task to individuals in various communities and environmental practitioners in the world (Amanor, 1991).

Traditional methods used in keeping food had no negative impact on human body as, no chemicals were used in treating, keeping and preserving food as it is used today. The findings showed that most of the traditional methods used in food preservation are no longer in use.

An elderly man of 69 years from Tema village said that:

"Traditional methods of preserving food are no longer in use due to technology. We use pesticides and insectised to store maize and beans."

The abandonment of the use of traditional method in food preservation is due to invention and technological development. People are now using different technologies in preserving food by ignoring the traditional methods. The traditional knowledge or IKS was affordable and not harmful to human beings as it is experienced today. The people interviewed and consulted listed different methods of preserving food items. The techonolgy or system used vary depending on the type of food or crops stored, and the food and method also varied from one ethnic group to another. The succeeding section tries to present different traditional methods used in preserving different crops among the Chagga people.

Maize and beans

Maize is the staple food for the people in Mbokomu ward and in Tanzania in general. Maize is grown in areas with fertile soils and moderate rainfall. Mbokomu ward is located in an area with moderate rainfall and volcanic fertile soil which support the growth of maize, beans etc. Maize is the main cereal crop for making flour used in making *ugali* and poridge.

According to the interviewed conducted by Mzee Shadrack Foya in Tema village:
"it is very rare for a day to elapse without taking ugali or poridge". Poridge is prepared and consumed in the morning as breakfast, while ugali is used in the afternoon as lunch. Eating ugali provides calories and energy to work on the farms." Foya continued by saying that, "To us maize is life, maize is very important for the survival of people in this ward."

This old man was emphasising the importance of maize. In 1950s to 1970s people had bumper harvests of maize, dried them on the sun or hung them on the tree without removing the cover. Maize stayed hanging on the tree for more than 5 years without being damaged or getting rotten. This system of preserving maize was affordable and simple as it required only rope and knowledge of arranging maize and putting banana leaves on top as cover against rainfall.

A mother of four children in Tema village narrated that:

"Maize was harvested once matured and dried on the sun without removing the cover. After drying, it will be stored inside the kitchen hung in the roof by arrangement. The well-dried maize could be stored in the roof for more than six years. The smoke which came from the fire place acted as both an insect repellent and a preservatory, which enabled the maize to be kept for so many years without any harm from weevils and other pests".

Maize stored in this way can be used as seeds during planting season, projected to a bumper harvet. The selling of maize from the previous season provided room for storing for the new harvest and also acted as an income generating project used to buy other necessities and pay for labourers who til the land. Other families built granaries known in Kichagga as *mbeshe* and in Kiswahili as *kiheng*e, of round shape using poles and withies, plaster the hut with mud and cow-dug.

Once the *mbeshe* is complete people used it for storing maize and beans.*.* The maize stored in the *mbeshe/kihenge* could last for more than five years without being eaten by rats or damaged by insects or pests. Banana and cassava was also stored in this way. Banana was harvested from the farm, then peeled off, sliced into small pieces and dried in the sun. The peeled cassava and banana was cut into small pieces, dried throughly on the sun and stored on the roof for future use. The well dried cassava and banana can be preserved in that way for more than six years. Dried cassava and banana was kept or stored close to the fire or kitchen by some families. The storing or keeping of cassava and banana close to the fire preserve it against insects, pests, rodents and make it last long. This system of storing food items close to the fire result in preserving of cassava and banabawithout the use of chemicals. In preparing food, grounded dried maize mixed with maize or cassava was used to make *ugali* or poridge. The flour obtained from mixing dried maize and cassava was prefered because of its sweetness and energy type of food.

An old man of ninety years old interviewed in Korini-Juu village commented that:

"In 1960s and early 1970s all household in Moshi had mbeshe or granaries for storing cereals. In those years the first thing you see during visitation is mbeshe. The architectural *knowledge of building mbeshe at family level was an art of women. Mbeshe was roofed by leaves of banana. For roofing of mbeshe, women prepared banana leaves used in roofing granary. In roofing, women did not use nails or rope. They had traditional knowledge of roofing in such a way that during the rain seasons no single drop of water or rain penetrated into mbeshe. The leakage was controlled, women used very high knowledge in roofing. In constructing mbeshe, men were responsible for building the structure while women do the roofing. The mbeshe had a very good shape and pattern. The granaries were plastered with cow-dung. Cow-dug acted as a preservatory and insectiside such that the cereals stored or kept in mbesehe (granaries) stayed very long without being damaged or rotten".*

Cassava, banana and beans

Cassava, beans, yams, sweet-potatoes and banana are some of food crops grown in Mbokomu ward. Banana and cassava were peeled, sliced into small pieces, dried in the sun, dried using smoke and treating crops using medicinal plants. These crops were kept for a long period of time. Others were keeping these crops in granaries. Most cereal crops once harvested were dried on the sun. The dried banana and cassava were mixed with maize to make flour. Flour can be used to make *ugali* and poridge.

In other families dried cassava and banana were kept on the inside rooftops of the houses for a long time and used during the drought time or shortage of food. The peeled and dried banana were tied on a rope and the rop was tied on the roof like someone arranging clothes to dry. As time goes on, cassava and banana get dried which remain there (on rope) for may years. The dried banana can be stored in the granaries or *kihenge* (*kihenge* is a Kiswahili word meaning granary). The same procedure was applied by other ethnic gropus for storing fish and groundnuts. Among the Chagga people, dried banana is known as *mangolo* and undried one is *maruu. Mangolo* is the food used during the food shortage seasons (Box 4). When a family is consuming or eating *mangolo* it is a sign of, lack of *maruu*/banana in the farm. This means that the area is experiencing food shortage. Thus, *mangolo* is used when there is no *maruu* available in the farm.

Execrpt 2. Preparation of mangolo

"Mangolo is a dried banana mainly kept for use incase of food shortage. There are two ways in which mangolo are prepared before consumed. You grind the mangolo to get flour which can be used to make ugali or poridge. Second, you can mix mangolo with beans then boil and eat. This type of food is more preferable to children". An old women intervewed in Tema village".

A woman interviewed in Korini-Kusini village retorted that:

"Our children do not know how to preserve or store cassava and banana for the future use." The researcher probed more by asking why? The woman proceeded saying, "technology and life style have contributed alot. Our children prefer to eat fresh food obtained directly from the farm or gotten from the shops, markets and supermarkerts."

A young lady aged 25 years old residing in Korini-Juu village. When asked why not the youth use traditional methods of preserving banana or food items in general? She had this to say:

"Why should I trouble myself since every thing is available in the shops provided you have money, above

all my parents have not trained or showed me how to preserve cassava or banana locally or in a traditional way? Of course I used to see my parents drying banana and cassava in the sun, once it gets dry they keep them in sacks and use them during food shortage or drought seasons".

Development of science and technology has influenced people to ignore or abandon the traditional methods of preserving food items. The traditional methods used for preserving food is no longer in use nowadays. People nowadays prefer keeping food in the refregerator or using chamicals like pesticides and insectcides to preserve food items.

Beans is another food crop grown in Mbokomu ward. Beans is used as vegetable to supplement other food like *ugali*, polished rice and banana. Banana is a favourite food for people in Mbokomu ward. Boiled banana is known as *machalari* in Chagga language. Banana can be boiled with beans or meat. Beans is stored or kept in *kihenge* or granaries as maize.

To show the place of preserving bananas among the Chagga people one informant had this to say:

"All the matured bananas that are ready for harvest are not harvested once. The family normally cut the bunch or part of banana which is enough for that time while others are kept for future use".

These happen because the remaining part of the ripe banana can also be used as a fruit, people use ripe bananas to supplement main menue. Leaves and stem of the banana are used as a fodder for animals and roofing houses while others use stem and leaves to make mulch.

This kind of preservation and maximum utilisation of the banana plant ensured that, there is enough food for the family and also for feeding animals. It ensured food security, material for building grannaries, acted as a supplement to the food diet as fruits. Through the traditional methods of harvesting and preserving bananas, the Chagga people ensured constant food supply by, not seeking foreign aid to suppplement their diet, thereby becoming food secure without the help of others.

Meat

People in Mbokomu ward engaged both in farming and animal keeping. Animal kept in the ward include cattle, goats, sheep, pigs and poultry. Poultry comprised of chickens and ducks. These animals provide people with meat, milk, hides, eggs and manure. Meat is an important part of food in different parts of the world. People interviewed have different experiences about meat.

A man interviewed in the Mbokomu wards commented that:

"families do slaughter animals together, animal slaughtered may not finished immediately or at once. After slaughtering animals people eat part of it, the family do boil or cook the remaining part of the meat, dry it on the fire and keep it for future use."

When boiling or cooking the meat, much salt is boiled with it. Salt helepd to protect meat from rotting.

Another man of 69 years old, added that:

"meat and skin is also dried on the sun and stored for many years. Once the skin is dry it can be used as food during the drought seasons. But before skin is prepared, you soak in water for some hours inother to become soft before cooking."

Meat is very importat for many people. Various ethnic groups have different means or ways of preserving meat for future use. After slaughtering animals, meat is boiled in water with high content of salt, once it is ready, you placed close to the fire containing hot charcoals to dry slowly until it becomes dry. It is stored in a cool dry place to prevent it from rotting. When ready for use, you soaked in a hot water to make it soft and tender. The tender meat will be cooked with banana or prepared as a soup to eat with *ugali*. The well prepared and dried meat can be stored for three to six years without being damaged. This demonstartes that the indigenous Chagga people had their own ways of preserving perishable foods like meat before the invention of the refrigerator. Their traditional method of preserving meat even lasted longer than the modern refrigerator which cannot preserve meat for up to six years as compared to dried meat.

Milk

Milk can be used whilst it is still fresh or fermented to get sour milk. *Nduwi* is a Chagga word meaning container for storing or keeping milk for future use. In other words *nduwi* is *kibuyu* in swahili. *Nduwi* was a special container for storing fresh milk until it ferments. The fermented milk is very delicious and can be used for eating banana, *ugali* and for drinking.

One elderly women of seventy one years old, said that:

"Fermented milk can be used with smashed banana. You just take banana, boil banana (maruu), smash them, then mix the smashed banana with maruu. Then you eat smashed banana mixed with milk. This is a very delicious food."

If you want to continue using fresh milk you boil the milk when ever you want to use it. Boiling of milk frequently deter the process of fermentation. The traditional Chagga methods of preserving and processing food ensured a frequent suppy of a balanced diet among family members and in a way enhanced food security among different house holds.

Threats to the use of IKS on food security

Several factors have been identified as the hindrance to the use of IKS. Thieves is the first threat identified by the people interviewed in Mbokomu ward. Maize was stored outside the house hanging on the trees. This system was simple and good as maize was stored hanging on the trees for several years without damage. As life styles changed, most youth did not want to work on farms, they started stealing the maize hanged on the trees. This situation forced people to stop the traditional knowledge or technology of preserving maize in this way.

Development of technology was another reason why people stop using IKS. Using of technology like pesticides, containers or tin for keeping maize, beans and sorghum has had an influence of not using traditional knowledge of keeping food crops. People just treat crops and store them in ready made containers. Technology of refregerator has influenced people to keep food in it rather than using IKS. However the new technology of pesticides gradually harms the body, which result in people suffereing from diseases like cancer and diabetes whilest the traditional preservation methods did not have such harmful effects. Also food items stored in a refrigerator still go bad, it is only the bactrial process that would have been retarded but not completely stopped, food stored in refregerators cannot last for more than 3 years as compared to traditional methods of preserving foodstuffs. The current power shortages in most African countries has resulted in loadshedding which means that the food stuffs kept in refrigerators can go bad easily. Therefore the traditional methods of preserving food come in handy as are not affected by power shortages.

Changing of life style is another bottleneck to the use of IKS. People do not keep or store food for the future. Food is available in the shops provided one has money to buy it. Other reason is the quantity produced. People produce less which suffice for a short period of time. This situation leaves people with nothing to store or preserve for the future.

One women interviewed narrated about less harvest as follows:

"Our soil is infertile; our grand-mother and grand-father used the same land. They had water for irrigation which is not available today. All natural streams and canals have dried up due to human activities and lack of maintenance. The same land used since time immemorial is the same land cultivated today. Do you think we will harvest enough to use today and remain with something or surplus to keep for future that is two or more years to come? No! thank you. I am now old, unable to cultivate, my children have migrated to urban areas. This is why most people in Tema village are harvesting less, they do not have money to pay someone to assit in farming, weeding and harvesting".

Streams and canals have dried-up due to irrational cut of trees around the water sources and poor maintenance of canals. Climate change have contributed to the drying of springs and streams. All these have contributed to decline of harvest. Most people living in rural areas are women and old people, youth have migrated to urban areas looking for jobs and so called better life. In Mbokomu ward only the old people are there, they can not work on farms and produce enough food.

CONCLUSION AND RECOMMENDATIONS

IKS is a knowledge held by local people in mind. IKS is a cornerstone of food security for many societies. During the communalism or stone age, people were living by depending on nature, on the environment. They played with nature to survive. Life was depending on hunting and gathering of animals and wild plants, respectively. In this stage, people were using traditional methods to preserve food crops by using traditional knowledge. A report from the United Nations Food and Agriculture Organisation (2003), warns the dangers posed by developmental initiatives that ignore indigenous knowledge. The research claims that the loss of this knowledge exposes communities residing in rural areas to food insecurity.

Indigenous knowledge is a critical factor for sustainable development. Innovative mechanisms for the protection of indigenous knowledge need to be developed and preserved. Many indigenous knowledge practices can at the same time be integrated into local, national, regional, or even global development efforts. This is paper recommends the following;

i) There should be efforts to conduct researches that document the IKS knowledge available in different groups, societies and ethnic groups in Tanzania. Without documenting IKS, the next generation will not know how the ancesters used IKS in preventing food insecurity.

Ii) IKS should be used in conjunction with Modern Knowledge Systems.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Analysis of physical and chemical parameters in ground water consumed within Konso area, Southwestern Ethiopia

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To improve water quality, there should be a mechanism of keeping safe water source from chemical contaminants in an effective and protective way through the application of regular checkup and with interventions by taking exact measure periodically before it is supplied for usage. The intention of this research is aimed at determining the level of common cations, anions, heavy metals and physical parameters in drinking water supply system in, Konso and its surrounding area, Southwestern Ethiopia. Water samples were collected from 23 different locations in the area where there is a hand pump or motorized supply system that is used for drinking purpose. The collected samples were analyzed for physicochemical parameters including total alkalinity, temperature, pH, electrical conductivity, total dissolved solids, turbidity, alkalinity, total hardness and total suspended solid. Common cations (Li^+, K^+, Na^+, Ca^{2+} and Mg^{2+}), common anions (NO_3^-, SO_4^{2-}, PO_4^{2-}, F^- and Cl^-) and heavy metals (Pd, Ni, Mn, Pb, Co, Zn, and Cu) were analyzed. Accordingly, the results obtained show that most of the physical and some common ions and heavy metals were within the accepted range of the guideline recommended by WHO. However, some parameters are at alarming state as compared to the WHO standards for drinking purposes, thereby suggesting the need for treatment and precautionary measures for use of the particular ground water.

Key words: Ground water, physicochemical parameters, common cations, common anions, heavy metals.

INTRODUCTION

Water is one of the most important and most precious natural resources. It is vital to man's existence and without it, there would be no life on earth. The earth holds approximately 1.4 × 10^9 m^3 of water in the form of oceans, seas, rivers, lakes, ice, etc., but only 3% of the total available water resources are in the form of fresh

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water found in rivers, lakes, and groundwater. The fresh water that is needed for a clean water supply is limited and the demand far exceeds the available supply due to increasing population and industrialization (Muthulakshmi et al., 2013; APHA, 2012). A clean water supply is one of the key indicators for development in any country; however, the situation of most African countries is not encouraging because more than 300 million people in Africa live in water scarce environments (WHO, 2004a).

The availability of water resources and the amount of freshwater continue to decrease time to time in Africa. In sub-Saharan Africa, the water requirements for major domestic and industrial purposes are usually not met. The need to determine the quality of public water supply has been intensified as a result of an increase in water pollution on a global scale caused by increasing population, urbanization and industrialization (Omaka et al., 2015). All these major causes have rampantly deteriorated the quality of water worldwide. This has resulted in the decrease in the quality of drinking water available and has also caused the decline of resources from our marine sources as the runoff water from the land is ultimately destined for the seas (Nikunj et al., 2015).

Groundwater is an important source of drinking water for humankind. It contains over 90% of the fresh water resources and is an important reserve of good quality water (Kanmani and Gandhimathi, 2013) and it is also used for agricultural, industrial, household, recreational and environmental activities all over the world (Ackah et al., 2011). In the last few decades, the ground water potential and its quality level in major cities and urban center's is getting deteriorated due to the population explosion, urbanization, industrialization and also the failure of monsoon and improper management of rain water (Appelo and Postma, 2005). Public ignorance to environmental considerations, indiscriminate disposal of anthropogenic, agricultural and mining wastes, unplanned application of agrochemicals and fertilizers and overexploitation of groundwater resources caused excess accumulation of pollutants on the land and contamination of available surface and groundwater resource (Ashwani and Abhay, 2014).

The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes. The ground water quality is normally characterized by physical characteristics, chemical composition, and biological parameters. These quality parameters reflect inputs from natural sources including the atmosphere, soil and water rock weathering, as well as anthropogenic influences of various activities such as mining, land clearance, agriculture, acid precipitation, and domestic and industrial wastes. These parameters change widely due to the type of pollution, seasonal fluctuation, ground water extraction, etc. Monitoring of water quality levels is thus important to assess the levels of pollution, to assess its potability for human consumption, also to assess the potential risk to the environment and for the sustainable management of these resources (Appelo and Postma, 2005; Shittu, 2008).

Metal contamination in groundwater is one of the most serious environmental concerns in the present world scenario, wherein metal contamination is a major problem due to its high toxicity, even at low concentration levels [34]. Groundwater usually contains dissolved mineral ions which can affect the water's usage depending on the type and concentrations of the ions involved. Major cations and anions found in groundwater include Calcium, Manganese, Chromium, Cadmium, Copper, Cobalt, Zinc, Lithium, Sodium, Potassium, Nitrate, Sulfate, Bicarbonate, and Chloride. Non-ionic constituents such as oxides, phenols, synthetic detergents, dissolved O_2 and CO_2 are also found in groundwater. These constituents determine the quality of ground water in terms of cations and anions. If it is present in excessive amounts above permissible limits of concentration, it may cause serious health hazards due to contamination and, the water may need to be treated before use (Blais et al., 1993; Radhey et al., 2010). The quality of water is more important compared to quantity in any water supply planning, especially for drinking purposes. Water quality standards are the foundation for the quality based control program and required for the treatment process. These standards support efforts to achieve and maintain protective water quality conditions (Omaka et al., 2014; AlSuhaimi et al., 2017).

The water used for drinking purposes should be free from toxic elements, living organisms and an excessive amount of minerals that may be harmful to health. The water supply in Konso and its surrounding villages for cooking, drinking, and other domestic purposes is often directly sourced from ground water without biochemical treatment and the level of pollution has become a cause for major concern. There is no any documented work that reveals the chemical composition of drinking water around Konso area. This will have a negative implication on the health condition of the society living around that area. The major aim of this research is to investigate the levels of cations, anions and trace metals in the ground water of Konso and its surrounding villages and thereafter compare results obtained with the standards set for water quality by the WHO and give direction for further intervention by the concerned body.

METHODOLOGY

General description of the study area

The study was conducted in Konso woreda and its surrounding villages and covers 23 different kebeles that have functional hand pump and motorized water supply system. Konso (also known as

Karat) is an administrative center of Konso Woreda of the Southern Nations, Nationalities, and Peoples Regional State which located at 595 km far away from Addis Ababa, Capital City of Ethiopia and 90 km far away from Arba Minch town. The total area of the study place is estimated about 2,273.79 km^2 and it lies at an altitude of 1650 m above sea level, its average temperature is 27°C (Konso special woreda, 2017). The specific sampling areas were identified by the help of the Konso wereda water resource bureau documentation and local names were used for identifying samples.

Chemicals and reagents

All the chemicals and reagents used for the analyses were in the analytical grade unless otherwise stated.

Sample collection and preparation

Samples were collected during March to May, 2016 from 23 sampling sites of Konso regions. Ground water samples from hand-dug wells were collected in polyethylene bottles that were soaked overnight in 15% nitric acid. The soaked polyethylene containers were washed with deionized water and dried at room temperature. Afterward, the containers were rinsed several times with the water source to ensure sufficient flushing before collection. These water samples are collected after pumping the water for 10 min. All samples were brought to the laboratory in an icebox jar to avoid unusual change in water quality and stored in a refrigerator (4°C) before analysis. The method of collection, preparation and preservation were similar to those reported in previous studies (Barati et al., 2010; Birke et al., 2010; Reimann et al., 2003; Brima, 2017) and Standard methods were followed that listed by American Public Health Association (APHA) (APHA, 2005; APHA, 1992; APHA, 2012).

Physiochemical determination

The water samples were analyzed for various physicochemical parameters using standards methods recommended by APHA (2012, 2005, 1992). On site sampling, five parameters, that is, temperature (°C), turbidity, pH and electrical conductivity (EC) of ground water were determined at the site with the help of digital portable water analyzer kit and other parameters were analyzed in the laboratory. Total hardness (TH) and calcium hardness are determined by complexometric EDTA titration methods using Eriochrome blackT (EBT) and murexide (ammonium purpurate) indicator, respectively. Magnesium concentration is calculated from total hardness and calcium hardness.

Total alkalinity (TA), carbonate and bicarbonate concentrations were estimated by titrimetric methods using phenolphthalein and methyl orange as indicator. To measure total dissolved solid (TDS), the filtered sample was evaporated in a hot oven at 180±2°C. After the whole sample was evaporated, the evaporated dish was cooled and the final weight was measured and computed with the initial weight measured. Estimation of heavy metals (Manganese, Lead, palladium, Nickel, Copper, Cobalt, and Zinc) carried by Flame Atomic Absorption Spectrometer (FAAS-210VGP). Estimation of cations (Na^+, K^+ and Li^+) was measured by single channel emission, Flame Photometer (JENWAY -PFP7).

Nitrate (NO_3^-), sulphate (SO_4^{2-}) and phosphate (PO_4^{-3}) were determined by a colorimetric method using a UV-Visible spectrophotometer type (JASCO V-530). For the analysis of chloride and fluoride ions, ion selective electrodes (Jenway-304 chloride and Jenway 924-305 fluoride) were used respectively. In this study, the precision of the results was evaluated by relative standard deviation of the results of triplicate measurements of each sample were used for the analysis of different parameter of ground water samples.

RESULTS AND DISCUSSION

The respective values of all water quality parameters (physicochemical properties, cation and anion content and trace metal content) of the groundwater samples are presented in Tables 1, 2 and 3, respectively. All the results are compared with standard's permissible limit recommended by the World Health Organization (1993, 2004) and American Public Health Association (APH) (1992, 2005, 2012).

Determination of physical parameters

The data in Table 1 reveals that there were considerable variations in the examined samples from different sources with respect to their physical characteristics and this indicates that the quality of water considerably varies from location to location. Determination of pH is very important because it influences the other physicochemical parameters and the availability of metal ion in the water and waste water. In addition, all the biochemical reactions are sensitive to the variation in pH and it is one of the most important operational water quality parameters (Reda, 2016). In this study, pH ranges between 6.55 (kolbeto) which is slightly acidic and 8.2 (Gersale) which is slightly alkaline. WHO acceptable pH value is 6.5 to 8.5. Hence, all the samples are in the recommended range by WHO and no effect on health with respect to pH.

The temperature of water and wastewater is one of the most important characteristics that determines, to a considerable extent, the trends and tendencies of changes in the river water quality. Increased water temperature decreases the solubility of dissolved oxygen and water temperatures ab''/over 27°C is "unsuitable" for public use. At above 32°C, it would be considered "unfit" for public use (Reda, 2016). In the present study, all measured sample temperatures were presented in permissive threshold value.

Turbidity in water arises from the presence of very finely divided solids which are not filterable by routine methods. The existence of turbidity in water will affect its acceptability to consumers. There is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escapes the action of the disinfectant (Istifanus et al., 2013). Water samples from Misako, Alatayto, Moriteta, Chiro, and Delbela have high turbidity value, greater than 8 NTU that is above a threshold value that is recommended by WHO, this indicates that it is necessary to treat water from this sampling area before

Table 1. Results of physical parameters of the water samples.

Sampling area	Total alkalinity (mg/L)	Conductivity (μs/cm)	T (°C)	pH	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	Total hardness (mg/L)
Kolbete	97.6	0.685	22.4	6.55	3.5	776.67	233.33	206.67
Misako	329.4	1.244	21.9	7.11	8.5	1463.33	270.00	477.78
Gera	234.24	0.703	22.0	7.24	1.7	406.67	256.67	340.00
Orbahe	175.68	0.966	22.0	7.44	7.3	793.33	406.66	442.22
Arfa	278.16	0.803	22.0	7.33	1.1	773.33	23.33	406.67
Arfa-1	200.08	0.581	22	7.23	7.5	1086.67	173.33	420.00
Docatu	297.68	1.766	22.1	7.23	2.0	353.3	76.66	817.78
Alatayto1	292.8	1.038	22.3	7.64	8.0	660	20	335.56
Alatayte2	283.04	1.050	22.4	7.74	2.3	1130	156.67	315.56
Moriteta	483.12	1.531	21.7	7.55	8.2	1756.67	336.67	297.78
Kadadeshe	112.24	0.838	22.2	7.64	2.5	873.33	196.67	368.89
Orshale	375.76	1.574	22.6	7.63	3.9	640	36.67	457.78
Airport	200.08	0.743	22.2	7.46	4.0	726.67	6.67	126.67
KonsoTown	283.04	1.051	22.4	7.41	7.9	1030	60.00	604.44
Fasha Town	112.24	0.396	22.3	7.91	1.8	626.67	2666.67	164.44
Chiro	204.96	0.579	22.4	7.95	8.3	396.67	106.67	275.56
Gersale	244	1.055	22.6	7.98	1.0	653.33	143.33	382.22
Fuchucha	229.36	0.600	22.3	8.02	7.8	536.67	153.33	173.33
Bahile	253.76	0.821	22.4	7.78	1.5	676.67	206.67	455.56
Sorobo	395.28	1.179	22.2	7.70	7.6	940	330.00	482.22
Sahayto	458.72	1.554	22.2	7.09	2.2	1310	220.00	666.67
Delbela	229.36	0.784	22.2	7.99	8.1	390	96.67	382.22
Dolbena	244	0.803	22.3	7.87	2.4	516.67	120.00	597.78

use. Electrical conductance is a measure of the ability of an aqueous solution to carry an electric current that depends on the presence and total concentration of ions, their mobility and valance and on the temperature. It is valuable to measure a number of ions dissolved in wastewater and water. It is a useful tool to assess the purity of water (Amanial, 2015). The WHO permissible limit for electrical conductivity (EC) of water is 300 μS/cm and the values of EC in all sampling points were ranged from 0.396 to 1.554 μS/cm. These values are below the WHO permissible limit.

TDS values depend on climate, the host rock, and the residence time of the groundwater in the geological matrix. Thus, it tends to be higher in arid/desert areas than in tropical areas that receive abundant rainfall. It also enhanced in agricultural arid areas due to cyclic salting process, in which salts are concentrated and precipitated in the soil zone from irrigated water due to high evaporation rates, and then leached from the soil zone by either irrigation or rainwater and percolated, hence reaching the groundwater (AlSuhaimi et al., 2017). The TDS was found to be in an acceptable range for the water samples collected from the Delbela, Gera, Docatu and Chiro. The possibilities of dissolution of rockery minerals are very low. However, the rest of water samples were found to possess high TDS value when compared with the tolerance limit of 100 to 500 mg/L of WHO. Since Konso and its surrounding villages found low altitude and there are farms, this can have possibilities to increase TDS of ground water in the sampling sites.

Regarding the values of TSS, all the water samples showed the excess presence of contaminants, and samples from Arfa, Alatayto and Airport TSS measured values were within the permissible limits of WHO (≤30 mg/L). However, other samples were above a threshold value set by WHO. The result indicates sample which has high TSS value may have high contamination and this may introduce different diseases which affect all living things.

Total alkalinity is a measure of the ability of water to neutralize acids. The alkalinity of groundwater is mainly due to carbonates and bicarbonates (Reda, 2016). Alkalinity in terms of HCO_3^- of all these water samples ranged from 97.6 to 483.12 mg/L, respectively. The acceptable limit of alkalinity is 200 mg/L and in the absence of alternate water source, alkalinity up to 600 mg/L is acceptable for drinking. In the present study, the

Table 2. Results of common and heavy metals.

Sampling area	Concentration (mean ± SD) of heavy and light metals (mg/L)										
	Cu	Mn	Zn	Co	Pb	Na	K	Li	Ca	Mg	Pd	Ni
Kolbete	0.176±0.029	0.074±0.000	ND	0.281± 0.013	0.003±0.00	5.312	1.229	ND	161.0	145.7	ND	ND
Misako	0.013±0.010	ND	ND	0.257±0.018	0.276±0.008	5.479	1.337	ND	219.3	258.4	ND	ND
Gera	0.063±0.010	ND	0.049±0.003	0.247±0.036	0.076±0.008	2.688	1.373	ND	168.0	172.0	ND	ND
Orbahe	ND	ND	ND	ND	ND	2.188	1.626	ND	221.7	220.6	ND	ND
Arfa	0.012±0.001	0.002±0.001	ND	0.257±0.017	ND	1.020	1.446	ND	172.7	234.0	ND	ND
Arfa-1	0.182±0.022	0.074±0.013	0.074±0.005	0.288±0.017	ND	0.521	1.554	ND	154.0	266.0	ND	ND
Docatu	0.208±0.001	0.078±0.007	0.107±0.001	0.281±0.016	ND	0.937	1.808	ND	289.3	528.4	ND	ND
Alatayto1	0.076±0.032	0.034±0.000	0.409±0.005	0.268±0.000	ND	1.104	2.460	ND	112.0	223.6	ND	ND
Alatayte2	0.013±0.028	ND	ND	1.355±0.963	ND	1.645	2.786	ND	74.7	240.9	ND	ND
Moriteta	ND	ND	ND	ND	ND	0.646	1.699	ND	46.7	251.1	ND	ND
Kadadesh	0.069±0.010	ND	0.040±0.002	0.247±0.017	ND	ND	1.482	ND	109.7	259.2	ND	ND
Orshale	ND	ND	ND	ND	ND	0.521	1.735	ND	144.7	313.1	ND	ND
Airport	0.132±0.019	ND	0.039±0.000	0.268±0.030	0.027±0.001	0.063	1.880	ND	42.0	84.7	ND	ND
KonsoTown	0.0189±0.018	ND	0.036±0.000	0.257±0.047	0.003±0.000	0.146	1.554	ND	186.67	417.8	ND	ND
Fasha Town	ND	ND	1.054±0.032	0.247±0.018	ND	ND	1.336	ND	86.3	78.1	ND	ND
Chiro	0.139±0.010	ND	0.162±0.009	0.289±0.018	ND	ND	1.590	ND	126.0	149.6	ND	ND
Gersale	0.038±0.022	ND	ND	0.247±0.018	ND	ND	2.422	ND	79.3	302.9	ND	ND
Fuchucha	0.063±0.063	ND	0.067±0.004	0.278±0.036	ND	ND	1.228	ND	56.0	117.3	ND	ND
Bahile	0.094±0.019	ND	ND	0.247±0.018	ND	ND	1.446	ND	193.7	261.9	ND	ND
Sorobo	0.038±0.019	ND	0.458±0.009	0.278±0.017	0.057±0.000	0.009	1.663	ND	235.7	246.6	ND	ND
Sahayto	0.032±0.010	ND	ND	0.257±0.064	ND	ND	1.699	ND	221.7	445.0	ND	ND
Delbela	0.025±0.021	ND	ND	0.278±0.047	ND	ND	2.207	ND	135.3	246.9	ND	ND
Dobena	ND	ND	ND	0.237±0.00	ND	ND	2.170	ND	179.7	418.1	ND	ND

ND: Not detected.

value of total alkalinity content in all sampling sites has been found under permissible alkalinity level.

Hardness is one of the very important properties of ground water from a utility point of view for different purposes. In groundwater, hardness is mainly contributed by bicarbonates, carbonates, sulphates and chlorides of calcium and magnesium. So, the principal hardness causing ions are calcium and magnesium (Reda, 2016). WHO standards given for hardness include 100 mg/L (highest desirable) and 50 0mg/L (maximum permissible). The samples, Sahayto, Dolbena, Konso town and Docatuhave very high hardness value, which is beyond the maximum permissible limit. But Airport and Fasha town and gets moderate hardness, and all the remaining samples are characterized by hard water though they are in the recommended range.

Determination of light and heavy metals

The mean (average) values for light and heavy metals determined in the ground water samples

Table 3. Results of common anions.

Sampling area	Concentration (mean ± SD) of metals (mg/L)				
	NO_3^-	PO_4^{-3}	SO_4^{-2}	Cl^-	F^-
Kolbete	2.03±0.050	0.411±0.000	1187±0.000	23.67±0.244	0.480±0.67
Misako	7.13±0.013	0.578±0.004	732±0.000	72.97±0.489	0.355±0.67
Gera	6.10±0.013	0.107±0.004	52±0.000	19.72±0.244	0.277±0.67
Orbaye	72.65±0.013	ND	174±0.000	60.15±0.044	0.247±1.11
Arfa	16.00±0.249	0.068±0.004	140±0.000	24.66±0.156	0.174±0.66
Arfa-1(upper)	17.75±0.013	0.066±0.004	137±0.000	21.69±0.089	0.138±0.44
Dokatu	23.12±0.000	0.167±0.004	196±0.000	114.39±0.177	0.173±0.67
Alatoyte-1	2.48±0.000	0.580±0.004	256±0.577	61.12±0.044	0.205±0.67
Alatoyte-2	2.10±0.000	0.059±0.004	99±0.000	91.71±0.200	0.186±0.44
Moriteta	11.38±0.000	ND	88±0.577	54.24±0.044	0.217±0.44
Kadadish	31.05±0.240	0.053±0.008	72±0.577	30.57±0.044	0.188±0.67
Orshale	22.88±0.249	ND	111±0.173	193.28±0.155	0.146±0.67
Airport	2.45±0.249	2.046±0.079	146±0.000	36.48±0.155	0.108±0.67
Konso Town	65.33±0.000	ND	64±0.577	55.22±0.044	0.123±0.67
Fasha Town	31.45±0.015	0.566±0.040	52±0.000	21.89±0.312	0.144±0.11
Chiro	4.28±000	ND	51±0.000	21.45±0.162	0.111±0.44
Gersal	58.53±0.000	0.162±0.004	65±0.000	101.56±0.444	0.105±0.44
Fuchucha	2.75±0.125	ND	127±0.000	14.79±0	0.178±0.44
Bahile	24.63±0.294	0.158±0.007	71±0.000	25.63±0.111	0.101±0.44
Sorobo	4.15±0.429	0.018±0.014	70±0.000	82.09±0.175	0.123±0.67
Sahayto	62.80±0.113	0.066±0.010	238±0.100	100.58±0.133	0.146±0.67
Delbela	2.80±0.132	2.470±1.961	198±0.100	46.34±0.05	0.088±0.67
Dolbena	2.60±0.011	0.438±0.007	204±0.000	52.26±0.089	0.775±0.67

are shown in Table 2.

The major sources of copper in water bodies are agricultural activities and municipal solid wastes, pesticides, batteries charging and blue color for consumer products. Ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very-high doses of copper can cause damage to your liver and kidneys, and can even cause death (Ediagbonya et al., 2015). Copper is one of essential dietary requirement, However, astringent tastes in water can be caused by levels above 1 mg/L Cu. At levels above 2.5 mg/L, copper imparts an undesirable bitter taste to water; at higher levels, the color of the water is also impacted (World Health Organisation (WHO), (2004a). As is indicated in Table 2, the average concentrations of copper in all water samples are below the threshold value, (2 mg/L), as set by WHO and all the samples are within safe permissible limits.

Zinc levels in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/L, respectively, concentrations in tap water can be much higher as a result of the dissolution of zinc from pipes. Zinc is found naturally at low concentrations in my rocks and soils principally as sulphide ores and to a lesser degree as carbonates. Most zinc is introduced into water by artificial pathways such as byproducts of steel production or coal-fired power station or from the burning of waste materials, from fertilizer that may leach into groundwater. Zinc is considered an essential trace metal which functions as a catalyst for enzymatic activity in human bodies. Drinking water contains this trace metal in very small quantities which may reduce the possibility of its deficiency in the diet. However, its accumulation in the human body causes harmful effects such as stomach cramps, nausea, vomiting, decrease good cholesterol and acceleration of anemic conditions (Quinn and Sherlock, 1990; Ediagbonya et al., 2015). The maximum permissible limit for Zn in drinking water is 0.01 g/ml as recommended by WHO. The mean concentration for Zinc (Zn) (Table 2) in this study varied from 0.036 to 1.054 mg/L; with the highest measured at Fasha town and the lowest was at Konso town. However, in some samples, Zinc concentration is not detected by instrument indicating too little concentration. Detected too much zinc concentration is above a threshold value that needs immediate intervention to improve the quality of water around sampling area.

The major sources of manganese are fertilizer, steel production, ores, rocks, pesticides, and batteries charging. It has not been particular toxicological to be too much harmful and poisonous, but the concentration of it in a particular spot may vary the taste and yet causes turbidity (WHO, 2004a). The health based standard guideline given by WHO for Manganese is 0.5 mg/L, hence in all samples the concentrations were found to be less than the threshold value. Exceptionally, sample from Kolbete Arfa, Arfa-1 and Docatu, their concentrations are very low to be detected by the instrument.

Lead is a cumulative general poison for the fetus and pregnant women. Infants and children up to 6 years of age are the most susceptible to its adverse health effects. Its effects on the central nervous system can be particularly serious. The almost universal use of lead is plumbing fittings and as solder in water distribution systems. Lead pipes may be used in old distribution systems and plumbing. Corrosion of plumbing systems is an important source of excessive lead in drinking-water, so lead levels in water should be measured at the tap, rather than at the drinking-water source, when estimating human exposure (WHO, 2004a). Samples from Misako, Gera, Airport, and Sorobo were above the permissive level recommended by WHO>0.01 mg/L, hence need a special attention. However, for other rest of the samples, the levels of lead are low and undetected by the instrument. This may suggest that the environment is free of lead contamination and hence ground water samples from these sampling areas are safe for human consumption and their animals.

The trace element Cobalt is detected in all samples that range from least concentration 0.237 mg/L (Dobena) to 1.355 mg/L (Alatayte2). The result for the analysis of light metal ions: sodium, potassium and lithium, shows the very less average concentration of the corresponding ions are present, and most of them are in the recommended range. When the result of sodium concentration compared with the standard given by WHO based on aesthetic quality, there is no maximum contaminant level set for sodium, but 200 mg/L was fixed based on taste. For potassium and lithium, there are no specific standards in drinking water given by WHO.

Calcium has no effect on human health in water, but it can cause hardness problem risk and directly related to hardness (Welch et al., 2000). Except for sample area from Alatayte2, Moriteta, Airport, Fasha town, Gersale and Fuchucha, rest of the samples' concentrations of calcium are above permissive standard limit prescribed by WHO. This indicated that in terms of the calcium content, the water is not safe for drinking and other domestic purposes for this area. Mg^{2+} is the most abundant elements in nature and it is a significant member in water hardness, it gives an unpleasant taste to water (Konso special woreda, 2017). In all of the samples, the content of magnesium level was above standard limit sated by WHO. This indicated that in terms of the magnesium content, the water is not safe for drinking and other domestic purposes for this area.

In most of the water samples, the concentration of Ni, Li and Pd is very low to be detected by the instrument. None of this element was detected in all samples which show that the water samples contain very less amounts of Ni, Li and Pd, that is less than the detection limit of the instrument. Therefore, ground water around Konso area has very less level of these ions; hence, the water is safe for drinking with respect to these ions. Lithium (in all samples), zinc, sodium, and manganese were below the detection limits in some samples and are reported as not detected (ND).

Determination of common anions

Chloride and fluoride are very common in water systems as they are added to drinking water for various health and sanitary purposes. However, chloride and fluoride levels can be increased by contamination of fertilizers, road salt, and industrial pollution as well as human and animal waste. The contaminants can cause dramatic increases in chloride and fluoride concentrations, which should be closely monitored (Jason and Christina, 2012). The concentration of chloride is the indicator of sewage pollution and also imparts laxative effect. Atmospheric sources or sea water contamination is the reason for the bulk of the chloride concentration in groundwater which may exceed due to base-exchange phenomena, high temperature, domestic effluents, septic tanks and low rainfall. Porosity soil and permeability also plays a key role in building up the chlorides concentration (Reda, 2016). According to WHO recommendation (1993), the permissible value is 250 mg/L. As shown in Table 3, the current analysis result reveals that all the samples of water from different areas of Konso have low values of chloride ranging from 0.34 to 4.45 mg/L which is in the permissible range for drinking.

Most ground watersamples have low or acceptable concentrations of fluoride (<1.5 mg/L) according to the recommendation of WHO (1993). However, some large groundwater provinces have significant concentrations which cause prominent health problems. Presence of large amounts of fluoride is associated with dental and skeletal fluorosis (>1.5 mg/L) and inadequate amounts with dental caries (< 1 mg/L). From the result indicated in Table 3. All samples have average fluoride concentration below 1.5 mg/L, which is found between 0.088 and 0.775 mg/L. This shows the water is recommended for drinking purpose with respect to fluoride. On the other hand, this result reveals that the amount of fluoride concentration is very small in the range of 0.1 ppm, which is reflected by dental caries in some areas. This requires some remedial action to be done, that is, more supply of fluoride to the water or from other sources is required.

Nitrate is the highest oxidizable form of nitrogen and occurs in trace quantities in surface water, but may attain high levels in some ground water and is toxic when present in excessive amounts in drinking water. Mostly nitrate comes from industrial, agricultural chemicals and fertilizer application. The most common source of nitrate concentration is attributed to animals and human waste disposal practices and the use of agricultural fertilizer (Mohammed and Nur, 2013). The nitrate concentration measurements, for these water samples range between 2.03 and 65.33 mg/L. The recommended value of nitrate is 50 mg/L as expressed by WHO (1993). In this study, the experimental result listed in Table 3 shows sample from Orbaye, Konso town, Gersal, and Sahayto has above the maximum threshold value, so the water in these areas needs immediate attention/treatment to make water safe for drinking. Other samples are recommended for drinking purpose since they have concentration below a threshold value.

The sulfate concentration ranges from 1187 to 9.51 mg/L most samples falls below 500 mg/L threshold value that recommended by WHO (1993) guidelines for drinking water, however, samples Kolbete and Misako have a high amount of sulfate concentration. The sulphate concentration in the analyzed sample is probably derived from oxidation of sulphate in the igneous rocks. These shows it is above threshold value; it needs further treatment to make safe water for the drinking purpose. The remaining samples' analysis result shows that they are in the recommended range for drinking purpose, according to WHO.

Phosphates enter waterways from human and animals waste, phosphorus rich bedrock, laundry, cleaning, industrial effluents, and fertilizer runoff. Phosphates become detrimental when they over fertilize aquatic plant and cause step up eutrophication. Though, there is no clear guideline set for the phosphate ion concentration by WHO (1993), some research articles and guidelines suggest that concentration of 0.01 mg/L of phosphate is acceptable while 0.02 mg/L is excessive (Istifanus et al., 2013; Ediagbonya et al., 2015). The result obtained (Table 3) shows that no phosphate content is detected in some samples. This shows the concentration of phosphate in the samples is very small and below the detection limit of the instrument. In the remaining samples, a high level is detected that is above recommended limit, however, the high amount is exceptionally detected in airport area and it needs treatments to make it safe for drinking purpose.

Conclusion

Chemical constituents in water can cause a variety of problem in living things. To improve its quality it should be recognized that the most effective and protective way is through the application of regular checkup and taking exact measure with a specific period of time before it is supplied to living things. The ground water samples which were taken from the various places in Konso area were analyzed for different physicochemical parameters and most of the parameters are found to be below the maximum permissible limits of WHO. However, the following results are noted as exceptions to meet the standards of WHO. Dolbena, Sahayto, Konso town and Docatu have very high hardness value, which is beyond the maximum permissible limit. In terms of light metal ions, sodium, potassium and lithium, the result shows that the very less average concentration of the corresponding ions are present, and most of them are in the recommended range. Samples collected from Misako, Gera Airport and Sorobo areas, respectively, have more lead content than the threshold value. For a sample with above permissive value need immediate interventions and need a special attention to improve the quality of drinking water. Generally, most of the parameters in the waters samples were found to be within the limit of drinking water quality standards and are safe for dirking and other domestic purposes at the physicochemical level. However, it is also important to investigate other potential water contaminations such as chemicals, microbial and radiological materials for a longer period of time, in order to assess the overall water quality.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Genotoxicity assessment of three industrial effluents using the *Allium cepa* bioassay

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The *Allium cepa* assay was employed, in conjunction with physico-chemical analysis, to investigate the potential cytotoxicity and genotoxicity of three industrial effluents (soap, beverage and paint) from the southeast of Nigeria. For *in situ* monitoring of cytotoxicity level, inhibition of mitotic division was investigated and for genotoxicity evaluation, chromosomal aberration assay was carried out. The results showed certain sample-constituents of the wastewaters (e.g. pH, turbidity) to be at concentrations beyond the maximum permissible limits required by international regulatory authorities. On the basis of the 72 h effective concentration (72 h EC_{50}), the paint effluent was the most toxic while the beverage effluent was the least toxic. The mean root lengths of *A. cepa* exposed to different concentrations of the industrial effluents, when compared to the control, were shown by Analysis of Variance (ANOVA) to be significantly ($p<0.05$) concentration dependent. The three industrial effluents were observed to induce chromosomal aberrations, laggards and sticky chromosomes being the most frequently seen. The findings show that a combination of physico-chemical analysis and genotoxicity assay is effective in assessing industrial effluents for the environmental monitoring of pollutants.

Key words: *Allium cepa*, industrial effluents, soap, beverage, paint, genotoxicity

INTRODUCTION

Waste water and solid discharge from anthropogenic activities has resulted in an alarming rate of pollution of most aquatic and terrestrial environments worldwide. The sources of such wastes include industrial effluents, domestic waste water and agriculture waste water. The rapid strides in the urbanization and industrialization of developing nations have necessitated pollution becoming an inevitable challenge. The problem is further aggravated by wrong handling and indiscriminate disposal of industrial effluents into the various water ways, coupled with the apparent ignorance of urban residents with respect to the dangers associated

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with such acts. Raw water for public water supply has continued to be the recipient of industrial wastes from multiple sources and not much attention has been paid to assessing the biological effects of inland surface waters impacted by such industrial effluent discharge.

Effluents are complex mixtures containing numerous inorganic as well as organic compounds, and most industrial effluents may contain metallic compounds in addition (Nielsen and Rank, 1994). Such pollutants may have direct health implications due to their potential cytotoxic and genotoxic effects (Grover and Kaur, 1999; Lah et al., 2004). The chemicals in effluents can also bioaccumulate (Abdel-Migid et al*.,* 2007) and biomagnify in a food chain (Alimba et al*.,* 2011; Eisen-Cuadra et al., 2013) leading to adverse effects on indigenous biota (Claxton et al*.,* 1998). The complexity of industrial effluents makes it almost impossible to carry out hazard assessment merely on the basis of conventional water chemistry analysis (El-Shahaby et al., 2003). It is therefore imperative to evaluate hazardous wastes and effluents by genotoxicity assays in order to obtain data that can be used for hazard identification and comparative risk assessment (Organisation for Economic Co-operation and Development (OECD), 2015).

Although Nigeria has undergone relatively rapid industrialization over the last four decades, this was not guided by comprehensive environmental awareness, governance, efficient regulatory systems, enforced planning regulations and environmental sound waste management practices. In the southeast of Nigeria, most industries are sited close to residential houses and other urban areas thereby exposing nearby human populations to great health risk from pollution. Of particular interests are the paint, food processing and cosmetic industries, which are the major industries in the region and among others discharge large volumes of raw or partially treated effluents containing hazardous substances continuously into nearby gutters or drains. These end up in streams, rivers and wetlands thereby leading to gross pollution of the ecosystem. There is a general paucity of reports on genotoxicity evaluation of industrial effluents in Nigeria in general (Odeigah, et al., 1997; Bakare et al., 2009; Samuel et al., 2010, Oladele et al., 2013) and little or no reports on the southeast region in particular. A recent study in the region was focused only on the potential impact of effluents on water quality (Oladele et al., 2017).

Of all the investigations carried out with higher plants that have been recognized as excellent genetic models for the detection of environmental mutagens, the *Allium cepa* assay stands out. It was introduced by Levan (1938) to examine the effect of colchicines on mitotic spindles and has been rated as a standard method in environmental monitoring and toxicity screening of waste water and river water (Fiskesjö, 1985, 1993; Rank and Nielsen, 1993, 1998; Abdel-Migid et al*.,* 2007; Grover and Kaur, 1999; Junior et al*.,* 2007; Vesna et al*.,* 1996).

In this study, the *A. cepa* assay was employed to evaluate the toxicity of waste waters from three industries in Southeast of Nigeria in consonance with chemical analysis. The results of this study will go a long way in providing the much needed data that can be used as a scientific basis for the regulation of the discharge of potentially hazardous substances into the environment.

MATERIALS AND METHODS

Sampling sites and analysis of samples

The soap effluent (Sp) was collected from the PZ Cussons Factory, Aba, Abia State; the beverage effluent (Bv) from Consolidated Breweries, Awomama, Imo State; while the paint effluent (Pt) was from Saclux Paint Industry Ltd., Umuahia, Abia State. The three raw industrial effluents (Sp, Bv and Pt) were collected from the industrial waste water discharge pipes of the respective factories. The effluents from these industries are discharged into nearby municipal rivers and drainages. At the time of collection, the water reaction (pH) and the electrical conductivity (EC) of the samples were determined and the samples were analyzed for other standard physico-chemical parameters such as turbidity, alkalinity, Cl, So_4, Co_3, Na, Ca, No_3, K, organic carbon and inorganic carbon according to standard analytical methods (United States Environmental Protection Agency - USEPA, 1996; American Public Health Association - APHA, 1998). Collection was done in plastic containers and the samples were stored at 4°C (in a refrigerator), pending use.

Biological materials

The common purple onion *A. cepa* L. Stuttgarter Reisen (2n=16, Family Amaryllidaceae) bulbs (2.5 - 2.8 cm diameter) used for the study were commercially procured from Eke Okigwe Market, Abia State, Nigeria. They were sun dried for 2 weeks and the dry bulbs (excluding the rotten ones) were later used for the tests.

The *Allium cepa* assay

The modified assay (Fiskesjö, 1997; Bakare and Wale-Adeyemo, 2004; Babatunde and Bakare, 2006) was carried out using 100-ml beakers. Lead nitrate ($Pb(NO_3)_2$) solution and distilled water were used as positive and negative controls respectively while distilled water was used for the dilution of the industrial effluents. The effluent in each case was equilibrated to room temperature (26±2°C) and diluted with distilled water to produce the series of concentrations investigated. Prior to the test, the outer scales of the bulbs and brownish bottom plates were removed, leaving the ring of root primordial intact. The peeled bulbs were placed into fresh water during the cleaning process so as to protect the primordial from drying. Afterwards, the bulbs were exposed directly to 100, 75, 50 and 25% (v/v, effluent/distilled water) of each of the test liquid. Five onions were used for each concentration of each individual effluent and the control, that is, each concentration was set up in 5 replicates. The base of each onion bulb was suspended on the test liquid in 100-ml beakers in the dark at 27±1°C. The test liquids were changed daily.

Genotoxicity investigation

After 48 h, the root tips of one bulb in each group of the

Table 1. Physico-chemical characteristics of industrial effluents analyzed for genotoxicity.

Parameter	Sp	Bv	Pt	FEPA[a]	USEPA[b]	WHO[c]
pH	13.47	7.50	5.34	6-9	6.5-8.5	6.5-9.5
Electrical conductivity	18.4	25.6	57.6	NS	NS	NS
Turbidity (NTU)	64	49	320	NS	NS	<0.1-5.0
Alkalinity	22500	32	35	250	20	250
Total Hardness	1300	10	40	NS	0-75	100-300
Calcium Hardness	1100	9	26	200	NS	NS
% Nitrogen	0.125	0.118	0.164	NS	NS	NS
NO_3	1.42	0.62	4.91	20	10	50
PO_4	0.68	0.24	2.81	500	5	NS
Na	300	18	50	NS	NS	150
K	750	30	80	250	NS	150
% Total Carbon	0.260	0.408	1.343	NS	NS	NS
% Organic Carbon	0.113	0.064	0.162	2.50	NS	150
% Inorganic Carbon	0.147	0.344	1.181	NS	NS	NS
Moisture content	97.86	99.94	98.43	NS	NS	NS

Values are in mg l^{-1} except turbidity and pH with no units; NS-Not stated (that is, no guideline established). [a]Federal Environmental Protection Agency (1991). Permissible limits for effluent discharge into surface water, [b]United States Environmental Protection Agency (1999) National recommendation water quality criteria-correction; [c]World Health Organisation (1996) Guideline for drinking water quality recommendation.

experimental organisms were fixed separately in ethanol:glacial acetic acid (3:1, v/v) and were used for the chromosomal analysis. The root tips (for each effluent concentration and the control) were hydrolyzed in 1N HCl at 60ºC for 5 min and rinsed in distilled water. Two root tips were placed on each slide and stained in aceto-carmine for 20 min (after squashing). Excess stain was removed with filter paper and cover slip was carefully lowered to prevent air bubbles being trapped under. The edges of the cover slip in each case were sealed with clear nail polish as suggested by Grant (1982) to prevent drying out of the preparation by the heat of the microscope (Sharma, 1983). Five slides were prepared for each effluent concentration and for the control. The prepared slides were coded and examined for chromosomal aberrations at high magnification (X1000). The mitotic index (MI) was calculated as percentage of the number of dividing cells per 1000 (400 cells per slide per concentration and control) observed cells in each case (Fiskesjö, 1985, 1997) and the mitotic inhibition was estimated as the percentage of the difference between the mitotic indices of the control and the group divided by the mitotic index of the control. The frequency of aberrant cells (%) was calculated based on the number of aberrant cells per total cells scored at each concentration of each effluent (Bakare et al*.,* 2000).

Root growth inhibition test

The effects of the industrial effluents on the morphology of growing roots of *A. cepa* were examined. The growth inhibition assay was performed as a 72 h semi-static exposure test (Bakare et al*.,* 2009), that is, the test organisms were exposed for 72 h to the different concentrations (100, 75, 50 and 25%) of the industrial effluents. At the end of exposure, the length of the root bundle was measured for the remaining four bulbs at each concentration for each industrial effluent and the control. Growth inhibition was estimated as EC_{50} (concentration of a toxicant that gives half-maximal response).

Statistical analysis

Pearson correlation analysis was carried out to test for significant relationship (positive or negative) between the average root lengths and effluent concentrations. One-Way Analysis of Variance (ANOVA) and Student Newman Keul's (SNK) post-hoc tests were used to test for significant differences in the mean root lengths of *A. cepa* exposed to different concentrations of the soap, beverage and paint effluents. The analysis was performed using the IBM SPSS ® 22.0 statistical package. The results were expressed with 95% confidence limits, that is, 0.05 probability level. The EC_{50} was determined from a plot of root length as a percentage of control against the sample concentrations by using Microsoft Excell computer program.

RESULTS AND DISCUSSION

Physico-chemical characteristics

The physical and chemical properties of the effluents from the soap industry (Sp), beverage industry (Bv) and paint industry (Pt) at their discharge points are shown in Table 1. The results indicate the presence of certain sample-constituents at concentrations beyond the maximum permissible limits required by international regulatory authorities (Federal Environmental Protection Agency (FEPA), United States Environmental Protection Agency (USEPA), World Health Organisation (WHO)). The pH of the soap industry effluent was extremely alkaline (13.47) while that of the paint industry was acidic (5.34) and that of the beverage industry was close to

Table 2. Mean (±SD) root length of *A. cepa* exposed to different concentrations of the three industrial effluents.

Soap effluent (Sp)		Beverage effluent (Bv)		Paint effluent (Pt)	
Concentration (%)	Mean root length (cm)	Concentration (%)	Mean root length (cm)	Concentration (%)	Mean root length (cm)
Control (0)	3.86 ± 1.05	Control (0)	3.86 ± 1.05	Control (0)	3.86 ±1.05
25	2.31 ± 1.09	25	3.20 ± 0.13	25	2.40 ± 0.12
50	2.19 ± 0.82	50	3.04 ± 0.08	50	2.25 ± 0.09
75	1.73 ± 0.79	75	2.07 ± 0.11	75	1.19 ± 0.08
100	1.15 ± 0.08	100	1.45 ± 0.09	100	1.02 ± 0.05
EC_{50}	58	EC_{50}	84	EC_{50}	52

neutral (7.50). The Sp, Bv and Pt effluents were characterized by considerable pollutants of suspended matter and dissolved matter, thus having high values of turbidity, that is, 64, 49 and 320 respectively, exceeding the maximum permissible limits required by the World Health Organization (WHO). A turbidity value < 5 NTU is considered acceptable as higher values indicate the presence of particulates which can protect bacteria from disinfection thereby stimulating their growth. The total hardness of the soap effluent (Sp) was very high (1300), likewise the Na and K levels. Although elevated levels of total hardness has not been shown to have any adverse health effects, high levels of Na and K have been implicated in different human diseases. Excessive Na in water has been associated with hypertension, although this is yet to be firmly established, while high levels of K is known to cause health defects in susceptible individuals (e.g. kidney dysfunction, heart disease, coronary artery disease, hypertension etc.) (WHO, 1996). However, the analyzed constituents do not by any means represent all or even most of the chemicals that could have been included in the test-samples. The heavy metals and metalloids components of the industrial effluents were not investigated. It is however well known that an effluent is a complex mixture of organic and inorganic chemicals and of many unidentified toxicants known as non-conventional pollutants (NCPs) which, either singly or synergistically, may pose risks of an unknown magnitude to humans.

Macroscopic analysis

The summary of the results of root growth analysis of *A. cepa* exposed to different concentrations of the industrial effluents investigated are presented in Table 2. The estimated EC_{50} values of *A. cepa* exposed to soap, beverage and paint effluents were 58, 84 and 52% respectively. The EC_{50} is used as a measure of potency. The results therefore indicate that the paint effluent is the most toxic while the beverage effluent is the least toxic. Statistical analysis (with analysis of variance - ANOVA), showed that there was a significant ($p<0.05$) difference in the mean root lengths of the test organism exposed to different concentrations of the soap, beverage and paint effluents. Generally, root growth inhibition analysis, using Pearson correlation, was observed to be positively correlated to concentration in all cases. Further Post Hoc analysis using Student Newman Keul's (SNK) test confirmed that root growth retardation was significantly ($p<0.05$) concentration-dependent, that is, high growth rate was observed with decreasing effluent concentration in most cases and vice versa.

Root growth inhibition occurs as a result of the inhibition of cell division (indicating toxicity) and it is thus an index for estimating general toxicity. It occurs when roots are exposed to a wrong pH, or to unsolved substances that may prevent nutrition uptake (Fiskesjö, 1993). The pH value of 5.34 obtained for the paint effluent is quite acidic for a living system and this could be responsible for the high toxicity of the effluent. The inhibitory effects can also be on cell extension, that is, cessation of root elongation which is correlated with the disappearance of mitotic figures. It has been observed that some mechanism associated with cell division is highly sensitive to certain chemicals or metals (such as those found in industrial effluents) and is permanently damaged by short exposures (Clarkson, 1965). Thus, the root growth analysis results indicate that all the effluents investigated had cytotoxic effects on the roots of the test organisms although statistical analysis of the mean root growth of *A. cepa* exposed to the different effluents did not show any significant ($p<0.05$) difference.

Microscopic effects

The cytological analyses of *A. cepa* roots exposed to different concentrations of the industrial effluents examined are presented in Table 3a-c. When compared to the negative control value of 40.3%, there was a statistically significant ($p<0.05$) decrease in mitotic index (MI) with increasing effluent concentration in the onions grown with the three effluents investigated. The

Table 3. Cytological effects of the three industrial effluents on *A. cepa* root cells.

Conc. (%)	No of dividing cells	Mitotic index (MI)	Mitotic inhibition (%)	Stickiness	Laggards	Bridges	Fragment	% Freq. of aberrant cells (±SD)
Soap effluent								
Control (0)	403	40.3	0.0	0	0	0	0	0.00 ± 0.00
25	320	32.0	20.60	0	1	2	2	1.56 ± 0.10
50	238*	23.8	40.94	1	0	1	1	1.26 ± 0.60
75	173*	17.3	57.07	0	1	0	0	0.58 ± 0.05
100	104*	10.4	74.19	1	2	0	0	2.88 ± 0.90
Beverage effluent								
Control (0)	403	40.3	0.0	0	0	0	0	0.00 ± 0.00
25	296	29.6	26.55	0	1	1	1	1.01 ± 0.75
50	245	24.5	39.21	1	0	1	0	0.82 ± 0.45
75	206*	20.6	48.88	2	0	0	0	0.97 ± 0.05
100	185*	18.5	54.09	2	1	0	0	1.62 ± 0.82
Paint effluent								
Control (0)	403	40.3	0.0	0	0	0	0	0.00 ± 0.00
25	197*	19.7	51.12	1	3	1	1	3.05 ± 0.86
50	143*	14.3	64.52	0	1	1	0	1.40 ± 0.06
75	96*	9.6	76.18	2	1	0	0	3.13 ± 0.90
100	72*	7.2	82.13	4	6	1	0	15.28 ± 1.25

* Values are significantly different from control at p<0.05 (ANOVA).

mitotic index, which is estimated as the ratio of number of cells in mitosis and the total number of cells, is an indirect measure of cell proliferation and it is considered to reliably identify the presence of cytotoxic pollutants in the environment (Chandral and Kulshreshtha, 2004). The mitotic index thus gives an insight into the inhibition of cell division and it is observed microscopically by counting the number of cells in metaphase, which is an index of the meristematic cell.

Dose-dependent inhibition of the mitotic indices in the test organisms could be due to intracellular stress, including DNA damage, preventing cells from entering mitosis. It could also be due to a negative interference of the active substance contained in the effluents tested with DNA synthesis, microtubule formation, impaired nucleoprotein synthesis and reduced level of ATP to provide energy for spindle elongation, microtubule dynamics and chromosomal movements (Majewska et al., 2003; Türkoğlu, 2012). A mitotic index (MI) decrease below 22% of control causes lethal effects on test organism while values below 50% is sublethal and is called cytotoxic limit value (Sharma, 1983). Thus, the mitotic indices show that the effects of the effluents were sublethal at 25 and 50% concentrations in the soap and beverage industrial wastewaters but lethal at higher concentrations (75 and 100%). However, the effects were lethal at all concentrations of the paint effluent.

The microscopic analysis of the cells of *A. cepa* exposed to the test liquid showed that chromosomal aberrations were induced in the root tip cells of *A. cepa* exposed to the different industrial effluents at different concentrations and no aberration was observed in the control group. Most aberrations were observed in *A. cepa* cells exposed to the paint effluent (Pt) indicating that it is the most toxic of the effluents investigated (Figure 1a-c). Previous studies have strongly suggested that the polycationic character of polymeric paint components may underlie their cellular cytotoxicity (Roberts et al., 1996; Hoet et al., 2000). The variation of chromosomal aberrations with the different test liquids was however not dose-dependent. This is in agreement with Odeigah et al. (1997) but in contrast to the observations by Qian (2004) who reported that chromosome aberration increased with increasing effluent concentration. A possible explanation for the former is that with increasing concentration, and consequently increasing toxicity, there was an inhibitory effect on cell division. This might result in prophase arrest with the attendant decline in the observation of chromosome aberration (Odeigah et al*.,* 1997).

In general, chromosome aberration induction by the industrial effluents indicates their genotoxic effects. The genotoxicity of various types of industrial wastewaters

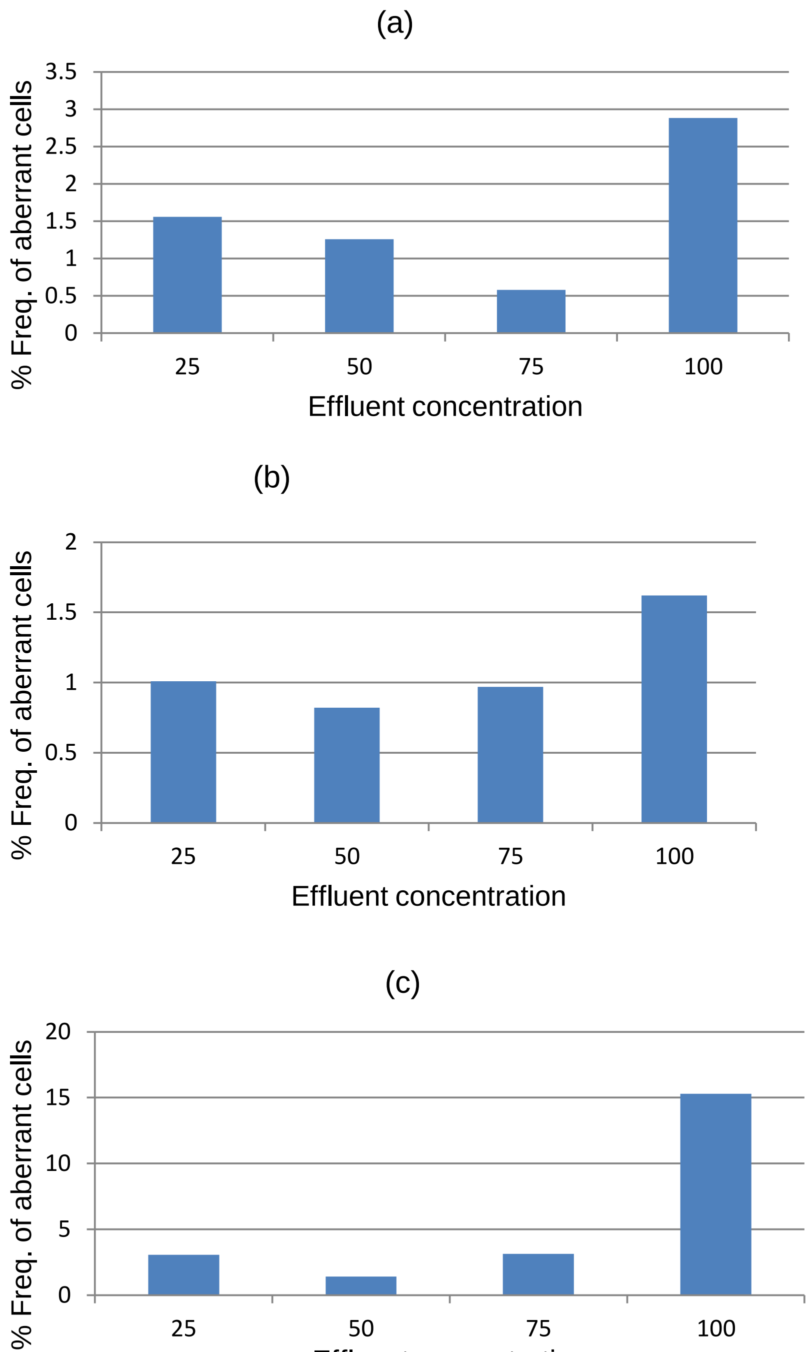

Figure 1. Histogram showing the percentage of chromosomal aberrations at the different concentrations of the three industrial effluents (a) Soap Effluent (b) Beverage Effluent and (c) Paint Effluent.

using the *Allium* test has been severally reported. Odeigah et al*.* (1997) reported the genotoxicity of oil field wastewater; El-Shaby et al. (2003) reported the genotoxicity of industrial wastewater from the Sandub area in Mansoura district in Egypt, while Babatunde and Bakare (2006) reported the toxicity of wastewaters from Agbara Industrial Estate, Nigeria. Olorunfemi et al*.* (2015) had also reported the toxicity of process water from Nigeria Agip Oil Company (NAOC) and Kannangara and Pathiratne (2015) reported the genotoxicity of textile

Figure 2. Chromosomal aberrations induced in *Allium cepa* by industrial effluents. (a) sticky chromosomes (b) disoriented chromosomes (c) bridge.

dyeing effluent and leachate from a tannery effluent. Hemachandra and Pathiratne (2017) also observed that raw water induced statistically significant root growth retardation, mitodepression and chromosomal abnormalities in the root system of plants. However, effluents were observed to provoke a relatively cytogenotoxic effects in *A. cepa* but toxicity in most cases was considerably reduced to raw water level with effluent dilution.

The most common cytogenetic aberrations observed were stickiness followed by laggards while other aberrations observed at various frequencies were bridges (Figure 2). Fragments were the least recorded. Chromosomal aberrations indicate the presence of certain cytotoxic or genotoxic substances in the industrial effluents investigated as no aberrations were observed in the controls (0%). The presence of sticky chromosomes indicate a highly toxic, irreversible effect which could lead to cell death while vagrant chromosomes are consequent of weak C mitotic effects indicating a high risk of aneuploidy (Fiskesjö, 1985, 1988). Many of the chromosomal aberrations induced by the action of various types of mutagenic agents might be due to the dysfunction of nuclear spindle (Fiskesjö, 1985). Structural chromosomal aberrations (such as bridges and breaks) are indicators of clastogenic actions; numerical ones (e.g. chromosome losses, delays, adherences, multipolarity and C-metaphases), are usually consequent of abnormal segregation while stickiness (that is, chromosomes without telomeres, fusing with other broken chromosome ends) may be induced by DNA breaks, inhibition of DNA synthesis at S-phase and replication of altered DNA (Metin and Burun, 2010; Glinska et al., 2007). Chromosome stickiness or adhesion as physiological aberration is a type of physical adhesion that involves mainly the proteinaceous matrix of the chromatin material and might be interpreted as a result of depolymerisation of DNA, partial dissolution of nucleoproteins, breakage and exchanges of the basic folded fibre units of chromatids, and a stripping of the protein covering DNA in chromosomes (Mercykutty and Stephen, 1980).

Conclusion

The results from the study show that the industrial wastewaters investigated were all toxic although to different degrees and thus their disposal constitutes serious pollutants to be reckoned with in the environment. It is therefore obvious that the discharge of the effluents into water bodies could lead to pollution of surface water and subsequently impair biolife. The results are also a clear indication of the reliability and high sensitivity of the *A. cepa* assay in the detection of genotoxicity of industrial waste waters because the test system provides information to evaluate action mechanisms of an agent about its effects on the genetic material (clastogenic and/or aneugenic effects). There is also a demonstration that in the *A. cepa* test, there is usually a relationship between growth retardation, mitotic indices and chromosomal damage (genotoxicity) (Olorunfemi et al., 2012). According to Samuel et al. (2010), the onion root growth inhibition test should be integrated in the whole effluent test (WET) program and a specified EC_{50} should be fixed as a condition to be met before the disposal of effluent into the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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