Aquaponics as a Sustainable Alternative to New Land Reclamation and Conventional Agriculture in Egypt

A Thesis submitted to the Graduate Program in Sustainable Development

The American University in Cairo

In partial fulfillment of the requirements for the Degree of

Master of Science in Sustainable Development

By

Hisham El Essawy

Under the Supervision of

Dr. Hani Sewilam

Professor, Mechanical Engineering Department and Director, Center of Sustainable Development, School of Science and Engineering

Fall 2017

ACKNOWLEDGMENTS

Prima facea, I am grateful to Allah for the good health and wellbeing that were necessary to complete this thesis. I feel so grateful to all the people who taught me that life is a marathon not a sprint, who make me learn that I never stop learning and working. I wish to express my sincere thanks to my mother who made me who I am now. I thank her for her continuous prayers, generosity and perseverance, Mehair Ezz El Arab I cannot thank you enough ever. I also thank my lovely beloved wife Maha Ragab, and my adorable sister May Samy El Essawy for their patience, love and unlimited support.

I would like to express my sincere gratitude to my advisor Prof. Hani Sewilam for the continuous support of my M.Sc. study and related research, for his patience, motivation, and immense knowledge. His guidance helped me during the research and writing of this thesis. I could not have imagined having a better advisor and mentor for my M.Sc. study.

A very special gratitude goes out to everyone at the Al Alfi foundation for helping and providing the funding for the fellowship, work and experiments for my M.Sc. study.
Besides my advisor, I would like to thank Dr. Ashraf Selouma and Dr. Peter Nasr for their insightful comments and encouragement, and unlimited support. My sincere thanks also go to the Center for Sustainable Development team in AUC, the team that I could not have finished my thesis without their help including Yomna El Awamry, Mohamed Khaled, and Nadine Gomaa, Ignacio Marcovecchio, Dr. Omar Elhosseiny and all CSD members in AUC.
My sincere thanks also go to my friends Iman Abaza and Basil Khattab, for helping and supporting me, and letting me know about this outstanding master degree program in AUC. Also thanks to all my friends in Maadi; May Khattab, Noha Korashy, Mai Sarwat and Yasser Shawki. Special thanks to the dearest Nathalie Roman for everything, also Riham Kabbani, Dr. Amr Sobhy, Dr. Heba Ahmed, Lobna Salem, Mostafa Abdel Fattah and my dears Shaza Adel and Nevine Bannouna for all the support and backup that they always give me. I want to thank the TriNex team in Montpellier, Aachen University, Bibliotheca Alexandrina, Cairo University, Alexandria University and of course my home, The American University in Cairo. Finally, I want to thank Rabea Gomaa for his outstanding efforts in the aquaponics' experiments and my dear Leo.

TABLE OF CONTENTS

Contents

List of Figures

List of Tables

CURRENCY EQUIVALENTS

Currency Unit	Egyptian Pound (EGP)
USD 1.00	= EGP 17.8
EGP 1.00	= USD 0.056

WEIGHTS AND MEASURES

1 kilogram (kg)	= 2.204 pounds (lb)
1000kg	= 1 metric tonne (t)
1 kilometre (km)	= 0.62 miles (mi)
1 metre (m)	= 1.09 yards (yd)
1 square metre (m^2)	= 10.76 square feet (ft^2)
1 acre (ac)	= 0.405 ha
1 hectare (ha)	= 2.47 acres
1 feddan (fd)	= 0.42 ha
1 feddan (fd)	= 24 kirat = 60 metre × 70 metre = 4200 square metres (m2)
1ha	= 2.38 fd
dS/m	deciSiemen per meter
Ppm	Parts per million
Meq/L	Milliequivalents of solute per liter of solvent
Mg/L	Milligram per liter
µS/cm	microSiemens per centimeter
mmho/cm	millimhos per centimeter

ACRONYMS AND ABBREVIATIONS

ARC	Agriculture Research Center
AUC	The American University in Cairo
B	Boron
BCM	Billion cubic meter
CAPEX	Capital Expenditure
CL	Chloride
CSD	Center for Sustainable Development
Cu	Copper
DWC	Deep Water Culture (Aquaponics system type)
EC	Electricity conductivity
Fe	Iron
GERD	Grand Ethiopian Renaissance Dam
GDP	Gross Domestic Product
HCO3	Bicarbonates
IAVS	Integrated Aqua Vegaculture System
IBC Tank	Intermediate Bulk Container - pallet tank
K	Potassium
Mg	Magnesium
Na	Sodium
NH3	Ammonia
NH4	Ammonium
NO2	Nitrite
NO3	Nitrate
OPEX	Operational Expenditure
P	Phosphorus
Ph	A measure of the acidity or alkalinity of water
QCAP lab	Central Lab of Residue Analysis of Pesticides and Heavy Metals
RAS	Recirculating Aquaculture System
RCFF	The Regional Center for Food & Feed
RSC	Residual Sodium Carbonate

SAR	Sodium Adsorption Ratio
SDGs	The Sustainable Development Goals
SO4	Sulfate
SWERI	Soil, Water & Environment Research Institute
TDS	Total Dissolved Salts
TriNex	Knowledge-Triangle Platform for the Water-Energy-Food Nexus
WEF Nexus	Water-Energy-Food Nexus
Zn	Zinc

Abstract

Agriculture in Egypt is facing dramatic changes that affect its productivity, and accordingly the Egyptian economy. Egypt started in the 1930s, expanding agricultural land through land reclamation projects. Many of these projects did not perform as expected or planned due to lack of water and other challenges. While land reclamation and conventional agriculture techniques have a lot of technical, social, and economical problems in Egypt; soilless agriculture and aquaponics are being successfully used in other regions for urban food production as a sustainable solution.

Aquaponics is a technique that integrates fish and crop productions by bringing aquaculture with hydroponics (soilless planting) together into one system. Although aquaponics has shown promising results in different regions worldwide, there are questions that need answering about the most suitable type of aquaponics for food production in Egypt.

Aquaponics have been investigated in this work in order to identify its potentials, hence recommend the suitable aquaponics systems for Egypt. The thesis shows that aquaponics is an ally or alternative to conventional agriculture and land reclamation in Egypt. In this thesis, two different Aquaponics systems were tested in an experiment, in the American University in Cairo, to determine which system design will be more efficient and productive for use in Egypt on a larger scale. The production and crops variety were more promising in the Integrated Aqua Aegaculture System than the Deep Water Culture aquaponics system. The elemental analysis results of water and plants samples, from both aquaponics systems, show that the Integrated Aqua Vegaculture system has more potential than the Deep Water Culture system, especially in Egypt under certain boundary conditions.

1 Chapter 1: Introduction

The population in Egypt, and across the world, is growing rapidly creating a real challenge for the food supply. Egypt was once referred to as 'the gift of the Nile'. More than 7000 years, the Egyptians developed the earliest, and one of the greatest cultures and civilizations, in the whole world. With recognized achievements in most disciplines of science, agriculture was among them. During the Roman era, Egypt was known as the 'bread basket' of the Roman Empire. Only very recently Egypt has become a living model of a developing country facing the challenges of land and water scarcity with a growing population (Kishk, 1993).

Despite this, Egypt began shifting towards industrialization in the 1950s (Szirmai, 2012), while the main source of the family's income remained agriculture. More than 50 percent of the population works in agriculture contributing up to 23 percent of the main national outcome product. Egyptian farmers are generally low-income families because they share unfairly in the national land resources (Kishk, 1993). Egyptian agriculture usage of fertilizers intensified as the fertility of the lands degraded significantly after the High Dam was established in Aswan in the 1960s (Shamrukh, Corapcioglu, and Hassona, 2001). However, fertilizers are not efficiently used. Egyptian farmers have at least 10 percent loss in the agricultural production annually due to the loss in soil fertility, and other inappropriate fertilization programs and policies (Kishk, 1993).

Nowadays, Egyptian agriculture faces even more challenges. Egyptian agriculture mainly depends on irrigated crops from the River Nile as shown in Figure 1. A high population and increasing water demands in a climate that is too dry are making it difficult for the River Nile to sustainably support crops.

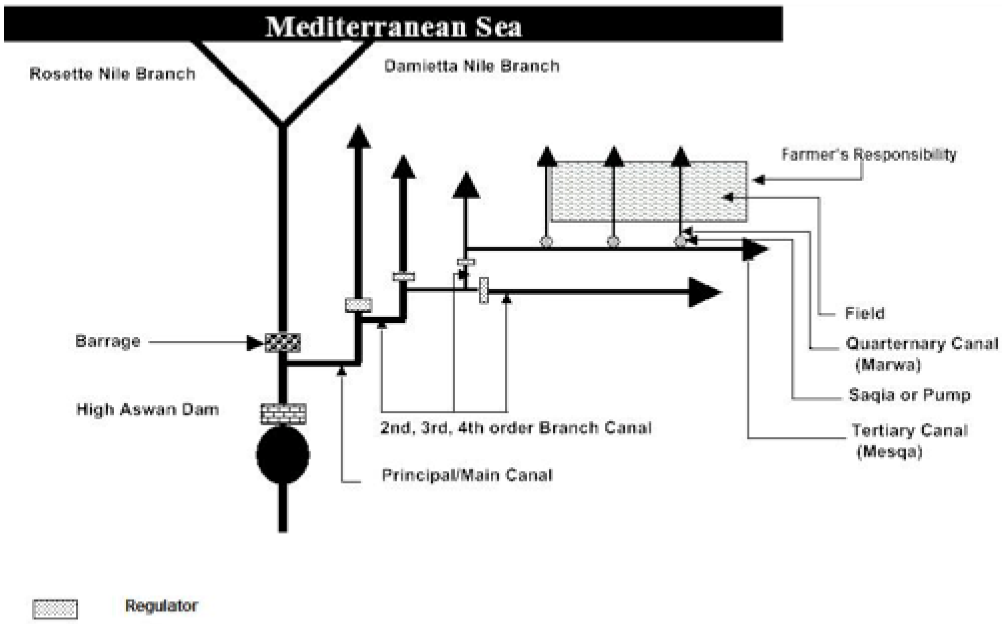

Figure 1: Schematic Irrigation System in Egypt (Radwan, 2013)

In 1987, Egypt initiated a study showing that land reclamation would provide innovative economic opportunities for youth through horizontal expansion, yet it appeared it might affect availability of resources both ecologically and economically (Adriansen, 2009).

Studies show the rise of sea level along the north coast will affect the Nile delta agricultural land because seawater leeches into the groundwater making it unsuitable for irrigating crops (Loutfy, 2010; Iglesias, Garrote, Flores, and Moneo, 2007). It is estimated that by 2100, the rise of sea level will damage Egypt's GDP by 0.25 percent with damage costs of above US$ 5 billion per year (Hinkel et al., 2012). Climate change will have huge effects on Egyptian water and agricultural use with increasing harm over time (McCarl et al., 2015). Nowadays, not only climate change, but also population and economic growth are affecting the availability of Nile River water in Egypt.

These factors, along with the increasing demand for water from the Nile basin from upstream countries (see **Error! Reference source not found.**) are imposing huge threat for the share per capita in Egypt. That was highlighted in the reopened negotiations with the upstream countries asking from their side decreasing the allocated share of Egypt that is currently 55.5 billion cubic meters (BCM) of Nile river water. Consequently, a conflict aroused between some of the upstream countries and Egypt, especially that Egypt is highly dependent on the river compared to upstream countries (Nigatu and Dinar, 2011).

The Ethiopians are now finishing the construction of the Grand Ethiopian Renaissance Dam (GERD) located on the Ethiopian and Sudanese border on the Blue Nile River. This is the main source of water for Egypt and Sudan. The GERD will become the largest dam in Africa and, with no specific, or declared plan for a reservoir-filling rate strategy; the phase of filling the reservoir will affect downstream flows to Sudan and Egypt. This becomes more complicated with climate change and water evaporation. There is a relationship between the GERD filling rates and how that impacts the water flow downstream to Sudan and Egypt. For example, holding 25 percent of the monthly river flow behind the GERD (see Figure 3) will cause an average 14 percent reduction of water flowing into Lake Nasser within the first five years of filling. Climate changes and evaporation may make the water loss worse (Zhang, Block, Hammond, & King, 2015). GERD is one of a series of dams Ethiopia is planning to construct, while Egypt is still struggling for its historical annual water quota from the Nile.

Figure 2: Map showing the Nile Basin countries, the course of the River Nile, the GERD, and other future Ethiopian dams (Zeinobia, 2013)

Figure 3: Illustration of the Grand Ethiopian Renaissance Dam (GERD) Dam ("No Progress on Egypt-Ethiopia Dam Negotiations", 2014)

Nowadays, Egyptian agriculture is facing significant challenges mainly due to its high dependence on irrigated crops, which are negatively affected by Egypt's dry climate, rising population and increasing water demands. In 2016, Egypt's population reached 94 million and the number is rapidly growing (The World Factbook — Central Intelligence Agency, 2016). Egypt's population inhabits 5.5 percent of the total land area, with 95 percent of the population living in Nile River valley and Delta (Heshmati and Squires, 2013). Egypt is 95 percent reliant on the Nile for water, with the remaining 5 percent sourced from groundwater and rainfall.

It is worthwhile noting that the Egyptian annual share of the Nile's water is fixed to at 55.5 BCM, based on a 1959 agreement with Sudan (Tortajada, 2008). At the time of the agreement, Egypt's population was 28 million people and that doubled in 1980; and, in 2011, it reached 82 million people (Khouzam, 2002; The World Factbook — Central Intelligence Agency, 2016). Additionally, Egypt's population is estimated to reach between 104 –117 million by 2030, and 113 – 162 by 2060 (EEAA, 2010) with the same

55.5 BCM share agreement of 1959 still in place (EEAA, 2010). This incremental population increase requires increase in the supply of water and food in Egypt. This affects Egyptian strategies to raise productivity per acre and increases desert reclamation, which causes a greater demand for irrigation water (Khouzam, 2002). Similarly, Egypt is at high risk of the negative effects of climate change (EEAA, 2010). Meanwhile the majority of Egyptian crops are irrigated from limited Nile water and lands in the Nile Delta face sea levels rises (Pérez et al., 2010).

Egypt now uses 77 BCM of water (55.5 BCM from the Nile and the rest from water recycling), 62 BCM of that is dedicated to the agricultural sector, 8 BCM for municipal use and 7.5 BCM for the industrial use. Conversely, Egypt is fully reliant on the Nile with its main supply of 55.5 BCM coming from there. Add to it an additional 1 BCM of deep aquifer and 1.2 BCM of rainwater, which are accounted for in the reuse of agricultural return flows and waste water (EEAA, 2010). In addition, only 4 percent of the total Egyptian land area is arable with nearly one quarter of that 4 percent is desert reclamation (El-Ramady, El-Marsafawy, and Lewis, 2013). This indicates the Nile River water is decreasing as a result of climate change (Beyene, Lettenmaier, and Kabat, 2010). Therefore, agriculture and food production in Egypt are in danger as the water supply decreases. Several studies examined the climate change negative impacts on Egyptian agriculture (Onyeji and Fischer, 1994; Conway, 1996; Yates and Strzepek, 1998).

This is a challenging situation and it is urgent for Egypt to identify new ways to best utilize water due to the current potential threat of reduced water resources, for a continuous growing population like that of Egypt. Part of the solution is to produce more crops per unit water (increasing water productivity) using modern food production methods such as aquaponics.

1.1 Research Motivation

Egypt is facing a steady increase in water scarcity, which seriously threatens the Egyptian food security. Geopolitical factors, population growth and climate change are all factors that stimulate approaching unconventional solutions to meet the challenge of providing food for future generations in Egypt. Soil and water contamination from traditional agricultural residues, fertilizers and heavy metals also pose a threat to the quality of crops and food production in Egypt. Therefore, as part of the search for unconventional solutions to the problem of food in Egypt, soilless agriculture represented in Aquaponics was a worthy alternative solution that presents itself strongly. Egypt can benefit from Soilless agriculture and Aquaponics, as Aquaponics can make a big difference by saving large quantities of water that are wasted from traditional irrigation methods in conventional agriculture. Auqaponics also produce organic crops, which contribute to solving the problem of food quality, offering export~~ing~~ opportunities and providing many lucrative and non-traditional jobs.

The high cost of Aquaponics poses a major challenge to spread this type of unconventional agriculture. Therefore, a practical experiment was required to determine which types of Aquaponics can be most suitable to contribute to solving the problem of food as an alternative to traditional farming methods in Egypt.

The experiment was carried out among one of the most widely known Aquaponics systems which is Deep Water Culture aquaponics system (DWC) and another customized Integrated Aqaua Vega-culture System (IAVS). This thesis is discussing a practical experiment that is conducted in the American University in Cairo (AUC) to find out which system is most suitable for the future of food production in Egypt in terms of quantity of production, multiplicity of crops' types produced, crops quality and consumption of water. Also to see which of the two systems is more economical in cost.

The significance of this thesis is that it attempts to provide the answers to the question: which kind of aquaponics design is more effective and efficient to use in Egypt? The outputs of both DWC and IAVS systems in terms of quantity and quality have to be considered. Also the characteristics of each system through chemical and bacteriological analysis of water, media and crops are to be considered. this work shows whether Aquaponics can be an effective alternative for land reclamation in Egypt to meet the challenges of water scarcity in agriculture.

1.2 Problem Statement

Because of the steady increase in its population, many geopolitical factors and recent global changes, Egypt is now facing a water scarcity problem that threatens its food security. Unconventional agriculture techniques such as Aquaponics may remedy this problem.

1.3 Aim of work and Research Context

The objective of this study is to determine unconventional alternatives to producing high quality food intensively, without depending on conventional agriculture techniques, using minimal energy and water. This concept can contribute to an increase per capita in people's incomes, without abusing existing natural resources or jeopardize the rights of future generations to Egypt's resources.

Growing crops and producing food without depending on soil (soilless agriculture) allows intensive production with less consumption of water and energy. This means urban areas can produce their own food, and will help to minimize the carbon and water footprints of these areas. Also, this concept can help people in other areas that face water scarcity, like the Egyptian eastern desert, western desert and Sinai produce more food, an export market for high quality food might be established then.

It is vital to search for other sustainable solutions to help solving Egypt's food problem. That is why aquaponics could be a good alternative to traditional farming methods. Aquaponics is a technology that combines fish and crop production using aquaculture and hydroponics (a method of soilless planting). It works using plants to filter waste products harmful to the fish from the water and using it as a nutrient source (Rakocy, Bailey, Shultz, &Thoman, 2004).

Nowadays aquaponics' systems exist as an application for unconventional agriculture and soilless agriculture either for research or commercial use. They are still not common in rural areas. This is somewhat because existing aquaponics systems require a large capital and operational expenditures. Finding new aquaponics technologies, designs, and techniques is necessary and this study contributes in a positive way to this challenge.

The context of this research is the application of aquaponics from concept, design, implementation, production process~~,~~ and results. This includes the variation of productivity and product quality through an experiment that compares two different aquaponics systems. One system is designed for testing and application specifically for Egyptian conditions. It is an efficient alternative to traditional agriculture, and uses minimal water and energy.

This study also considers the quality of the crops produced during testing two aquaponics systems. It then compares their results against each other, and then compares these aquaponics' crops with similar crops in the market. This is done by analyzing the main elements of each product including vitamins, heavy metals and pesticides residues.

1.4 Aquaponics and sustainability

Several food production methods are considered unsustainable, as per the three pillars of sustainable development. Aquaponics is considered an alternative agricultural method that can address sustainability by combining vegetable and fish production in a closed cycle system (Aguilara-Titus et al., 2014).

Minimizing the energy consumption and capital expenditure (CAPEX) of current aquaponic systems is a goal for researchers using locally available materials. Computer simulations using computational fluid dynamics (CFD), and utilizing alternative feeds, can be used to simulate more efficient aquaponics systems models.

The main goal is to design a sustainable and affordable aquaponics system using the available local materials easily located in developing communities, and to use recycled and recyclable materials. This can save up to 27 percent of the aquaponics CAPEX when compared to other systems of the same size (Nigam &Balcom, 2016). Using fluid dynamics software helps to identify the most efficient system setup. Simulating the flow through and throughout the system can help to decrease energy consumption by 40 percent (Nigam &Balcom, 2016). Using alternative nutrient sources with lower cost to supplement fish feed, will reduce the operational expenditure (OPEX) and the need for market access (Aguilara-Titus et al., 2014).

1.5 Aquaponics and the WEF Nexus

It became evident that Agriculture and food production is correlated with water and energy challenges. Water, Energy~~,~~ and Food (WEF) systems are interconnected together in a Nexus, and when these three systems intersect, this is what is called as a nexus (WEF Nexus) as shown in Figure 4. Actions related to any of the three systems can influence one or both of the other sources. Increased water demands of agriculture are a real challenge, as freshwater resources cannot always meet this demand. Energy and food generation are the main aim of the Nexus (Bizikova, Roy, Swanson, Venema, and

McCandless, 2013).

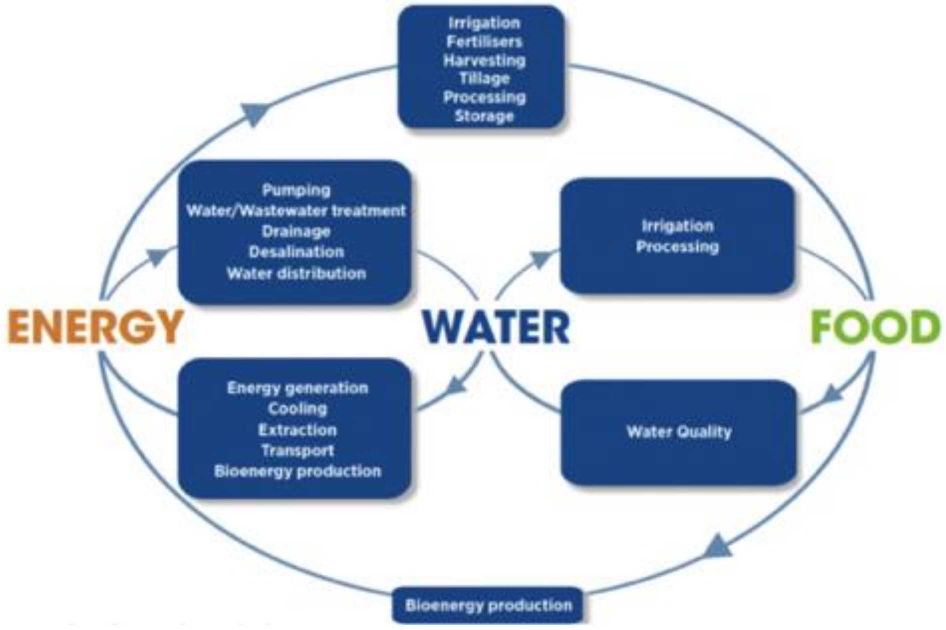

Figure 4: Illustration of WEF Nexus, adapted from (IRENA, 2015)

Aquaponics can be considered as a real application for the WEF Nexus. Aquaponics uses a closed water cycle with minimal energy consumption, which can be provided through renewable energy sources like solar energy to produce both fish protein and crops (Hanlon et al., 2013). Several food production methods are considered unsustainable, as per the three pillars of sustainable development (social, economical, and environments pillars). Aquaponics is an alternative agriculture method that can address sustainability by combining fish and plant crop production using a closed-loop system (Aguilara-Titus et al., 2014). The environmental pillar of sustainability will be tackled by minimizing the energy consumption and capital expenditures (CAPEX) costs of current aquaponics systems. The current goal for researchers is using local available materials. Computer simulations using Computational Fluid Dynamics (CFD) and utilizing alternative feeds can be used to simulate more efficient aquaponics systems models. This will tackle the economical and social pillar of sustainability by reducing the aquaponics CAPEX, creating new job opportunities and producing healthy organic food. Therefore, the main goal is to design a sustainable and affordable aquaponics system, by using the available local materials that are located in developing communities and can be recycled or made of recyclable materials to decrease the aquaponics' CAPEX. This can save 27% of aquaponics CAPEX compared to other systems with the same size (Nigam and Balcom, 2016). Fluid dynamics software helps identify the most efficient system setup, simulating the flow through and throughout the system to decrease the energy consumption by 40% (Nigam and Balcom, 2016). Using alternative nutrient sources with lower cost to supplement fish feed will reduce the OPEX costs and the need for market access (Aguilara-Titus et al., 2014).

1.6 Aquaponics for urban food production

Aquaponics help in urban agriculture, because they are closed cycle systems that fit into inside or outside of every home. Urban food and agriculture are becoming potential steps to enhance sustainability. Urban agriculture also promotes food systems that help the community's overall economic, social, environmental and nutrition aspects. The concept of urban food and agriculture also address key citizen issues like satisfying the fundamental need for healthy food, supports green economic goals, and strengthens community relationships (Hendrickson and Porth, 2012).

Urban spaces can have the capacity for commercial food production, which is a shift away from traditional farming in rural areas. Community gardening and weekend farmers' markets are trending now; and, therefore, architects and planners are addressing zoning changes to contain commercial applications for urban agriculture (Pfeiffer, Silva, and Colquhoun, 2015). Planners need to design urban agriculture land use guidelines, with training and educational programs (Howland, Kim, and Marks, 2012).

1.7 Research Questions

The specific research questions investigated in this research are:

- Is aquaponics an ally or alternative to conventional agriculture and land reclamation in Egypt?
- Which aquaponics system design will be more efficient and productive to be used in Egypt?
- What are the results of the water, chemical, elemental and crops analyses comparison between two different types of aquaponics systems' production?

2 Chapter 2: Literature review

2.1 Egyptian Land Reclamation for food production

According to the inherent limitations for Egyptian arable land, the Egyptian government has converted several desert land reclamation projects into agriculture production. The first land reclamation initiative started in the 1930s, and successive Egyptian governments are still working on land reclamation projects to the present day (Voll, 1980). Land reclamation efforts added 2.6 million feddans to the Egyptian agriculture land during the period from the 1930s to 2015, which is equivalent to a 44 percent increment.

In 2009, the Egyptian Ministry of Agriculture planned to reclaim an additional 3 million feddans by 2030. With political and economic instability by 2011, the plan was not implemented. However, in 2014, the Egyptian president Abdel Fatah Al Sisi declared the initiative of a 1.5 million feddans reclamation project, as a beginning of the previously planned 3 million feddans project. The 1.5 million feddan shall include agricultural industrial zones with integrated communities (1.5 million Feddan Project-SIS, 2016).

The Egyptian government has reclaimed an area of 10,000 feddans near Farafra, in the Western Desert, as a test. They drilled irrigation wells and planted crops on 7,500 feddans of the developed area. The next step in this project is to drill more than 5000 irrigation wells on the reclaimed land as 80 percent of the irrigation water will come from underground aquifers. Egyptian authorities plan to distribute 3 – 5 feddans as granted shares to young universities graduates using an agricultural cooperative organization to manage the project.

The project faces a lot of challenges; predominantly, the estimated costs for completing the project reaches as high as L.E. 37 billion (USD 4.7 billion), which affects the Egyptian economy. The second challenge is drilling, operating, and maintaining 5000 irrigation wells in harsh desert areas with tough conditions. This requires advanced technology and technical support. Consequently, this will have a negative impact on the sustainability of the underground water aquifers. The biggest challenge is that it is not clear how the land will be distributed, and who will be responsible for infrastructure and maintenance (Tate and Verdonk, 2016).

2.2 Land Reclamation Problems in Egypt

Major problems include the wrong use of reclaimed lands, the handiness of credit, land management, security, energy, qualified workers, high salinity, and poor drainage impacting negatively on land reclamation projects and the Agricultural National Product (ANP) (Hanna and Osman, 1995).

Land reclamation problems in Egypt can be listed in three main sections; technical, economic, and institutional challenges. Starting with the technical challenges, water resources are considered the most important aspect of land reclamation; accordingly, some studies propose applying water pricing in Egyptian agricultural economics.

Economic challenges are presented in the lack of investment in infrastructure for these projects, lack of foreign currency, and the inability to lure people from the Nile Delta and Valley into the reclaimed areas. One reason for this economic challenge is the land is already overpopulated and degraded due to urban uses. Secondly, the lack of money by new graduates who have to fully use their lands, the thing that affects their productivity.

Institutional challenges include a lack of coordination between water and land management authorities, vibrant implementations weakening and delaying projects' accomplishments, inefficient loan repayment programmes for investors, and the absence of an accurate database from executive authorities (Hanna and Osman, 1995). Over 70 years, Egypt's population has increased 300 percent (Monica, 2000). While the reclaimed land areas did not increase enough to meet the country's needs. This overpopulation requires better processes for reclaiming land~~,~~ ; water quality and quantity, irrigation systems, and new cropping methods.

The priority in the upcoming years should be focused on maximizing the returns from new reclaimed lands. Currently, the reclaimed land total area reached 1.9 million feddans, which represents 25 percent of Egypt's cropland. However, agricultural production from reclaimed land does not exceed 7 percent even with big investment from the government and private sector (Hanna and Osman, 1995).

2.3 Future of Agriculture in Egypt

While starting a new era, Egypt's main challenges are related to green economy, human development, and innovation (Browne, Di Battista, Geiger, and Gutknecht, 2014). For this reason, Egypt proposed its Sustainable Development Strategy (SDS) 2030 vision for an economy based on diversification, innovation, and knowledge to improve the quality of life for all Egyptians. Economic development, market competitiveness, citizens' happiness, and human development are the main goals of the SDS (SDS Egypt 2030, 2016). The SDS 2030 has a deeper focus on the agricultural becoming involved in vertical development to increase production per unit on 'old land' and horizontal development of 'new reclaimable land in the desert' (SDS Egypt 2030, 2016).

To support the government's 2030 objectives, sustainable agriculture can play an important role for the Egyptian green economy in ensuring efficient outputs from vertical and horizontal developments ("UNEP Year Book 2012", 2012). It opens the door for organic agriculture that can deliver sustainable and cost-efficient food production systems. Organic farmers enjoy better prices for their crops and a guaranteed market. Also, organic methods of production are better for a farmer's health as it avoids chemicals and creates employment opportunities (FAO, 2015). One percent of the total farming land in Egypt is devoted to certified organic farming, and it is showing significant growth in recent years.

A way to promote organic agriculture in Egypt is adding the negative costs to the cost calculations for agriculture such as penalties for polluters. On the other hand, there are currently no generic water prices for agricultural usage in Egypt. In turn, this will not show the real distribution for the true costs of agriculture production. Real costs must have a clear vision considering the rights of the upcoming generations in having sufficient resources and livable environment in Egypt.

The debate is not to promote organic versus agriculture, rather to support the transition towards more sustainable agriculture. For instance, it is recommended to conduct more studies for other crops in Egypt. The studies should include more details related to cost drivers, especially water and carbon footprints. A better overview will be developed regarding the challenges that the Egyptian agriculture facing and the potential benefits for organic agriculture production in Egypt (Seada, Mohamed, Fletscher, Abouleish, and Abouleish-Boes, 2016).

Food security, poverty reduction, and rural development are ways to achieve larger goals that lead to economic growth throughout its social connections and multiplier consequences in the environment. The agriculture division, however, faces some critical challenges (Hanlon et al., 2013). Therefore, it is important to search for other sustainable solutions to help in improving food security; quality and quantity. In this paper, Aquaponics is the proposed sustainable solution.

2.4 Soilless agriculture, Hydroponics and Aquaponics

Aquaponics is a method that utilizes an unconventional approach of fish and crop production combining aquaculture with hydroponics. The plants filter waste products harmful to the fish from the system by utilizing them as a nutrient source (Rakocy, Bailey, Shultz, and Thoman, 2004). Current aquaponics systems exist as an application for urban food either for research use or for commercial use; still, they are not common in rural areas as a means of sustenance. The reason is that existing aquaponics systems require large capital operation and management expenditures, including electricity and processed fish feed. In accordance, researching aquaponics' new technologies, new designs and new techniques is highly required. Aquaponics' designs include commercial scales such as low budgets technologies versus high budgets technologies. It is important to choose the right scale and design of aquaponics to reach optimum results.

2.4.1 Hydroponics

Hydroponics refers to soilless medium plant production, and is where nutrients are dissolved in water directly so there is no need for soil. Normally, by adding soluble fertilizers to irrigation water on a periodical cycle, hydroponics provides a constant supply of nutrients to plant roots water as shown in Figure 5 (Hussain, Iqbal, Aziem, Mahato, and Negi, 2014). Hydroponic nutrients, such as calcium nitrate, are highly soluble in. Hydroponics is successful because of its particular concentration of mineral elements based on injected chemicals into the system's irrigation water to control the delivery of nutrients, water, and environmental modifications (Jr, 2016).

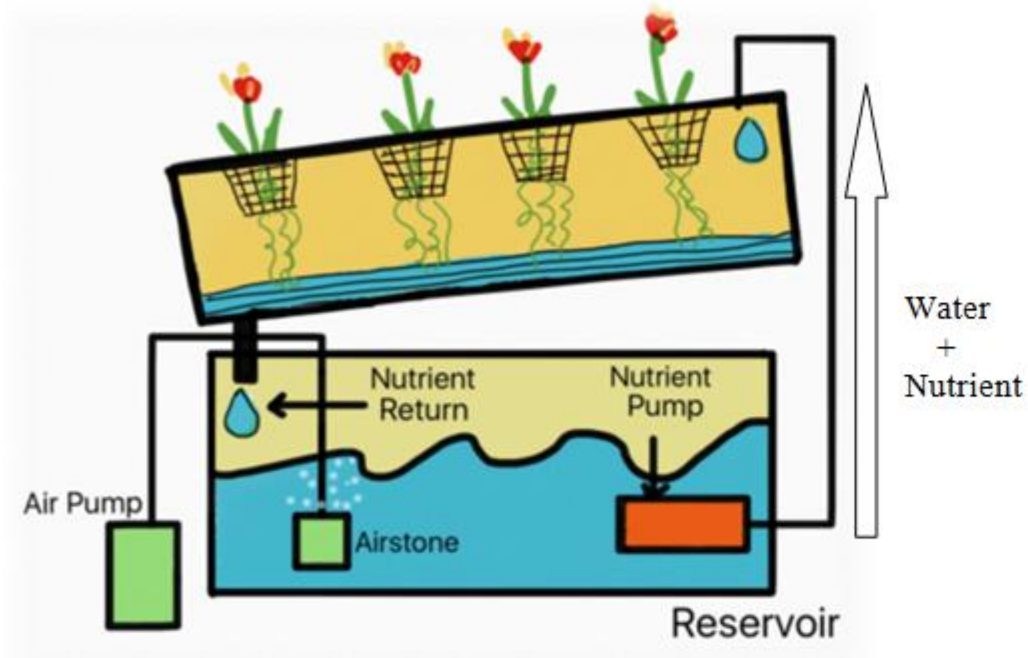

Figure 5 Hydroponics cycle diagram

2.4.2 Aquaponics

Aquaponics are bio-integrated systems that integrate aquaculture and hydroponics. Researchers and growers aim to turn the aquaponics into a real sustainable food production model because the waste from one biological system (fish) serves as nutrients for the other biological system (plants). Many different food products can be grown using a combination of plant and fish farming in an aquaponics system. Reusing water after mechanical and biological filtration and recirculation provides local healthy food that can support the local economy (Diver, 2006). Plant roots and rhizobacteria take nutrients from fish manure in the water and absorb them as fertilizers to hydroponically grow plants. In return, hydroponics acts as a biofilter stripping off ammonia, nitrates, nitrites, and phosphorus. Then, the water can be recirculated back, fresh and clean, into the fish tanks in a closed cycle as shown in Figure 6. The nitrifying bacteria multiplies in the gravel with the plant roots performing nutrient cycling. Nitrifying bacteria can live in different environments like soil, sand, water and air. The Nitrifying bacteria are the essential element of the nitrification process that transfers fish waste into suitable nutrients for plants.

Nitrification process is the natural process of nitrification by nitrifying bacteria that live on land or in water, converting ammonia from fish waste into the easily assimilated nitrate for plants to use. Nitrification process in aquaponic systems is the process that provides nutrients for the plants and eliminates ammonia and nitrite which are toxic for both plants and fish. The ammonia oxidizing bacteria (AOB) and the nitrite oxidizing bacteria (NOB) work on metabolizeing the ammonia from fish waste into nitrite (NO2-) by AOB bacteria then the NOB bacteria convert nitrite (NO2-) into nitrate (NO3-). Plants use nitrate (NO3-) as the main nutrient for its growth.

A closed water reuse cycling system is the most important role of the aquaponics system where it enables the production of fish protein and fresh vegetables in farms facing water limitations (Bernstein, 2011). Aquaponics also provides organic and sustainable food production by linking and integrating plant and animal agriculture by recycling of fish waste. In order to have a successful aquaponics enterprise, special training, skills, and management are required (Diver, 2006).

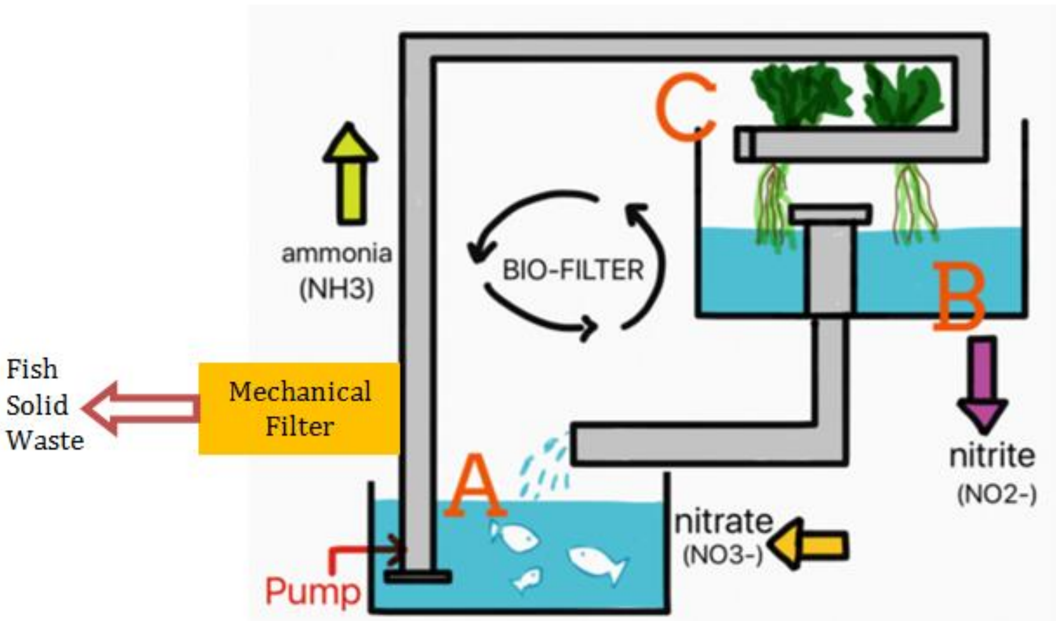

Figure 6 Aquaponics' cycle diagram

2.5 Plant, Fish, and Water Quality in Aquaponics

Plant selection in aquaponics is related to fish density in fish tanks and nutrient concentration. Lettuce, herbs, basil, and watercress are considered to have low nutritional requirements, while yielding fruit plants like tomatoes and peppers have higher nutritional requirements.

Several fish species have adapted to aquaponics. The Nile Tilapia (*Oreochromis niloticus*) is one species, which lives in warm water and grows well in an aquaponics fish tank culture. Nile Tilapia can also adapt quickly to different conditions of water such as temperature, pH, oxygen and other solids dissolved in water. Nile Tilapias are suitable to sell at local and wholesale markets.

Water testing kits from aquacultural supply companies are fundamental and crucial to test water quality including carbon dioxide, dissolved oxygen, nitrate, nitrite, ammonia, pH, chlorine and other characteristics (Diver, 2006).

2.6 Aquaponics system examples

There are also different types of aquaponics systems depending on the design and size required by aquaponics operators and investors as shown in Table 1.

Table 1 Types of Aquaponics systems (FAO, 2015).

Aquaponics Type	Method used	Usage
Deep water culture (DWC) systems	DWC involves plants in Styrofoam sheets that float over grow beds with air supplied.	DWC is the most common system for large commercial aquaponics growing one specific crop (like: lettuce, basil, and other leafy plants).
Media-filled bed systems (Flood and Drain Systems)	The media is used in grow beds to support the roots of the plants and for filtration.	These are the most popular design for small-scale aquaponics as they are efficient with space, relatively low cost, and suitable for beginners as they are ~~a~~ very simple in design.
Nutrient film technique (NFT)	NFT uses of plastic pipes laid out horizontally to grow vegetables. Water is pumped from the biofilter into each hydroponic pipe with a small equal flow creating a shallow stream of nutrient-rich aquaponic water flowing along the bottom. The pipe contains a number of holes along the top where plants are placed into to grow.	NFT aquaponics shows potential for custom aquaponics designs. While it ~~is~~ uses less water than the other two methods. But it is expensive and complicated.

In the DWC system (also known as raft system), the plants are grown on floating Styrofoam rafts in the grow bed tank. Grow beds, in this system, are tanks separated from the fish tank. Water flows from the fish tank, using gravity through mechanical filters and biofilters, to the grow bed tank where the plants are grown. The water is then pumped back to the fish tank.

In NFT systems, plants are grown in long narrow pipes. A thin film of water flows in each pipe after mechanical and biofiltration to provide nutrients and oxygen to the plants through plants' roots. The DWC system is more common for commercial size operations as NFT is more expensive, and there are problems with the clogging of small pipes and tubes.

A media-filled bed system uses a grow bed filled with gravel, perlite, or sand. Water is flooded periodically from the fish tank then pumped back to the fish tank after the plants absorb the nutrients. While in this system, all wastes including the solid wastes are used without filtration. Solid wastes are broken down within the plant bed. Media-filled bed systems also known as integrated aqua vegaculture systems.

.

2.6.1 Low-tech Aquaponics

Any existing aquarium can be transformed easily into a stand-alone herb production unit. The costs are very low and the process requires no special crafts, skills, or tools. Likewise, an aquarium can be manufactured from low cost materials with no additional special skills or tools required.

Using low-tech aquaponics systems allows people living in urban areas to get closer to nature and grow their own fresh herbs, leafy vegetables, and fresh fish protein with minimal production costs (Nicolae et al., 2015).

2.6.2 Small-scale Aquaponics

One of the best practices for producing organic food and vegetables at home in urban areas is a small-scale aquaponics system. It is a sustainable technology that requires minimal water and space (Menon, Sahana, Shruthi, and Suganya, 2013). It is a small unit that can be used indoors, placed on a terrace or integrated into the interior design of homes, offices, kitchens, and workspaces.

2.6.3 Micro Aquaponics

An innovative and simple design concept for a micro-scaled aquaponics system may pave the way for a new concept of eco-farming systems. Micro-scaled aquaponics aims to use the value of the residue in the water and transfer it through a combination of multidisciplinary efforts, such as simple low environmental impact technologies to become valuable end products (Khakyzadeh et al., 2015). This is a very small unit that can be used on the top of a desk or on a table indoors. It is portable and sets up the basis of sustainable farming.

New technologies, like wireless sensors, are used to control and remotely monitor aquaponics systems. These wireless sensors detect oxygen levels and pH parameters dissolved in the water. It is important to continually check the pH levels to ensure healthy growth conditions in both fish and plant tanks. The ammonia levels and water temperature can also be monitored; although, till now there is no developed working system for this purpose. Monitoring these parameters remotely is still difficult to control and requires further development. In addition, these systems can automatically feed the fish once being programmed in specific times (Guerrero, Edwards, Wan, and Sheth, 2013).

Testing the water in aquaponics is essential and can be done using water test kits. These are easy to use and available at an average price of US$ 10. Kits contain strips to use to measure the amount of ammonia and pH in the aquaponics water.

Other kits are used to measure nitrate. The individual and multi-parameter kits are still not the most accurate way for testing aquaponics water. It takes from 15 to 20 minutes to develop the color on the kit's strip to show the measures. Yet, these kits are cost effective if the time factor is not critical. Electronic sensors and meters used for testing water are considered accurate, but are the most expensive. Potentially, the cost can be reduced effectively by having many samples and frequent measurements. Still, electronic sensors and meters require calibration and special care from time-to-time. Alternatively, regular water test kits are considered enough for bench scale and backyard aquaponics (Klinger-Bowen, et al., 2011).

2.7 Aquaponics in Egypt

Aquaponics offers the opportunity for developing countries to produce animal protein and fresh vegetables. Aquaponics is a solution to meet multiplying food demands using simple production systems and limited supplies that utilizes animal waste to produce fish protein and fresh vegetables (Savidov, 2011). In Egypt, there is an opportunity in small-scale fish farming to generate income and provide protein rich food for many people all year-round. Small farmers, fishermen, and startups can benefit of aquaponics (Essa et al., 2008).

In 2011, aquaculture in the Egyptian desert covered more than 100 intensive tilapia farms in rural areas. Twenty farms are commercial aquaculture systems with an approximate annual production of 13,000 tonnes. There are various fish species that can be used in aquaponics in Egypt like Red Tilapia *(Oreochromis sp)* Nile Tilapia *(Oreochromis niloticus)*, flathead grey mullet *(*Mugil cephalus), North African catfish *(Clarias gariepinus)*, common carp *(Cyprinus carpio)*, silver carp *(Hypophthalmichthys molitrix)*, grass carp *(Ctenopharyngodon idella)*, European sea bass *(Dicentrarchus labrax)*, gilthead sea bream *(Sparus aurata)* and other species (Sadek, 2010).

Groundwater and agricultural drainage water are the main water source for aquaponics in Egypt, with range of salinity 0.5 to 26 g/liter, and temperature from 22° to 26° C. Fish fingerlings is sold in the local market at a price ranges between 300 to 400 EGP per 1000 fish fingerlings. Most farms buy fish fingerlings directly from local markets, while five farms established their own fingerling hatchery. Hatcheries are an example presenting development opportunities for commercial farms is highly related to the water quality and quantity, the availability and prices of fingerlings, fish feed quality and prices, capital expenditure, and operating expenditure (Sadek, 2010).

The success of aquaponics in Egypt is based on the fact that fish do not consume water. Fish farming is a clean production system, which offers more water to agriculture. There are some factors that assist in achieving success in aquaponics. First is the continuous application and assessment of the three pillars of sustainable development on the potential usage of water for desert based aquaculture production, either for fresh or brackish groundwater. Second, is calculating the water salinity tolerance and requirements for aquaponics. Pilot projects should be established for small-scale intensive aquaponics, and demonstrate these activities as opportunities for areas like the Central Sinai (Sadek, 2010).

Water scarcity is an important driver for hydroponic and aquaponic production in Egypt; yet, Egyptian consumers are still not fully aware that aquaponics is a sustainable alternative for water use. The main target groups for producers (until now) are high-end retailers and stores that are quality and service oriented rather than price oriented. Until recently, the main crops in Egyptian aquaponics were only leafy vegetables and herbs, while shifting to other vegetables like tomatoes as shown in Figure 7 and peppers appears more promising. There is a big opportunity for producing tomatoes that can be sold in small, medium and high-end retail shops (like Alpha market, and Saudi market) in areas like Maadi and Zamalek in Cairo (Soethoudt, 2016).

Figure 7: Pictures of tomatoes production in a small-scale aquaponics in New Cairo, Egypt.

2.8 Feasibility of Aquaponics versus Land Reclamation in Egypt

Land reclamation and conventional agriculture's capital expenditures (CAPEX) and operational expenditures OPEX depend on the land location, status, soil salinity, and availability of water and irrigation methods. Agriculture lands differ in fertility, and this will affect the CAPEX and OPEX because the land price will differ. Location is an important aspect that affects land's price either for ownership or for rent. Some lands are more saline than others and this need more efforts and CAPEX for agriculture production. Using chemical fertilizers and soil conditioners also increases the OPEX. Water availability for irrigation is another important aspect, as some lands are near to running water sources for irrigation and this affects the lands' prices by making it more expensive. Using irrigation pumps, the fuel that will be used by pumps and maintenance fees will be also added to the CAPEX and OPEX. Other lands do not have a direct access for running water source so in that case the owners will have to dig water wells for irrigation. The CAPEX for digging water well is exceeding EGP100000 (Gomaa, 2017). The water salinity of water wells varies, and the need to maintain the wells also affects the OPEX. Drip irrigation network cost and its' maintenance should be added to the CAPEX and OPEX of reclaimed lands.

Land rent price for agriculture uses varies from EGP3000 to 6000 / year per feddan due to the above-mentioned reasons. These rent prices apply for land reclamation and Aquaponics lands. The only different is that Aquaponics do not require any specific land qualities, as Aquaponics can be installed in rocky lands, saline lands, and any land type that is not even fertile or able to be used for agriculture production, while Aquaponics' crops will be also organic despite the lands status, as there is no use for chemical fertilizers, nor pesticides (Hassanen, 2017). Putting all that in consideration, it is estimated that land reclamation's CAPEX is around EGP 185,000 per feddan (Abou

Amra, 2015). While land reclamation OPEX is estimated to be EGP 4,000 / year per feddan (Hassanen, 2017).

Aquaponics' CAPEX and OPEX depend more on the Aquaponics scale and design; the bigger the Aquaponics scale the less CAPEX and OPEX. The Aquaponics' CAPEX for 1 feddan costs around EGP40 / m^2 for Plant beds and EGP 12/m^2 for Greenhouse roof. Pipes and hoses cannot be estimated as it varies from a design to another, but for example of a 1 feddan production unit, piping costs around EGP33,000, or EGP8 / m^2. Pumps CAPEX depend on the design, with estimated starting cost of EGP10000 plus an average of EGP5,000 for every 500 m^2 of plants, and other air pumps cost an average of EGP10000. Top quality fish feed of 32% protein cost ranges between EGP8500 to 9,500 per ton, but about half this price can be reduced in case of manufacturing the fish feed locally, Fish costs EGP 300 per 1,000 fingerlings of 7-10 gm. weight. Electrical fittings are dependent on the design. Yet, it is an expensive component and it correlates with the number of machines and devices that are included in the Aquaponics. Normally, electricity installation costs could reach up to EGP 100,000 - 120,000 per Feddan, or approximately EGP310 per meter square.

Overall CAPEX for a well-equipped Aquaponics module can cost up to EGP1.3Million per feddan with a capacity of 90,000 net cups and around 11 tons of fish in the system (Hassanen, 2017).

Aquaponics' OPEX mainly depends on the system design. For example, water capacity of the first fill in the Aquaponics system is estimated to be 0.23 m^3 for each m^2 of plants, substituting from 5 to 7% of the water capacity per week, and this depends on the agriculture practice, system design and weather conditions. Water cost is 600 EGP per month and the effective maximum capacity of water to be withdrawing 1500 - 1800 m^3 per month which results in a cost between EGP 0.4 per m^3. Electricity consumption depends on the Aquaponics design; estimated total electrical load is around 50 kW or 8000 kWh per month. Seeds depend on the crop type, origin, supplier, and specifications such as coating, bread, genetic properties/resistance...etc. One premium seed can cost anywhere between EGP 0.01 - EGP 0.15. Overall OPEX for a well-equipped Aquaponics module can cost up to EGP17,500 per feddan per month (Hassanen, 2017).

The following Table 2 summarizes the CAPEX and OPEX for aquaponics farm in Cairo Alex desert road in Egypt on 400 m^2 area. It shows that the CAPEX in 400 m^2

Aquaponics is higher than that for 1 feddan because the larger aquaponics scale the less CAPEX and OPEX.

Table 2: CAPEX and OPEX for Aquaponics farm in Cairo Alex desert road in Egypt on 400 m2 area (Gomaa, 2017)

Aquaponics' CAPEX and OPEX (area 400 square metre)				
Serial	Item	Qty	Price (EGP)	Total (EGP)
CAPEX				
1	Tank (Fiber Glass) capacity 3.5 m³	2	12000	24000
2	Mechanical filter Capacity 2 m³	2	3000	6000
3	Construction for Graw beds / installation fees	5	2000	10000
4	500 micron vinyl	350 square metre	30	10500
5	styrofoam thickness 2-3 cm	6 m³	1200	7200
6	Air pump 1 horsepower	2	3000	6000
7	Submersible pump 1 horsepower	1	2000	2000
8	Green house + winter shade(200 micron 40m x 9m + summer shade	1	40000	40000
9	Net cups 9 cm	9000	1.25	11250
10	plumbing and piping / water supply		30000	30000
11	Electricity control panel and connections		10000	10000
12	installation fees		10000	10000
Total CAPEX				**166950**
OPEX / year				
1	pittmoss + perlite + sponge	10+10+100	5000	5000
2	plants seeds		5000	5000
3	fish feed (protein 30%) + transportation	1 ton	8400	8400
4	bio supplemtents	6 kgms	1000	1000
5	Insects and inficttions bio fighters		1000	1000
Total OPEX / year				**20400**
Total CAPEX and OPEX for the first year				**187350**

Table 2 shows the total Aquaponics CAPEX / square meter = EGP418 / m^2, total Aquaponics OPEX / year / square meter = EGP51 / m^2 and the total Aquaponics CAPEX and OPEX for the first year / square meter = EGP469 / m^2. Upon initial review CAPEX and OPEX of this aquaponics considered very expensive compared with land reclamation for the same area. Therefore, Table 3 shows CAPEX and OPEX comparison between Aquaponics and reclaimed lands per feddan. This table eliminates land rent or ownership costs from both Aquaponics farms and land reclaimed farms. The comparison also illustrates the estimated profits from lettuce farming in Aquaponics farms vs. land-reclaimed farms per feddan. The Aquaponics production of lettuce lies between 90.000 - 120.00 lettuces per feddan, average of 30 lettuces per square meter. While the conventional agriculture or land reclamation production of lettuce is 30,000 – 40,000 lettuce per feddan with average of 9 lettuces per square meter. The Aquaponics' lettuce production sales in winter for mass market is approximately EGP5 per one lettuce, and in summer the selling price reaches EGP 10 per one lettuce. The Aquaponics' lettuce is considered organic and is sold mainly to niche market, while lettuce production sales from conventional agriculture and land reclamation in winter is EGP 1 per one lettuce and in summer for EGP 4 per one lettuce. Lettuce production in reclaimed lands is better to be one time per year in winter season, as 1 feddan produces 30,000 – 40,000 lettuce, and needs from 3 to 4 months to be harvested, while in Aquaponics it takes from 30 to 45 days for harvesting the lettuce, without maximum times per year (Zaki, 2011). Fish is a byproduct of the Aquaponics' lettuce production comprising almost 11 ton / year. Nile tilapia price per kilo in mass market is in the range of EGP18-25 depending on quality. Fish from Aquaponics is organic and the price is around EGP20 /kg. Fish profit reaches EGP220,000 per year per feddan. The table shows the total profit of the aquaponics after deducting CAPEX and OPEX in the first year per feddan is EGP4.8 million, and total profit in the following years is EGP6 million per year per feddan. While the total profit of land reclamation after deducting CAPEX and OPEX in the first year per feddan is EGP31,000, and total profit in the following years is almost EGP200,000 per year per feddan. Despite that aquaponics' CAPEX and OPEX are very expensive, yet the table shows that aquaponics are much more profitable than land reclamation in Egypt.

Table 3: CAPEX and OPEX comparison between Aquaponics and reclaimed lands per feddan.

1 feddan	Aquaponics	land reclamation
CAPEX per feddan	EGP1,300,000	EGP165,000
OPEX per feddan / year	EGP214,200	EGP4,000
Lettuce Production / per one harvesting time per feddan	90000	40000
lettuce price in winter per unit (mass market price)/EGP	EGP4	EGP1
lettuce price in summer per unit (mass market price)	EGP10	EGP4
times of harvesting / year (per feddan)	10 times/ year	2 times per year
total lettuce production / year (per feddan)	900K unit	80K unit
total lettuce production in winter (per season "6 months") per feddan	450000	40000
total lettuce production in summerr (per season "6 months") per feddan	450000	40000
total lettuce sales in winter (per season "6 months") per feddan	EGP1,800,000	EGP40,000
total lettuce sales in summer (per season "6 months") per feddan	EGP4,500,000	EGP160,000
total lettuce sales / year (per feddan)	EGP6,300,000	EGP200,000
Total profit after deducting CAPEX and OPEX in first year	EGP4,785,800	EGP31,000
Total profit in the next years / year	EGP6,085,800	EGP196,000

2.9 Integrated Aquaponics systems

The term aquaponics involves converting fish waste into nutrients to be used by plants. Aquaponics is a soilless agricultural solution and concept that helps to provide high food quality. While a wide range of vegetable crops might not be easily produced, or might not be produced at all using aquaponics as a soilless agriculture method. Aquaponics is perfect for producing leafy vegetables, but other vegetable crops cannot be productive in soilless plant beds.

Aquaculture and its integration with agriculture is not a new technology. It has been traced back into the ancient history of several cultures and nations such as Egypt and China 5000 years ago (Jones, 2002). In the last twentieth century, a lot of developments have been applied to increase the number of species and production levels through the integration of aquaculture and controlled environments for vegetable production. The technique of integrated aquaponics systems is not new. It offers more benefits than a normal aquaponics system has by itself. There are two main methods that today's aquaponics systems follow:

1. First is using water plant beds and a floating raft system or the DWC.

2. Second, is the integrated aqua-vegaculture system (IAVS), which started as a concept in the 1980s using sand in plant beds to grow plants or with plants growing in gravel or other non-soil medium as shown in Figure 8. Some

commercial systems today are starting to integrate both systems.

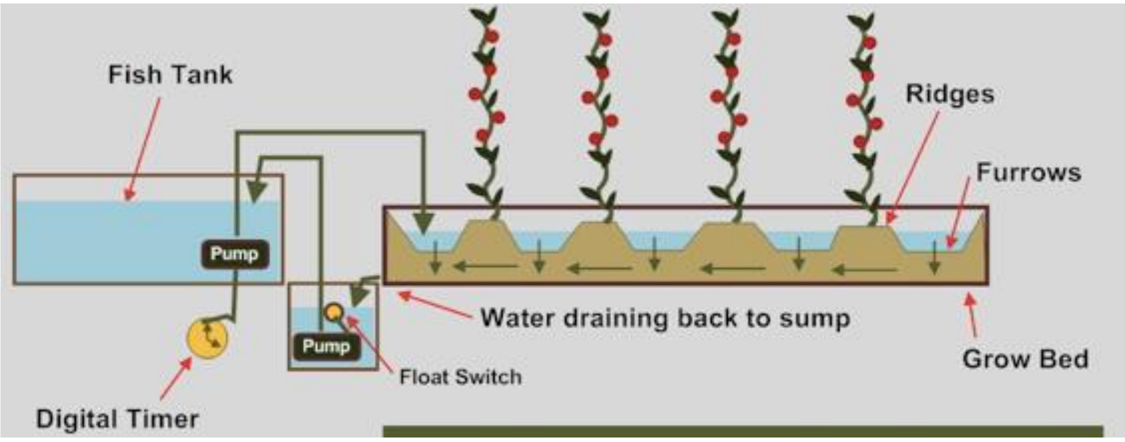

Figure 8: Adapted from (“IAVs Layout Options | IAVs,” 2017)

DWC aquaponics and IAVS aim for the same goal to produce more food faster, while the differences between the two methods are that DWC mixes hydroponics and aquaculture using water plant beds covered with floating foam panels. These hold net pots that allow plant roots to extend through into the water to absorb the nutrients in the water (either purchased nutrients or natural nutrients from fish waste, or even both). The water must be aerated to grow plants. A pumping system, mechanical filters and biofilters are used to refine fish waste to contain the correct nutrients for the plants need. The water passes onto the plant beds and is then pumped again to the fish tanks once the plants absorb the nutrients.

While IAVS is considered simpler as the fish tanks are beside the plant grow beds that do not contain water. The grow beds contain other growing media like sand, gravel or any other small mineral particles with a wider and bigger surface area. Grow beds also work as biofilters so there will be no need for a stand-alone biofilters like DWC.

Sand in the IAVS will work as a mechanical filter and it is one of the best mechanical filtration systems in terms of cost effectiveness and efficiency. Sand is widely used today for the same reason in different industries such as pool filters. In IAVS aerobic bacteria is more likely to grow than in DWC. The beds are lines with plants directly planted into the media (eg. sand) without net pots. Fish tank water flushes directly onto the plant bed surface for the plants to absorb the nutrients and then pumped again to the fish tanks. There are no filters, foam panels, net pots or plant grow bed aeration, which means less CAPEX and also less OPEX.

DWC and IAVS have similarities, as each system is a form of recirculating aquaculture system (RAS). Each system relies on the nitrification process of the aerobic bacteria that transfers Ammonium (NH_4) or Ammonia (NH_3) from fish waste by Ammonia oxidizing bacteria into Nitrites (NO_2) then Nitrates (NO_3) using nitrite oxidizing bacteria to become useable nutrients for plants. Also both systems rely on fish waste, which means that fish food is the main nutrient input. They also rely on an aeration system to enable the growth of aerobic bacteria that transforms fish waste into useful nutrients for plants. DWC and IAVS can produce yields of vegetables and fish and both system rely on the existing technologies of plumbing, plastic tanks, water pumps, and other readily accessible equipment.

The main differences between both DWC and IAVS systems are:

The DWC system needs more labor to clean its filters and deal with the excess solid fish waste. There is also the potential for equipment failure and the need for further skills. Adding all these factors together means that the system is less scalable and of a higher risk for investors. In spite all these disadvantages, the DWC system is considered very successful in producing fish and vegetables compared to traditional hydroponics. However, the world's technology in sustainability is moving towards simpler systems with higher outputs in production.

IAVS is simpler with a lower technology concept, as it is closer in design to the natural ecosystem in wetlands. Using one pump, it is possible to create a lower budget system. Even larger, commercial IAVS systems are built with the same simplicity, as there is less cost in implementing the system and it allows for more creative solutions in the fish tanks such as water heaters for the fish in winter and making suitable constructions for plant grow beds and both the DWC and IAVS can use high-end solutions for remote monitoring.

IAVS is expected to result in greater yields with less risk. Also IAVS has been used mainly for small-scale growers, while it has a potential for success on a commercial scale.

There are great opportunities for innovation in the IAVS and other integrating aquaponics systems. With a properly designed system, investors and operators can have amazing yields' results compared to basic aquaponics systems that currently used. Aquaponics generally continues to develop into a real commercial industry, which is why it is so important to evaluate and discuss its standards (McMurtry, Nelson, Sanders, and Hodges, 1990).

3 Chapter 3: Research Methodology

3.1 Research Design

The research methodology is using quantitative methods. The following represents the process followed in the research in order to meet its objectives and ~~to~~ answer the research questions:

- Summarize and synergize existing literature on Aquaponics and IAVS.

- Determine the required resources for starting an experiment of installing two systems; first one is a Deep Water Culture Aquaponics system (DWC) and an Integrated Aqua-Vega culture System (IAVS) in The American University in Cairo (AUC).

- To test variables being measured, both systems were designed similarly as regards to the number of plants and fish, amount of food, and external environment. Fish were of the same weight and plants were of the same kind. These are the controlled variables of the experiment.

- Dependent variables being measured are crop variation, quality, quantity, and growth of plants and fish in both systems. Variables will be measured by performing a comparative study between both DWC and IAVS systems. Also variables will be measured by chemical, elemental and Bacteriological water analysis for both DWC and IAVS systems before and after the experiment. Elemental sand analysis will be also measured in IAVS before and after the experiment. Elemental, chemical, pesticides residues and heavy metal analysis of crop will be done to Molokheya crops in both systems and results will be also compared with another source of organic Molokheya from the market. Vitamin A – beta carotene analysis will be measured in Molokheya from both DWC and IAVS systems and will be compared with another source of organic Molokheya from the market.

- Discuss the experiment assessment results and present a list of recommendations.

3.2 Research subject

This research is comprised of several phases. The first phase is a review of Egyptian conventional agriculture and land reclamation procedures, focusing on new challenges such as the rapidly increasing population and climate changes. Water-Energy-Food nexus is presented as a real solution for these challenges, through new food production techniques via soilless agriculture and integrated systems. The second phase was associated with understanding the methodology and structure of the study for performing a comparative analysis between DWC and IAVS selected systems. The basis of the comparative analysis is to explain the comparative experiment results. The results of this analysis include issues that other researchers should take into consideration based on local context and conditions. The final stage, which is the outcome of this research, is a list of recommendations and suggestions to the upcoming researchers in the field of soilless agriculture, Aquaponics and other unconventional agricultural methods.

3.3 Comparative experiment between DWC and IAVS Aquaponics systems

The main objective of this experiment is to compare the productivity variations, and quality of DWC and IAVS systems in a lab scale experiment in the AUC. Both DWC and IAVS systems were designed and implemented with the same proportions, dimensions, surroundings, and conditions. They had the same inputs and amounts of plants and fish. The results from both systems were analyzed and compared to determine which system is more efficient, economic, and productive producing higher quality products. The following Figure 9 shows the experiment location in AUC.

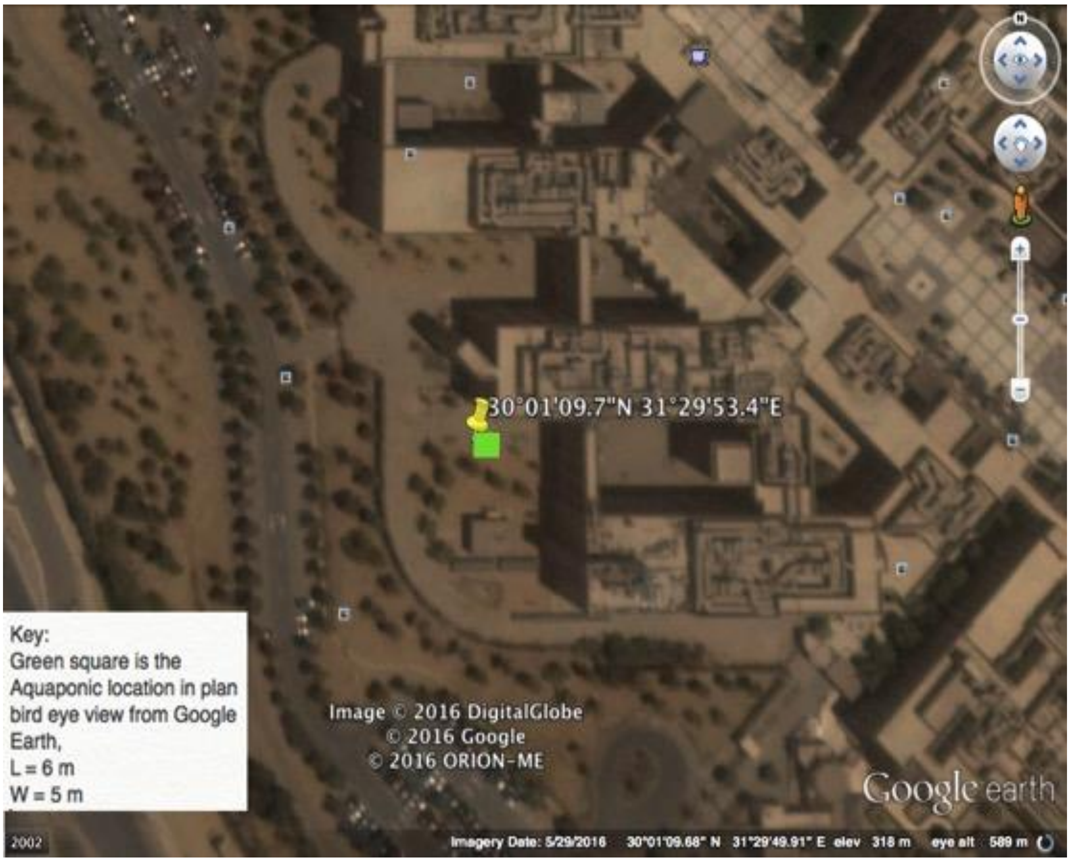

Figure 9: Satellite map from Google earth shows the location with altitudes and latitudes for the lab scale DWC and IAVS experimental systems in The American university in Cairo.

3.4 Materials and methods of the experiment

The DWC system method uses plastic net cups set into holes in Styrofoam floating rafts. These hold the plant seeds using gravel. Styrofoam floating rafts cover and float on top of the water over the grow bed in the tank. The tank is 4.2 m long, 1.2 m wide and 0.35 m high. Panels of yellow pine wood are used to construct the grow bed. A double layer of vinyl was applied to the wooden grow bed from inside to pad it to a thickness of 500 microns for the one layer. This makes the wooden grow bed waterproof.

The water grow bed is attached to a fish tank made of simple plastic materials such as IBC tanks. Tanks are put into a stainless-steel cage to prevent the deformation of the plastic due to the weight of the water as IBC tank holds 1 Ton of water and fish per 1 cubic meter. The DWC system is using a mechanical filter made from blue plastic barrel with capacity of 200 the solid liters to remove waste from water. The nitrification process works in DWC by transforming the ammonia in the water from the fish waste into nitrates that are the main source of plant nutrients. Water flows from the fish tank to the water grow bed using gravity.

The DWC system also has a submersible water pump for recycling the water through the whole system, and an air pump to provide the fish and plants with oxygen through rubber tubes and air stones. Another water collection container is used under the water grow bed. It collects the water that comes out of it and pumps it to the fish tank using the submersible water pump in a closed water cycle. The water-collection container is also made of wooden yellow pine panels and measures 3.8 m long, 1 m wide and 0.4 m high. It is also padded with a double layer of vinyl with a thickness of 500 microns as shown in Figure 10, Figure 11 and Figure 12. The submersible water pump can pump 2000 liters of water per hour, which can circulate the water in the system twice per hour.

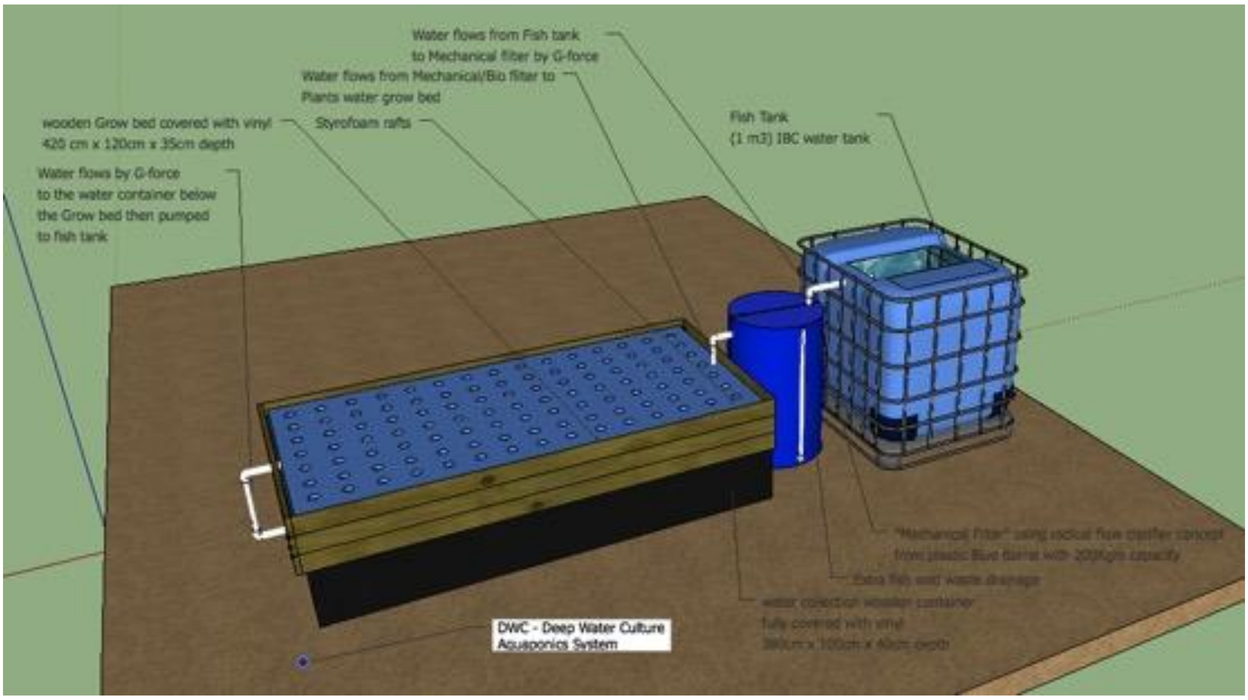

Figure 10: Perspective of the DWC Aquaponics system used in the AUC experiment.

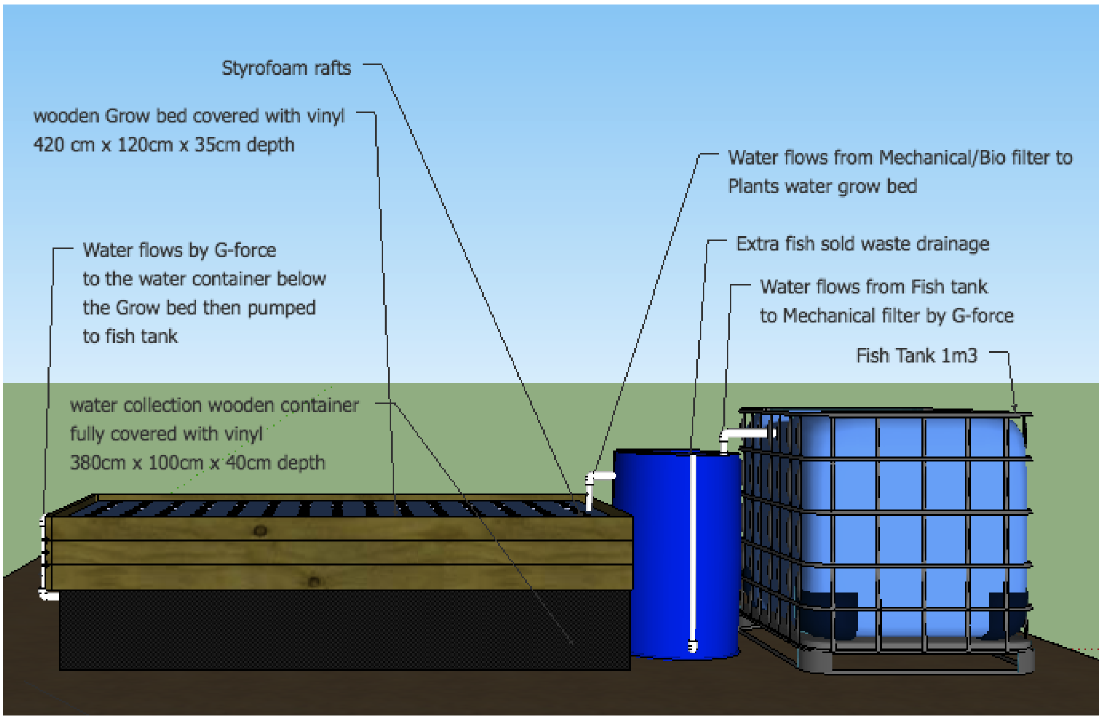

Figure 11: The DWC Aquaponics system used in the AUC (side view) experiment.

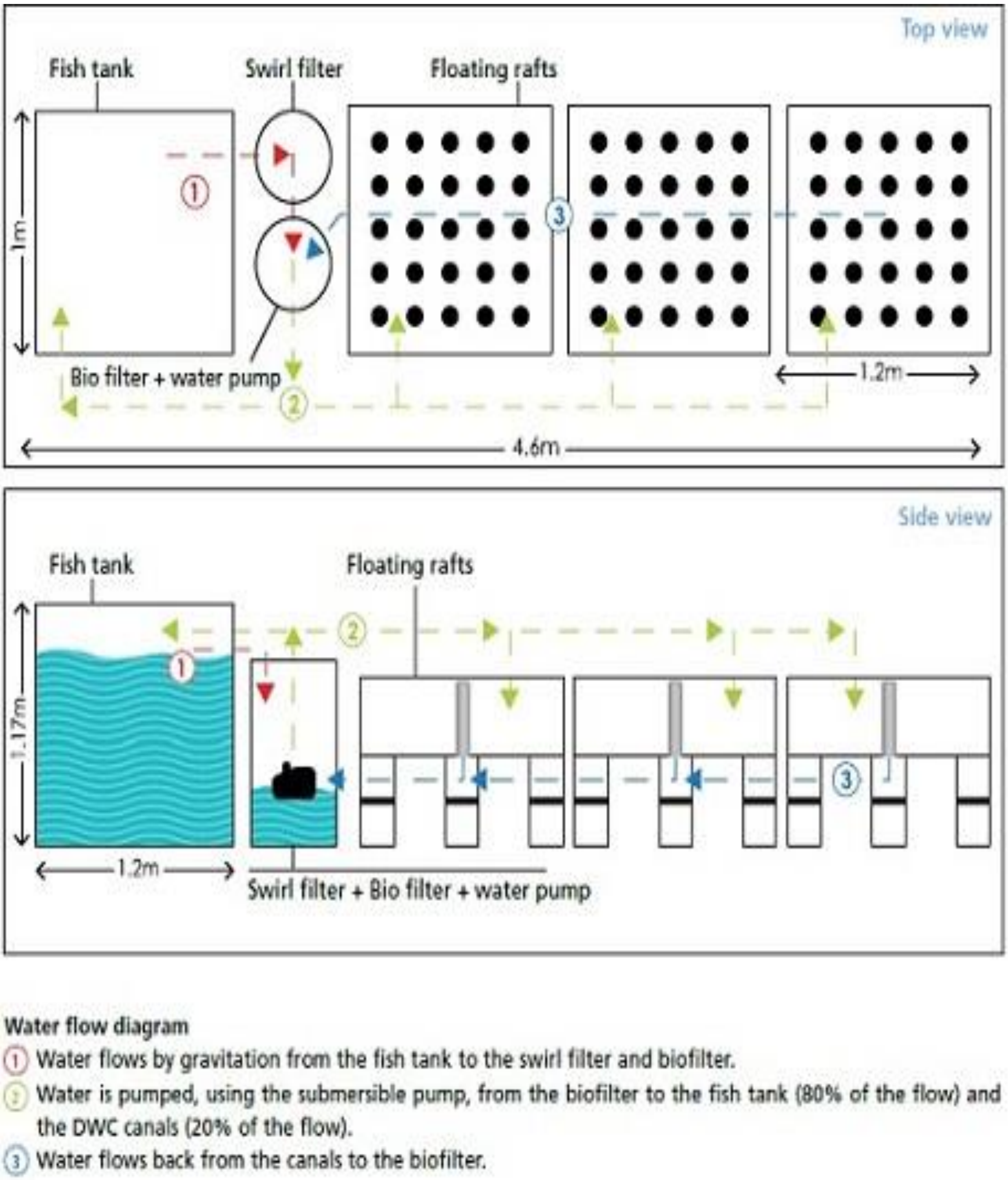

Figure 12: DWC design concept – Plan & side view - Adapted from (FAO, 2015)

The IAVS is similar to the DWC system, only it uses sand instead of waterbeds to grow plants. Sand beds are supposed to be able to grow a greater variety of plants than the DWC system. The IAVS is designed and constructed using the same materials and dimensions of DWC system; 4.2 m long, 1.2 m wide and 0.35 m high. The construction is made of yellow pine wood panels covered with double layered vinyl with 500 microns. The sand grow bed is attached to an IBC fish tank. It holds 1 Ton of water and fish per 1 cubic meter. The IAVS system does not include any mechanical filters, as the sand will work as a natural filter (Figure 13, Figure 14 and Figure 15).

The nitrification process works by transforming the ammonia in the water from the fish waste in the fish tank into nitrates in the sand grow bed. Water flows from the fish tank into the sand grow bed by force of gravity. A timer is used to control the water flow from the fish tank to the sand grow bed. Water flows using the timer for 30 minutes every two hours, five times per day, starting from 7.00 am to 5.00 pm. This method is supposed to be more efficient in water consumption as the sand grow bed is inclined for more water consumption through the evaporation and trans evaporation from plants, while the water grow bed in DWC system is fully covered with Styrofoam floating rafts to limit the evaporation and trans evaporation. A submersible water pump is used for recycling water from the sand grow bed to the fish tank. The same air pump is used to provide fish with oxygen, as plants get the oxygen from the spaces between sand particles in the grow bed. A water collection container is used under the grow bed to collect the water that comes out and pumps it to the fish tank in a closed the water cycle. This water-collection container is the same as the one in the DWC system. The submersible water pump power is also 2000 liter/hour like DWC.

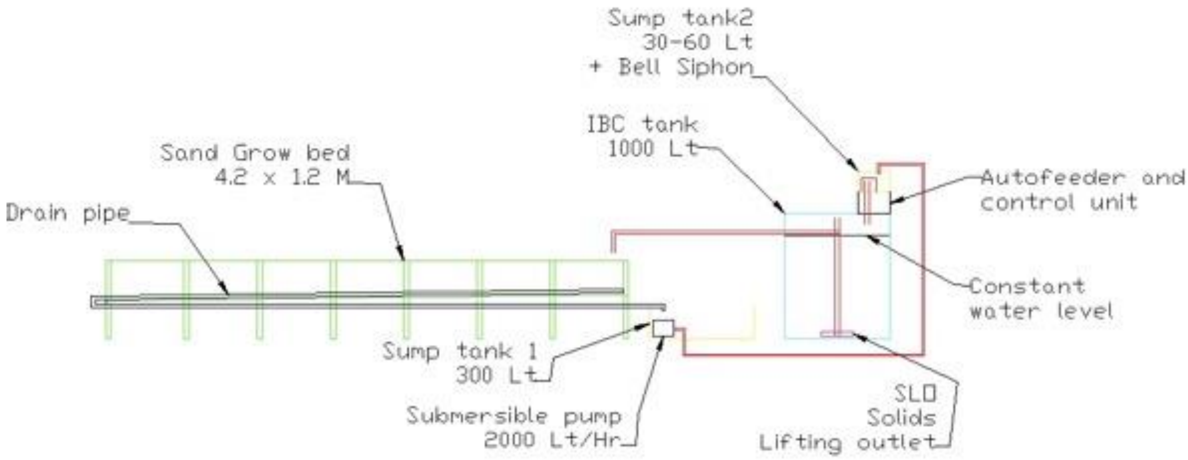

Figure 13: IAVS system preliminary design – side view with dimensions and descriptions.

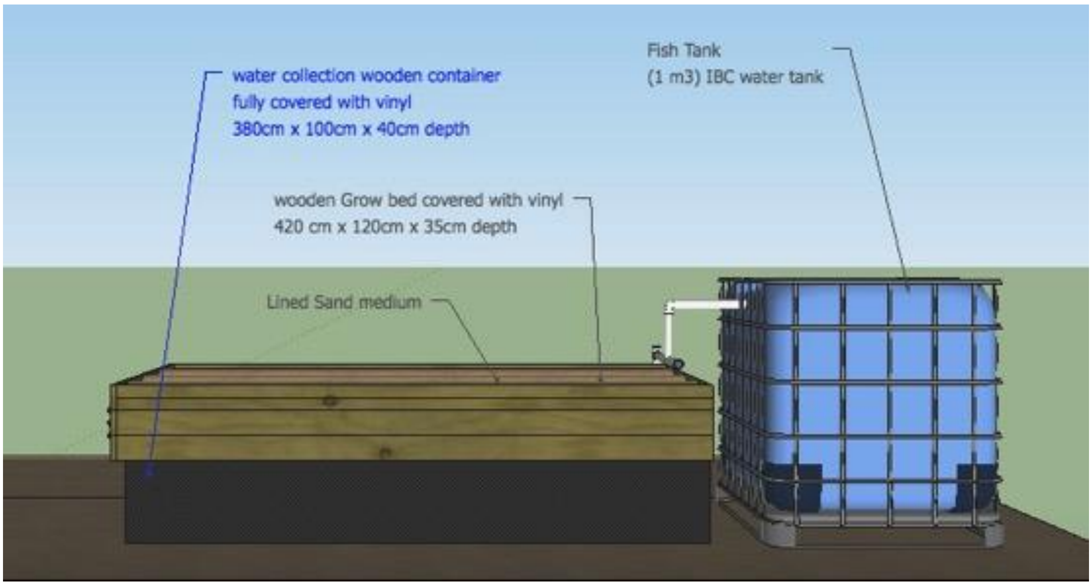

Figure 14: IAVS system design – side view with dimensions and descriptions.

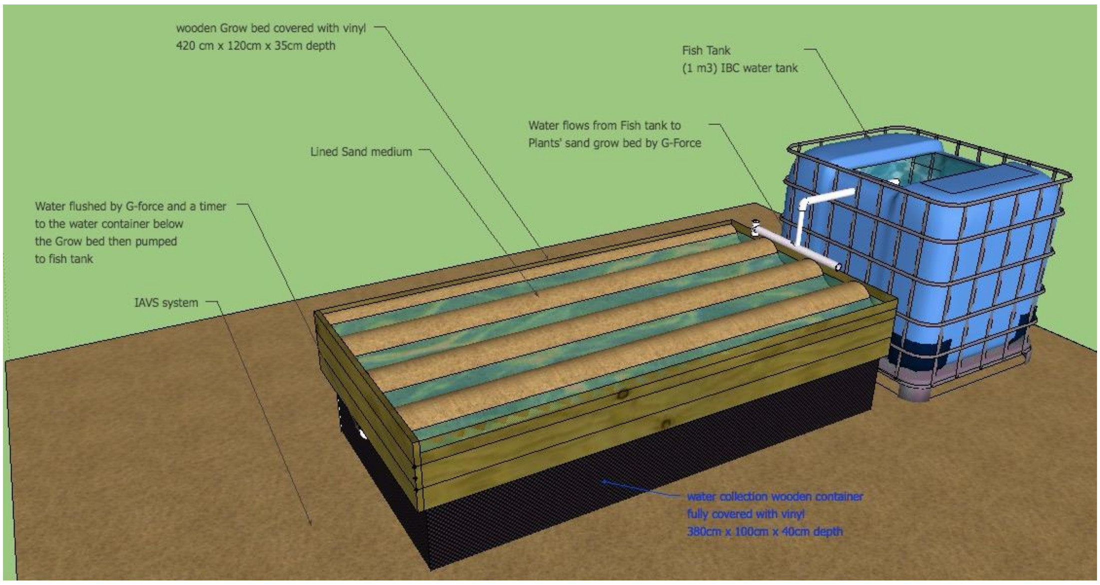

Figure 15: Perspective of the IAVS used in the AUC experiment.

Designing and implementation started in June 2016 by creating an action plan. It also determines the tools and materials required after setting the initial design for both systems, as shown in Table 4 and Figure 16. Both systems needed modifications, monitoring and testing before starting the experiment on April 21, 2017.

Table 4: DWC and IAVS work plan before starting the experiment in April, 21st, 2017.

DWC & IAVS Aquaponics sysems updated action and time plan														
Ser	Action item	Period	Status	2016							2017			
				Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Meeting to discuss: - High level Requirements - Available resources - Design guidelines - Non-Design related materials list (water test kit + pumps+ ammonia......) - Common components between the two systems (growing tables+pluming+..) - Action plan	2 Days	Done											
2	**Initial design and layout & Items List**	7 Days												
3	List of major items sized to Initial design (submitted to purchasing & Order major items sized to Initial design **(purchasing process)**	60 days												
4	Items delivery & Assemble the system	7 days												
5	**Cycling phase**	90 days												
6	Develop operating materials/vendor list: - Fish fingerlings - Fish feed source + storage place - Plants nursery Develop operating daily/weekly/cycle tasks list: - Monitoring the system working - Fish feed - Start of operating phase Fish and Plants added to the system	45 Days												
7	**Operating phase** - Fish & Plant growth and time lapse photos - Pest monitoring /control - Water quality tests	6 Months												

The weather becomes colder in autumn and winter, and cold weather affects both plants and fish. Nile Tilapia fish were chosen in this experiment on purpose. Tilapias can live in a wide variation of temperatures (FAO, 2015). In summer, the temperature can reach more than 40 degrees and the water in the fish tanks can reach 35 degrees. In winter, the water temperature in the fish tanks can drop to as low as 11 degrees. Temperature variations can directly affect the plants. However, temperatures have an indirect effect on the fish. Cold weather affects the appetite of the fish. This makes the fish eat less than their usual fish food portions. Less fish food means there is less fish waste dissolving in the fish water tank. This affects the nutrients levels after the nitrification process.

Plants will have fewer nutrients to grow accordingly, and this affects the plants negatively. Special waterproof heaters were applied to both fish tanks in DWC and IAVS systems to make the water in the fish tanks warmer, helping fish in both systems to eat more in cold weather. A simple arched greenhouse construction is also implemented in the Aquaponics site in AUC, surrounding both DWC and IAVS systems. The Greenhouse helps to mitigate weather temperature variation. It is made of metal arches covered with vinyl to increase the temperature inside the greenhouse during winter. In hot weather, the vinyl layer is removed and another layer from agriculture shading net is applied. The agriculture shading net prevents sun and direct heat to affect the systems and it provides shades. It also allows the air to flow inside the systems as shown in Figure 17 and Figure 18.

Applying the greenhouse option will help in controlling the weather and temperature inside the site for both DWC and IAVS. It will also help in improving the fish appetite. On the other hand, these improved weather conditions can also provide a suitable environment for insects to grow and affect the plants inside the greenhouse. Neem oil and Pheromone traps are used as Bio-pesticides to fight insects and infections in a sustainable, green and organic way.

Both systems are connected to sensors to test the water current temperature, pH, and dissolved oxygen. These sensors are attached to a motherboard and a battery designed to send data through a GSM mobile network to a cloud server to monitor the Aquaponics systems remotely in the runtime. Also the system will be sending alarms in case of any emergency through SMS using the GSM mobile network. The needed electricity power in both systems for the water pumps, air pumps and other needs like heaters for fish in the cold weather or sensors is less than 0.5 kilowatt/hour.

Figure 16: The implementation process.

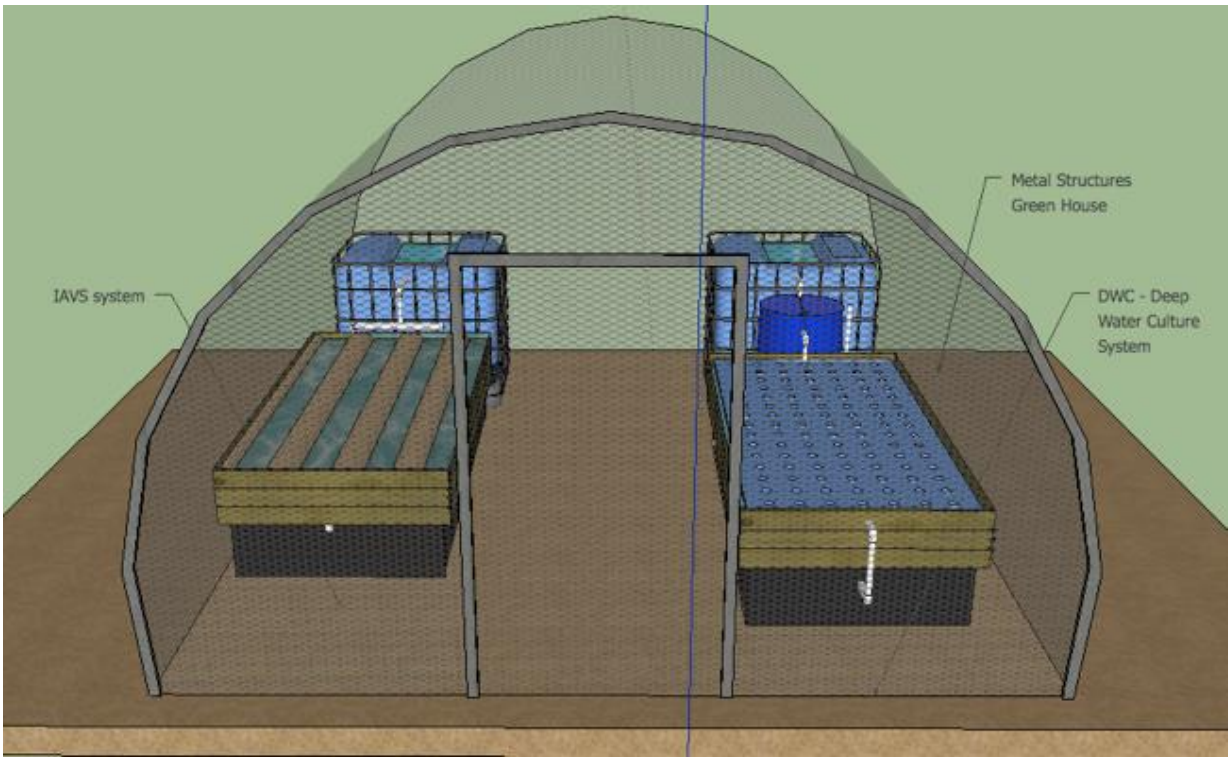

Figure 17: Lab scale of the DWC and IAVS systems used in the AUC experiment (Front view).

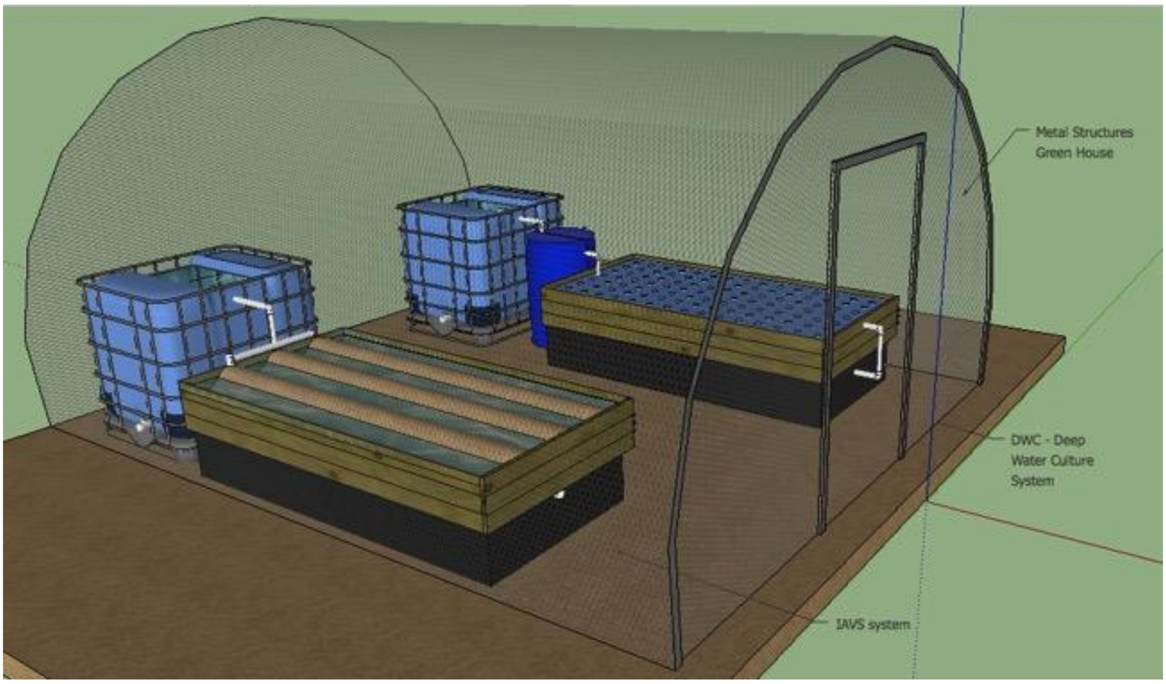

Figure 18: Lab scale of the DWC and IAVS used in the UAC experiment.

3.5 Fish

The experiment started on Friday, April 21, 2017 by distributing fish in both DWC and IAVS fish tanks equally, with a total of 150 fish in both systems. Seventy-five Nile Tilapia fish were added to each tank with total weight 2600 gm and average weight of 34.5 gm per fish. The total fish weight in both DWC and IAVS fish tanks was 5200 gm for the 150 Nile Tilapias fish. Figure 19 shows the Nile Tilapias before and after adding them to the DWC and IAVS fish tanks.

Figure 19: 150 Nile Tilapias are distributed equally to DWC and IAVS.

4 Chapter 4: Results and Analysis

It was noticeable in the beginning of the experiment that the fish consumed more fish feed in IAVS than those in the DWC, despite the rise of ammonia rates in IAVS. However, in the last month of the experiment, the fish in the IAVS started to lose their appetite. With higher rates of ammonia, all the fish in the IAVS fish tank were found dead on August 21, the last day of the experiment. The fish weighed 13 kg in the IAVS and 15 kg in the DWC. Fish in both systems consumed 35 kg of food from April 21 to August 21, 2017. Fish in the DWC gained 12.4 kg during the experiment with an average gain per fish of 200 gm. Fish in IAVS gained 10.4 kg with the average weight per fish reaching 173 gm.

The fish turned 35 kg of fish feed into 22.8 kg of fish biomass in both DWC and IAVS systems. In the DWC, 17.5 kg of fish feed turned into 12.4 kg of fish biomass with each fish fed with an average of 165 gm of fish biomass per fish. In the IAVS system, 17.5kg of fish feed turned into 10.4 kg of fish biomass. Each fish consumed an average of 233 gm of fish food during the whole experiment. In the IAVS, the fish feed turned into an average of 138.5 gm of biomass per fish.

4.1 Plants

One of the main objectives of the experiment is to compare plant growth and productivity in both the DWC and IAVS systems. Another objective is to plant different crops in aquaponics, as most aquaponic systems grow only leafy plants. That is why the experiment started by planting the same amount of various kinds of plants in both systems. Plants were distributed in both systems as shown in Table 5. The DWC and IAVS systems were prepared as shown in Figure 20.

Table 5: Names and quantities of plants have been seeded in the beginning of the experiment.

Plant's Name	Number of seeded plants in DWC	Number of seeded plants in IAVS
Arugula	15	15
Basil	5	5
Bell Pepper	2	2
Cantaloupe	3	3
Cherry tomato	3	3
Chili pepper	1	1
Corn	5	5
Cucumber	3	3
Dill	15	3
Eggplant	1	1
Molokheya (latin: Corchorusolitorius)	60	60
Parsley	2	2
Peppermint	2	2
Pumpkin	3	3
Radish	5	5
Thyme (oregano)	1	1
Sunflower	3	3

Figure 20: On the left (DWC) and on the right (IAVS) are prepared to start planting the equal amount of the above-mentioned crops.

The Nitrification process worked normally from the first day in both systems. In the first week, and after three days, the plants started to grow in both systems as shown in Figure 21, Figure 22, Figure 23, and Figure 24.

Figure 21: Plants started to grow in DWC in the first week

Figure 22: Plants started to grow in DWC in the first week.

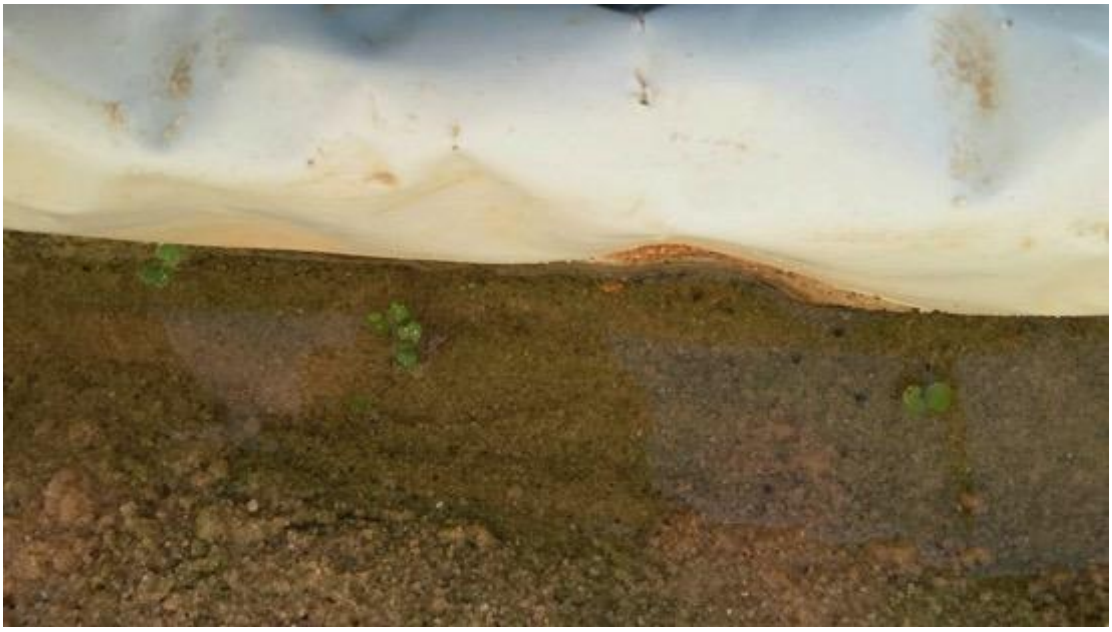

Figure 23: Plants started to grow in IAVS (in the sand) in the first week.

Figure 24: Plants started to grow in IAVS (in the sand) in the first week.

Before the experiment started, elemental analysis of water and sand were completed for comparative analysis on completion of the experiment. Water analysis before the experiment showed that water pH at 7.6, which is almost neutral. After starting the experiment, and within the first week, the pH in both systems reached 8.2 making water alkaline. Phosphoric acid was added to lower the pH to 7.4 as high alkalinity or high acidity affects plants and fish negatively. The graphs in Figure 25 and Figure 27 show both systems with high pH before using the phosphoric acid to lower the pH to 7.4 as shown in Figure 26 and Figure 28.

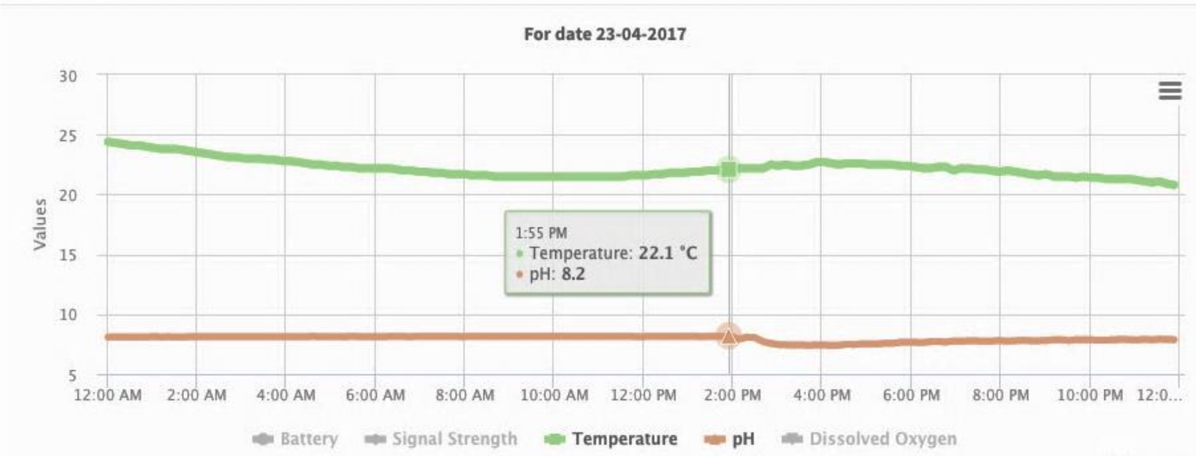

Figure 25: DWC fish tank PH = 8.2 before phosphoric acid

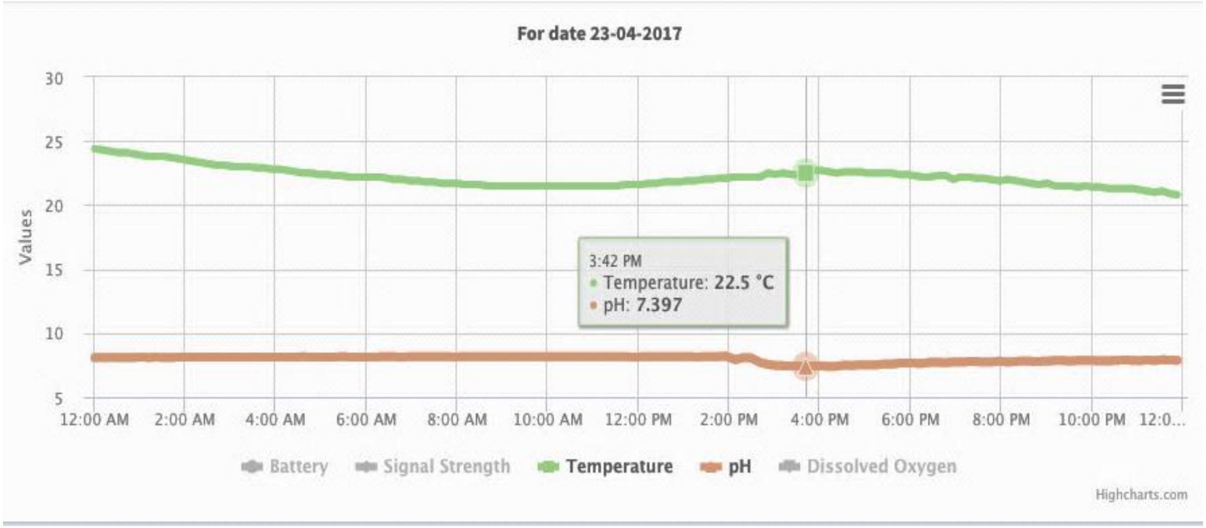

Figure 26: DWC fish tank PH = 7.4 after adding phosphoric acid

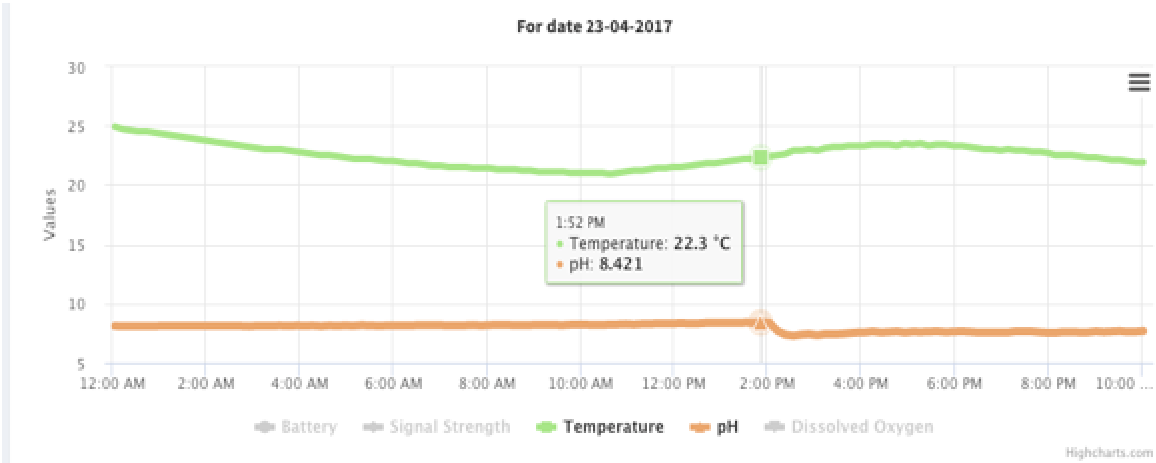

Figure 27: IAVS fish tank PH = 8.4 before phosphoric acid

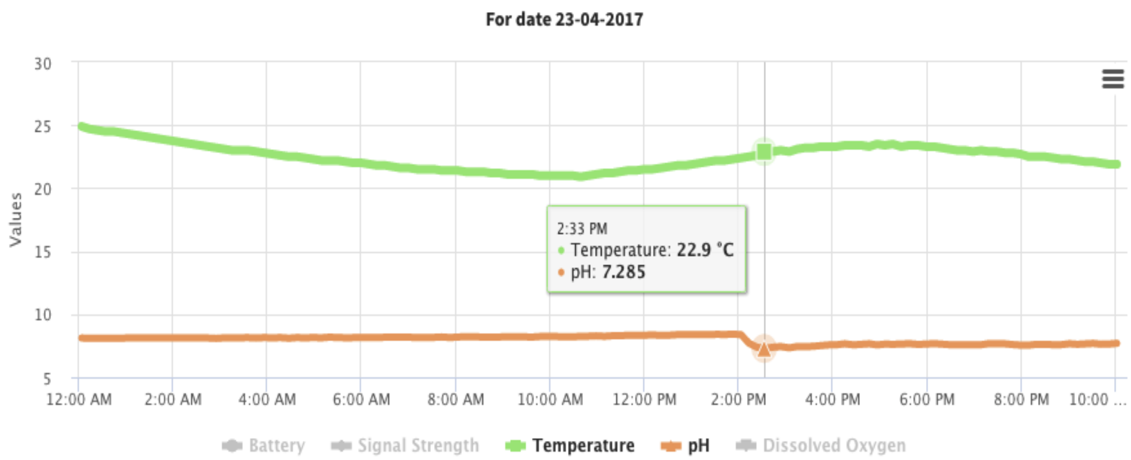

Figure 28: IAVS fish tank PH = 7.3 after adding phosphoric acid

Figure 29: Leafy plants (Dill, Radish and Arugula) in DWC water grow bed.

From April 27 to May 1, 2017, corn grew faster in the DWC system while leafy plants, such as dill, radishes and arugula, grew better in the IAVS system, as shown in Figure 29 and Figure 30.

Figure 30: Leafy plants (Dill, Radish and Arugula) in IAVS sand grow bed.

Figure 31: Plants are growing in DWC & IAVS systems on April 27th, 2017 in the second week of the experiment.

In the second week of the experiment as shown in Figure 31, the corn is growing faster and healthier in the IAVS system than the DWC system as shown in Figure 32 and Figure 33. Also mites started to appear and infect the plants in both systems. Neem oil was used as a bio pesticide to kill them, along with pheromone traps, as shown in Figure 34.

Figure 32: Corn growth in DWC in the second week.

Figure 33: Corn growth in the IAVS in the second week.

Figure 34: Pheromone traps

Leafy plants like arugula, dill, peppermint and radishes are growing more in the DWC than in the IAVS, as shown in Figure 35 and Figure 36.

Figure 35: On the left shoes peppermint growth in DWC, on the right shows peppermint growth in IAVS in the second week.

Figure 36: On the left shoes Basil growth in DWC, on the right shows Basil growth in IAVS in the second week.

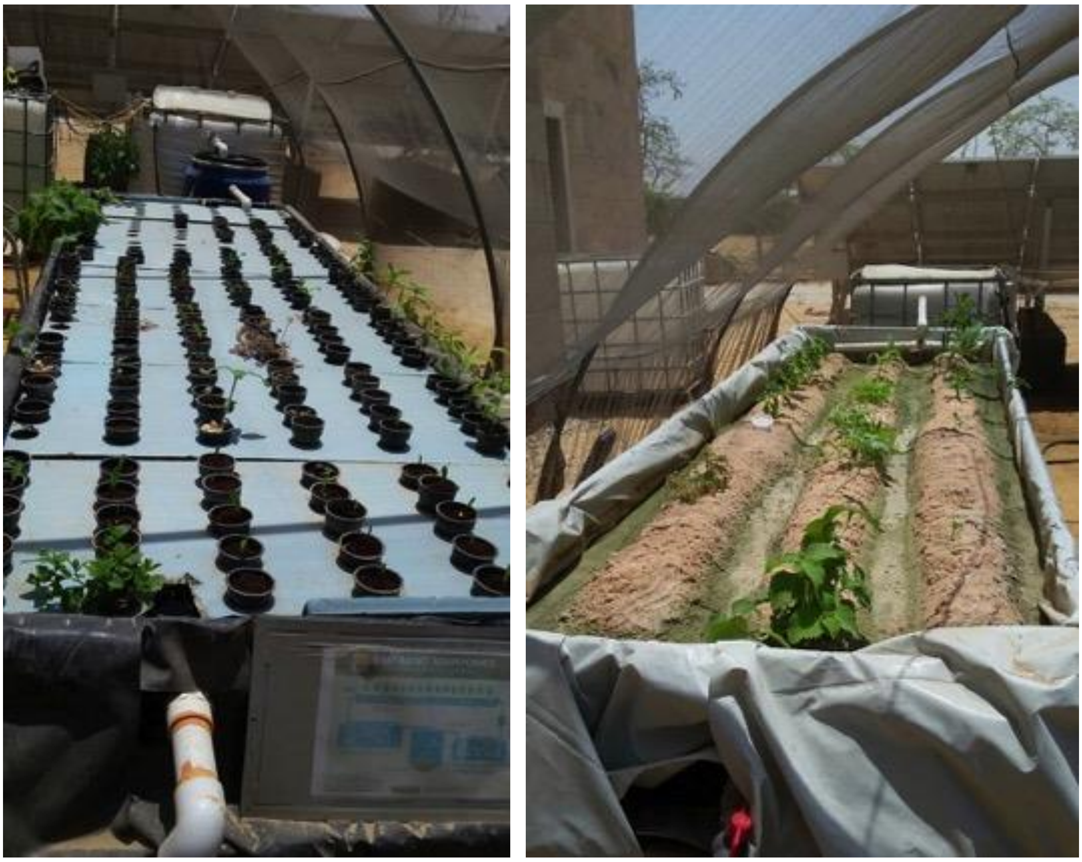

Figure 37: Both systems in the third of the experiment (May 11, 2017)

In the third week of the experiment, plants were facing a rapid attack from insects as weather got warmer, as shown in Figure 37. White fly started to appear on plant leaves in both the IAVS and DWC, as shown in Figure 38.

The insects attacked the plants more in the IAVS than in the DWC. Neem oil was sprayed and more pheromone traps are added to eliminate the white fly. Basil, parsley, radishes, dill, sunflower and molokheya were growing better in the IAVS than in the DWC, as shown in Figure 39.

Thyme and Egyptian mint grow better and faster in the DWC as shown in Figure 40. Corn is almost growing at the same rate in both systems. Generally, plant growth was faster in IAVS than DWC (see Figure 41 and Figure 42). Pumpkin, for example, stopped growing in the DWC, but flourished in the IAVS.

Figure 38: Small white flies on the back of pumpkin leaf in IAVS – Third and fourth week

Figure 39: On the left shoes Basil growth in DWC, on the right shows Basil growth in IAVS in the third week

Figure 40: On the left shoes Thyme growth in DWC, on the right shows Thyme growth in IAVS in the third week.

Figure 41: Plants growth in DWC – Third week.

Figure 42: Plants growth in IAVS – Third week.

On May 17, 2017, in the fourth week of the experiment, sun affected the plants grow bed vinyl layer causing a leakage in the DWC system. A new vinyl layer of 200 microns thickness was added to the water bed after removing the plants and rafts. More water was added, as shown in Figure 43.

Wooden supports were also added to the sides of the DWC systems. They were attached with ropes to help support the growth of some plants (like the peppers and sunflower). After fixing the vinyl layer and returning the plants to the grow bed, the system worked normally again.

Plants grow faster and healthier in the IAVS system than in the DWC, as shown in Figure 44 and Figure 45.

Figure 43: DWC before (on the left) and after (on the right) installing the new vinyl layer.

Figure 44: Growth in DWC – Fourth week

Figure 45: Growth in IAVS – Fourth week

The following will show each plant progression in both DWC and IAVS systems during the experiment until the final day of the experiment.

4.1.1 Arugula

Arugula vegetative growth and germination was better in the IAVS than in the DWC. Its growth was deteriorated due to the excessive heat. In July Arugula could not survive in the DWC and died.

4.1.2 Bell peppers

Bell peppers grew very slowly in both the DWC and IAVS. High temperatures in July negatively affected the Bell pepper's growth in both systems. In the DWC, vegetative growth stopped at a height of 9 centimeters without producing any fruit.

In the IAVS, vegetative growth was excellent, as shown in Figure 46, and it produced three fruits that weighed 220 gm. It was harvested by the end of the experiment.

Figure 46: Bell pepper growth in IAVS

4.1.3 Cantaloupe

The vegetative growth of cantaloupe was very good in both the DWC and IAVS. Both grew with the same rates until July. The high temperatures and the absence of bees caused the plants to fail to fruit. Just only one cantaloupe fruit was produced from the IAVS system. It weighed 750 gm at the end of the experiment, as shown in Figure 47.




Figure 47: Cantaloupe growth in IAVS

4.1.4 Cherry tomatoes

Cherry tomatoes grew equally in both DWC and IAVS. Due to the extreme rise in temperatures in July, the heat affected the cherry tomatoes in the DWC negatively. The first tomatoes appeared in the IAVS on August 6, as shown in Figure 48 and Figure 49. It was harvested on August 21, by the end of the experiment. It weighed a total of 620 gm from IAVS. The DWC produced 80 grams of cherry tomatoes during the whole experiment.

Figure 48: Cherry tomato in DWC

Figure 49: Cherry tomato in IAVS

4.1.5 Chili peppers

In the beginning the chili peppers grew faster in the DWC than the IAVS, but after the first month it grew better and faster in the IAVS. In July and August, the high temperatures, that reached 40 degrees inside the shaded greenhouse, negatively affected chili peppers and dried them out in the DWC, as shown in Figure 50.

In the IAVS, the chili peppers survived the high temperatures until the end of the experiment, as shown in Figure 51.

Figure 50: Chili peppers in the DWC

Figure 51: Chili pepper in IAVS

4.1.6 Corn

Corn growth was almost the same in both systems at the end of the experiment. Corn in the IAVS was healthy with no deficiencies detected. While in the DWC, the corn showed iron deficiency and this was treated by adding 2 cm3 of iron to the water every two weeks. This caused the water in the DWC to turn red color. Both systems suffered from mite insect attacks. Mites in the IAVS did not affect corn, while in DWC the impact of the infection was high, even after using bio pesticides and pheromone traps.

The height of the greenhouse and the grow beds from the ground in both systems was insufficient for the corn to grow, which reflected negatively on the grain production. On July 13, the first corn kernel appeared in the IAVS as shown in Figure 52, Figure 53, and Figure 54.

Figure 52: Corn growth in DWC (left) and in IAVS (on the right) in the second month of experiment.

Figure 53: Corn production in July 2017

Figure 54 Three Corn ears produced in July 2017

4.1.7 Cucumbers

The first harvest of cucumber was collected after 45 days of seeding from the DWC and weighed 450 gm. While the first harvest from the IAVS was after 48 days from seeding and weighed 1500 gm.

Average length of the fruit was 8 cm. The second harvest collected from both systems was on June 27. The DWC produced 125 grams while IAVS produced 500 grams.

On July 1, a third harvest was collected from the DWC with a weight of 400 grams and 1500 grams from the IAVS. On July 7, a fourth harvest was collected from the DWC weighing 400 gm, and from the IAVS a crop of 500 gm. In that week, cucumber production was affected by the high temperatures that reached 40 degrees Celsius inside the shaded greenhouse.

On July 12, a fifth harvest was collected from the DWC weighing 250 grams and from IAVS a crop weighing 1250 grams. On July 21, a sixth harvest was collected from the DWC weighing 220 grams and from the IAVS a crop weighing 680 grams. On July 28th, a seventh and last harvest was collected from the DWC weighing 225 grams and from the IAVS a crop that weighed 600 grams.

The total DWC weight of production throughout the experiment was 2070 grams; while the total cucumbers produced using IAVS was 6530 grams. The IAVS produced cucumbers three times bigger than those frown in the DWC in the same conditions, as shown in Figure 55 and Figure 56.

Figure 55: Cucumber in DWC

Figure 56: Cucumber in IAVS

4.1.8 Dill

Dill vegetative growth and germination was better in the IAVS than in the DWC. Dill deteriorated from the excessive heat. In July, it could not survive in the DWC and died.

4.1.9 Eggplant

Eggplant was planted in equal seedlings and it grew better and faster in the IAVS than in the DWC. First eggplant fruit was produced 37 days from the first day of the experiment. Eggplants were deteriorating in the DWC due to the extreme high temperature and did not grow very well. In the IAVS, it continued to grow and produce in an excellent manner as shown in Figure 57.

Figure 57: on the left Eggplant in DWC, on the right Eggplant in IAVS

4.1.10 Molokheya

The growth of Molokheya was similar in both systems, but it was better in the IAVS. The plant showed a tendency to flower and fruit with the high temperatures in the DWC. In the DWC, the Molokheya started to produce seeds as the plant matured, while it did not produce seeds in IAVS. The color of Molokheya branches turned red in the DWC, while in the IAVS it was looking fresher and greener with no red color. Molokheya produced more leaves in the IAVS than in the DWC. Mites did not affect the Molokheya in the IAVS, but was affected by mites in the DWC, as shown in Figure 58, Figure 59, and Figure 60.

Figure 58: Molokheya red branches from the DWC on the left. Molokheya seeds on the right DWC.

Figure 59: Molokheya branches on the left from the IAVS, and reddish branches on the right from the DWC

Figure 60: Molokheya leaves from DWC on the left with Mites and white flies on the leaves, and Molokheya leaves from IAVS with minimal infection of Mites or white flies

4.1.11 Parsley

Crispy parsley was growing taller and better in the IAVS despite the high temperatures as shown in Figure 61, while it did not survive in the DWC. In July, the parsley deteriorated and died in the DWC.

Figure 61: Crispy parsley growth in IAVS

4.1.12 Peppermint

In the beginning peppermint grew faster in the DWC than in the IAVS. After the first month, it grew equally in both systems. The high temperatures of July and August affected all leafy plants including the peppermint, especially in the DWC system. Peppermint growing in the IAVS could withstand the temperatures more, as shown in Figure 62.

Figure 62: Peppermint growth in DWC on the left, and Peppermint in IAVS on the right

4.1.13 Pumpkins

Pumpkins were the star of the experiment. Pumpkin leaves and branches reached every place in the greenhouse. Pumpkin grew only in the IAVS, as shown in Figure 63. The first appearance of this pumpkin was after 60 days from seeding. On the July 7, a manual fertilization was done to form the first fruit. The second fruit appeared after one week of the manual fertilization. Several flowers were produced, but the number of pumpkins was three. After 37 days from fertilization, on July 24th, 6800 gm of pumpkin was harvested. On the last day of the experiment, on August 21, the second pumpkin weighed 3300 gm and the third weighed 4900 gm.

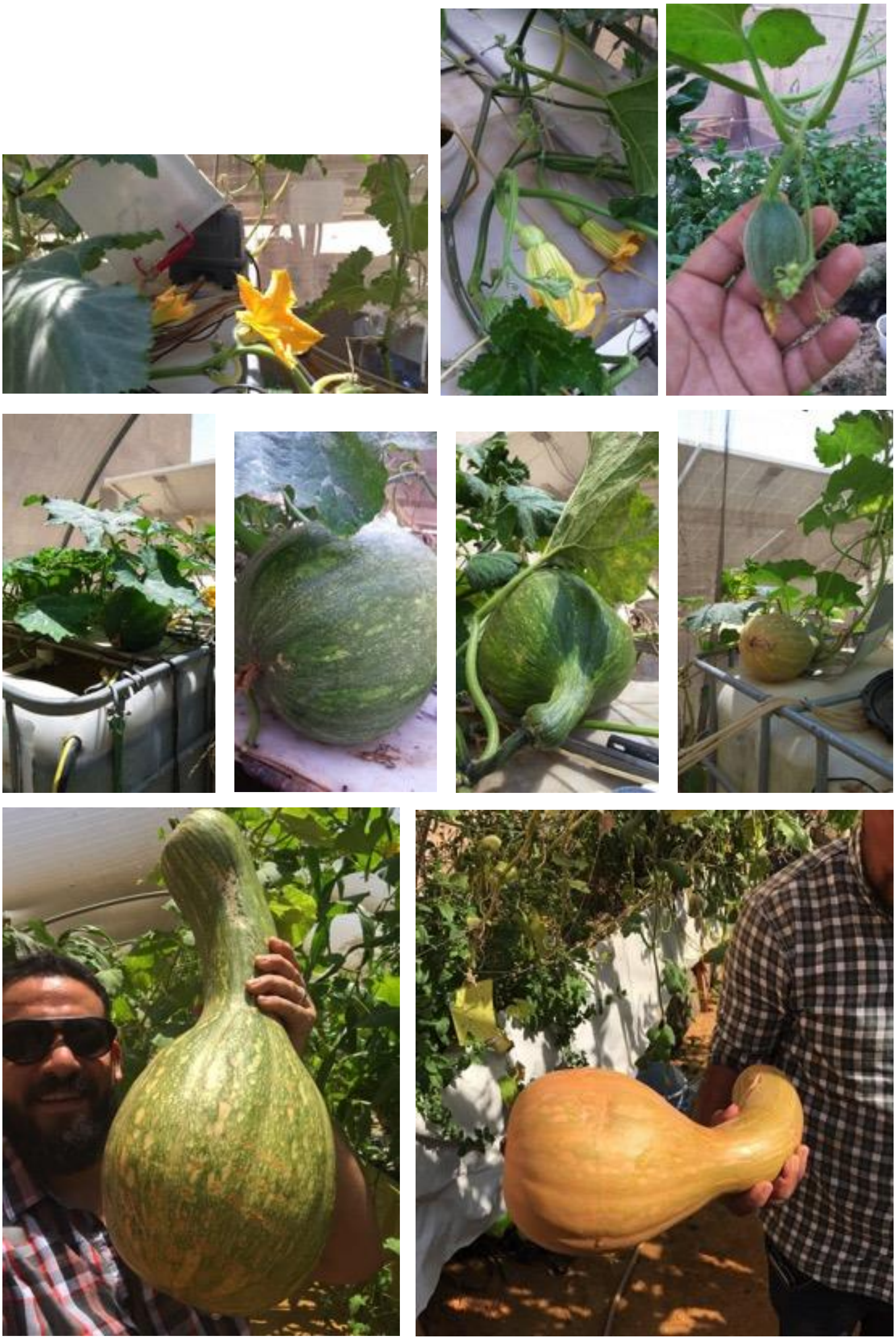

Figure 63: Pumpkin growth in IAVS

4.1.14 Radishes and Thyme

Thyme production and growth in the DWC and IAVS was the same until the last day of the experiment.

The radishes grew faster and healthier in the IAVS; both roots and leaves grew faster and bigger. Figure 64 shows the first radish root head that appeared in both systems after 35 days from the beginning of the experiment, meanwhile, the maximum production was from the IAVS 56 days after planting the seed. The radish root radius reached 2.5 cm in the IAVS.

Figure 64 Radish root in the IAVS

4.1.15 Sunflowers

Sunflower vegetative growth and germination was equal in both systems. From the first week in July, sunflowers in the DWC were affected negatively by the high temperatures and deteriorated over time. The sunflowers stopped growing in the DWC after an advanced stage of growth and flowering, while it continued to flourish in the IAVS. It produced four flowers, yet it needed bees for fertilization. Fertilization was done manually. Sunflower seeds appeared on the plant in the IAVS on July 18. Only one flower produced sunflower seeds and the majority of seeds were empty, as shown in Figure 65.

Figure 65: Sunflower growth in IAVS

4.2 DWC and IAVS water quality

The water test kit tool was available from mid-June 2017. The ammonia ratio was higher in the IAVS than the DWC, with average ammonia reading of 2 (and higher) and from 0.5 to 1 in DWC (see Figure 66).

Figure 66: Showing IAVS water test results on the left with Ammonia = 3 vs. Ammonia in DWC = 0.5 on the right (on July 18th, 2017)

On July 24, the fish in the IAVS were not eating well, although all water test results were normal as shown in Figure 67. On July 30, the ammonia levels were 4 in the IAVS vs 0.5 in the DWC, as shown in Figure 68. Accordingly, fish in the IAVS were not fed for one day to decrease ammonia levels.

Figure 67: IAVS water test results on the left with Ammonia = 1 vs. Ammonia in DWC = 0.5 on the right while PH is the same in both systems = 7.5 (on July 24th, 2017)

Figure 68: Showing IAVS water test results on the left with Ammonia = 4 vs. Ammonia in DWC = 0.5 on the right (on July 30th, 2017)

On August 6, the ammonia levels decreased to 2 in the IAVS vs 0 in the DWC after decreasing fish feed, as shown in Figure 69. On August 13th, the ammonia levels increased again to 4 in the IAVS while it was 2 vs 0.5 in DWC, as seen in Figure 70. Consequently, the fish in the IAVS tank were not fed for one day again.

Figure 69: Showing IAVS water test results on the left with Ammonia = 2 vs. Ammonia in DWC = 0 on the right (on August 6th, 2017) after stopping IAVS fish feed.

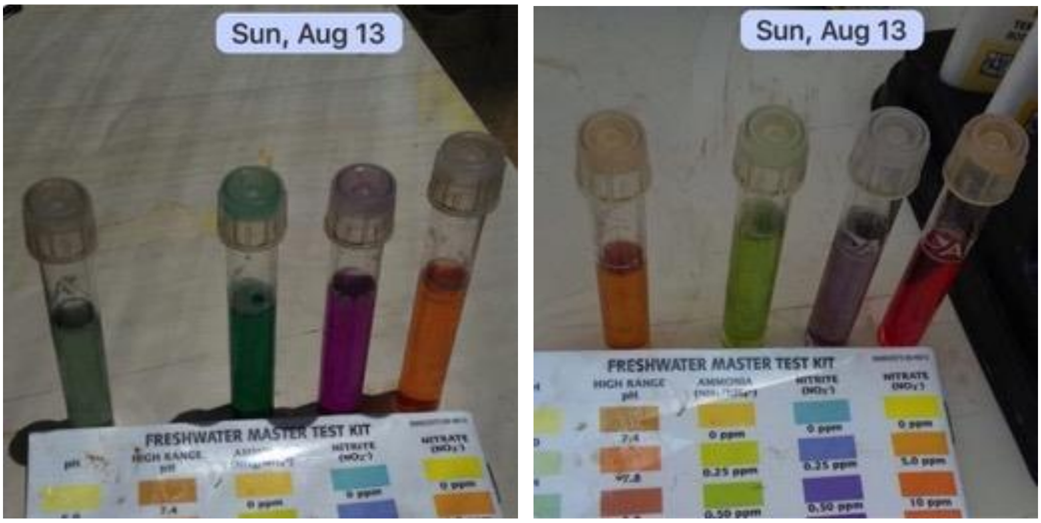

Figure 70: Showing IAVS water test results on the left with Ammonia = 4 vs. Ammonia in DWC = 0.5 on the right (on August 13th, 2017).

On the night of August 17, the ammonia levels were still high and the fish were not eating. Therefore, a decision was made to stop feeding the fish for an extra two days. On August 21, 2017 at 11 am, all fish in the IAVS tank were found dead. The first assumption was that the solid waste in the IAVS system accumulates on the soil surface, enabling the growth of toxic bacteria. The bacteria prevent the nitrification process so the ammonia rates remain high and harmed the fish. An instant water test was completed to prove the assumption. The water analysis showed that the ammonia rates were above 4 (from 4 – 8) as per the water test kit, as shown in Figure 71. Nitrates =1, which means that the nitrification process was not working in the IAVS system.

Figure 71: Showing IAVS water test results on the left with Ammonia = higher than 4 (4 – 8) vs. Ammonia in DWC = 0.25 on the right (on July 30th, 2017).

Samples from the water in the DWC and IAVS were taken for an elemental and bacterial analysis, and sent them to Soil, Water & Environment Research Institute. A sample from the source water from both systems was tested before starting the experiment to compare water elemental analysis before and after the experiment. The pH in both systems was always the same level from 7 – 7.7. Air stones in both systems were covered with algae. This lowered the dissolved oxygen levels in both systems to a range of 5. In the DWC system, the fish were not affected even though it had the same inputs as the IAVS system.

4.3 Analysis of Crop Quality

4.3.1 Elemental crop analyses by The Regional Center for Food & Feed – RCFF in the Egyptian Agriculture research center - ISO certified lab.

Selecting the main vitamins and minerals in each planted crop in both DWC and IAVS systems as shown in Table 6.

Table 6: Main crops from the experiment in both systems and their principle vitamins and minerals found in each of the plants arranged starting from the highest content to the least.

Plant	Vitamins	Minerals
Bell pepper (colored pepper)	C, A, B-6 and E (according to %content)	Manganese, iron, and phosphorous
Cucumber	K, C and A.	Manganese, iron and phosphorous
Radish	C and E	Copper, iron, and calcium
Molokheya	A	Calcium and iron
Pepper mint	A, C, and B-6	Iron, calcium and magnesium
Thyme	C, A and B-6	Iron, calcium and magnesium
Cherry tomato	A and C and B-6	Magnesium
Chili pepper	C, B-6 and A	Magnesium, iron and calcium

The selection process of the crops was mainly dependent on the crops abundance in both systems that can be examined, as the production of other type of crops were either limited, such as tomato, or unsuccessful in one of the systems as pumpkin. For example, one of the laboratory requirements is to provide at least half a kilogram of each crop for predetermination for drying and turning onto power, in order to be analyzed.

Accordingly, in the light of what mentioned earlier, ‘Molokhyea’ was selected because it produced sufficient quantity; an average 2 kg, in both systems (DWC and IAVS). Moreover, the Molokhyea crop from the aquaponic systems provided the needed criteria for comparison with another source of organic Molokhyea in terms of elemental, chemical, pesticides residues, and heavy metal analysis. Additionally, it was suitable to compare both the quantity and the quality between the two systems. Molokheya is rich in beta-carotene/vitamin A, which is an essential nutrient for human bodies. As a result, the elemental analysis was completed to compare beta-carotene/Vitamin A levels in the DWC, IAVS, and the organic product in the market. On the contrary, other crops grew differently in the two systems, which hindered conducting further analysis as that for Molokheya. For example, pumpkin successfully grew in the IAVS system, while it has failed to grow in the DWC.

So, the elemental analyses for Molokheya, from both systems, were compared with the results of the organic Molokheya from the Metro market. This comparison showed the beta-carotene/Vitamin A amounts in the DWC and IAVS were the same as that of the organic product from the market.

4.3.2 Residue analysis for pesticides and heavy metals analyses by Central Lab of Residue Analysis of Pesticides and Heavy Metals in Food (QCAP Lab) .

Quick and Easy method (QuEChERS) has been used for the determination of pesticide residues in all Molokheya tests. Using LC-MSMS, GC-MSMS as per the European Standard Method EN 15662:2008. The ICP-OES method has been used for the Determination of Heavy Metals analyses in Molokheya using inductively coupled plasma optical emission spectrometry after high-pressure microwave digestion. The Danish official HPLC method no. AF 255.1, 3rd ed. 1996 from the national food agency of Denmark was used for the determination of Vitamin A/Beta-carotene in Molokheya.

4.3.3 Sand Analysis by Soil, Water & Environment Research Institute - (SWERI) in the Egyptian Agriculture research center.

IAVS sand was tested before and after the experiment to determine the main elements, either soluble or insoluble that may help or harm plant growth.

4.3.4 Water Analyses Soil, Water & Environment Research Institute - (SWERI) in the Egyptian Agriculture research center.

To know the percentages and amounts of elements in the water before and after the experiment, samples have been taken from the fresh water used to fill both systems. It was tested for chemicals, macro and micro nutrients, and heavy metal content.

Bacteriological water analyses for water samples from both the DWC and IAVS systems after the experiment was issued as a method to estimate the numbers of bacteria present and, if needed, to find out what sort of bacteria they are. It is a microbiological analytical procedure, which uses samples of water to determine the concentration of bacteria in both systems to compare them. In the previously mentioned analysis, all results included in the labs reports are after calculating the error factor.

4.4 Volume and costs of DWC vs. IAVS

The IAVS uses less area than the DWC, as the IAVS system does not have the mechanical nor biological filters needed in DWC. This means the IAVS needs less space than the DWC which could be used either to make the plant grow bed bigger or make the whole systems smaller, as shown in Figure 72.

DWC system materials and implementation costs were EGP 8720, compared to the cost of IAVS of EGP 7650 as shown in Figure 73 . Greenhouse costs extra EGP10000 for covering both systems.

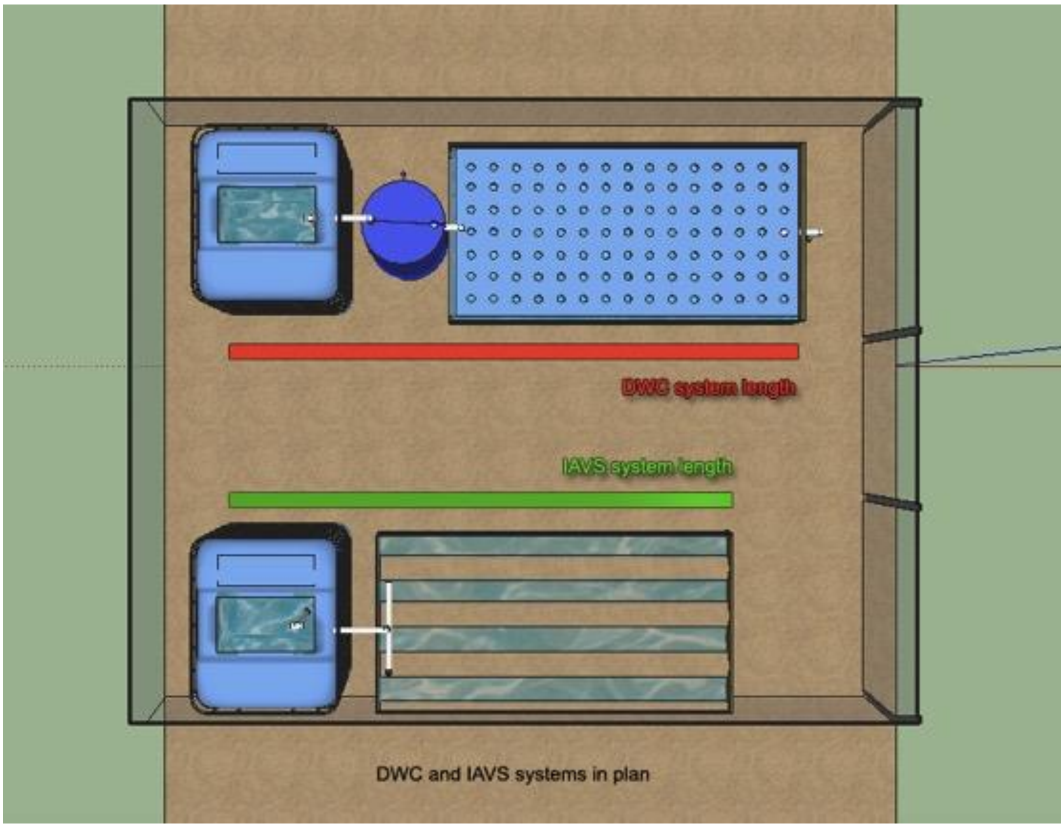

Figure 72 Showing the DWC is longer than the IAVS.

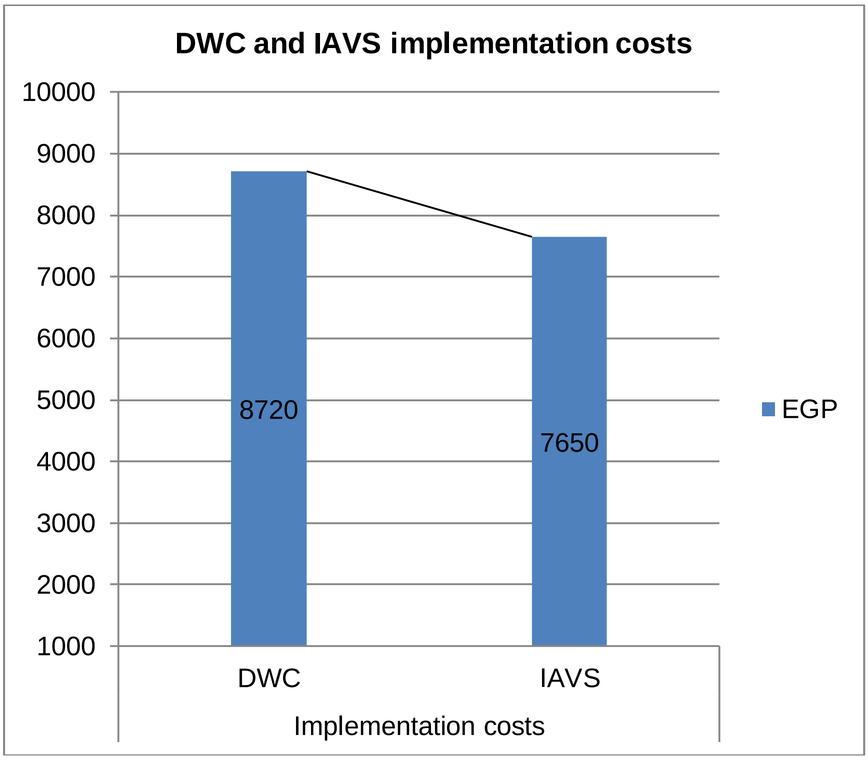

Figure 73: DWC and IAVS implementation costs

4.5 DWC and IAVS water analyses tests before and after the experiment

Full analyses for the water used in both systems before starting the experiment was completed by the Unit of Soils, Water and Environment at the Egyptian Agriculture Research Center (ARC). This includes a chemical analysis of the macro and micro nutrients content in the waters. The analysis shows the electrical conductivity (EC) is 0.41 deciSiemen per meter, which shows a low conductivity. Total dissolved salts (TDS) are 262 ppm and pH is 7.6, which shows the water is neutral with a very little alkalinity.

Soluble ions found in water are anions and cations. The soluble anions found in the water analysis were Bicarbonates (HCO3) at 1.51 milliequivalents of solute per liter of solvent (meq/L), Cl is 1.27 meq/L and Sulfate (SO4) was 1.45 meq/L.

The soluble cations found in the water analysis were Calcium (Ca) at 1.90 meq/L, Magnesium (Mg) was 1.30 meq/L, Na is 0.96, and Potassium (K) was 0.07 meq/L.

The element concentrations in the water were as follows: NO3 was 10.01 mg/L, Phosphorus (P) was 0.317 mg/L, Iron (Fe) was 0.169 mg/L, Mn was 0.145 mg/L, Zinc (Zn) is 0.155 mg/L, Copper (Cu) was 0.0147 mg/L and B was 0.079 mg/L. Sodium Adsorption Ratio (SAR) is 0.76 which is not hazardous, while Residual Sodium Carbonate (RSC) was not detected in the water analysis.

At the end of the experiment the analysis shows that the highest EC was in DWC with 0.85 dS/m. The highest TDS in the last day of the experiment was also in DWC with 544 ppm. pH remained 7.6 in IAVS as in the beginning of the experiment, while in DWC it was 6.9 at the end of the experiment as shown in Figure 74, Figure 75 and Figure 76.

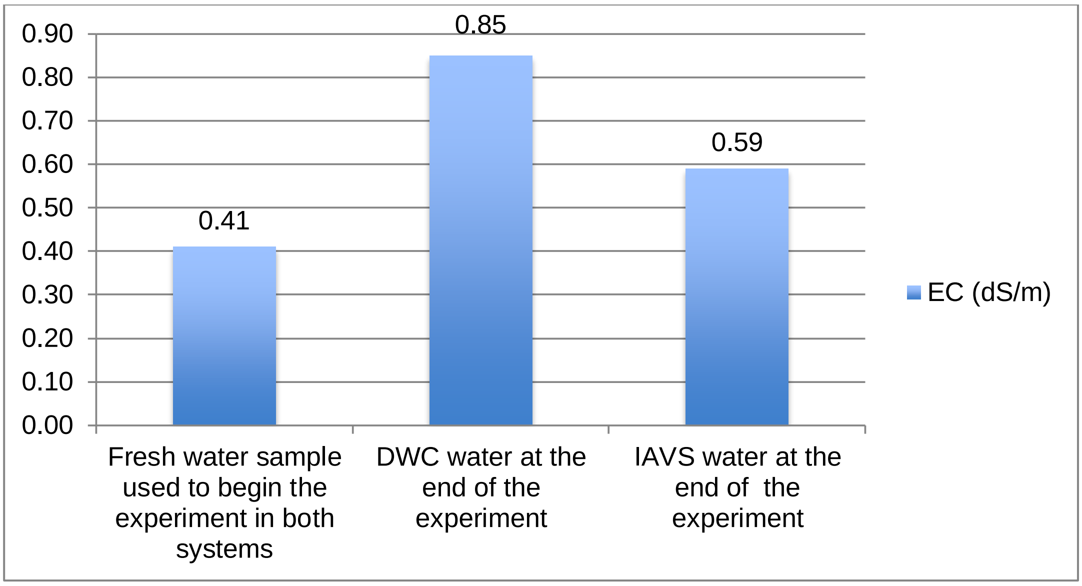

Figure 74: DWC has the highest EC, 0.85 dS/m

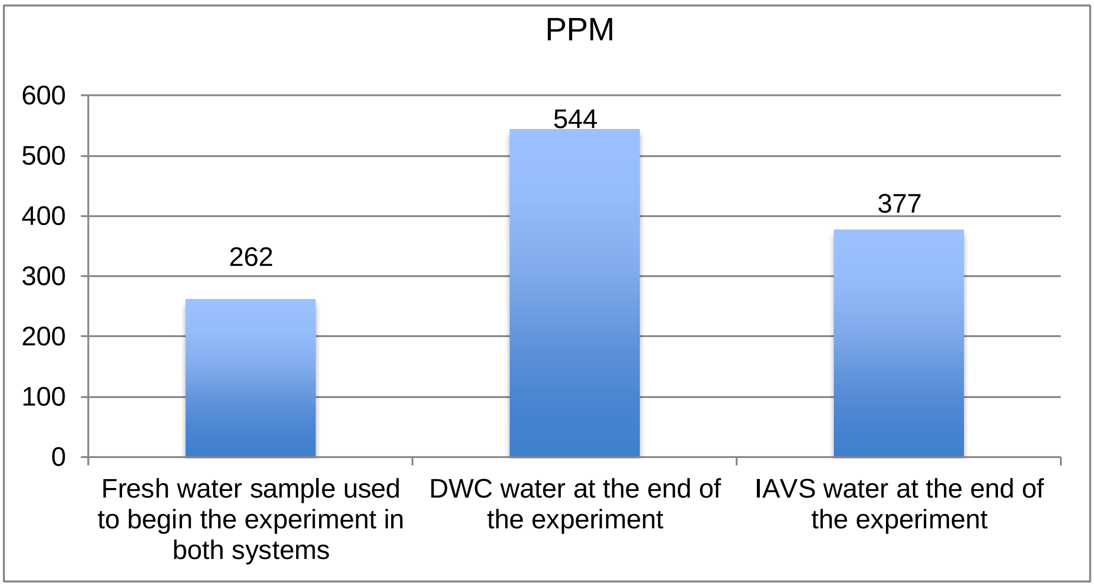

Figure 75: DWC has the highest TDS of 544 ppm

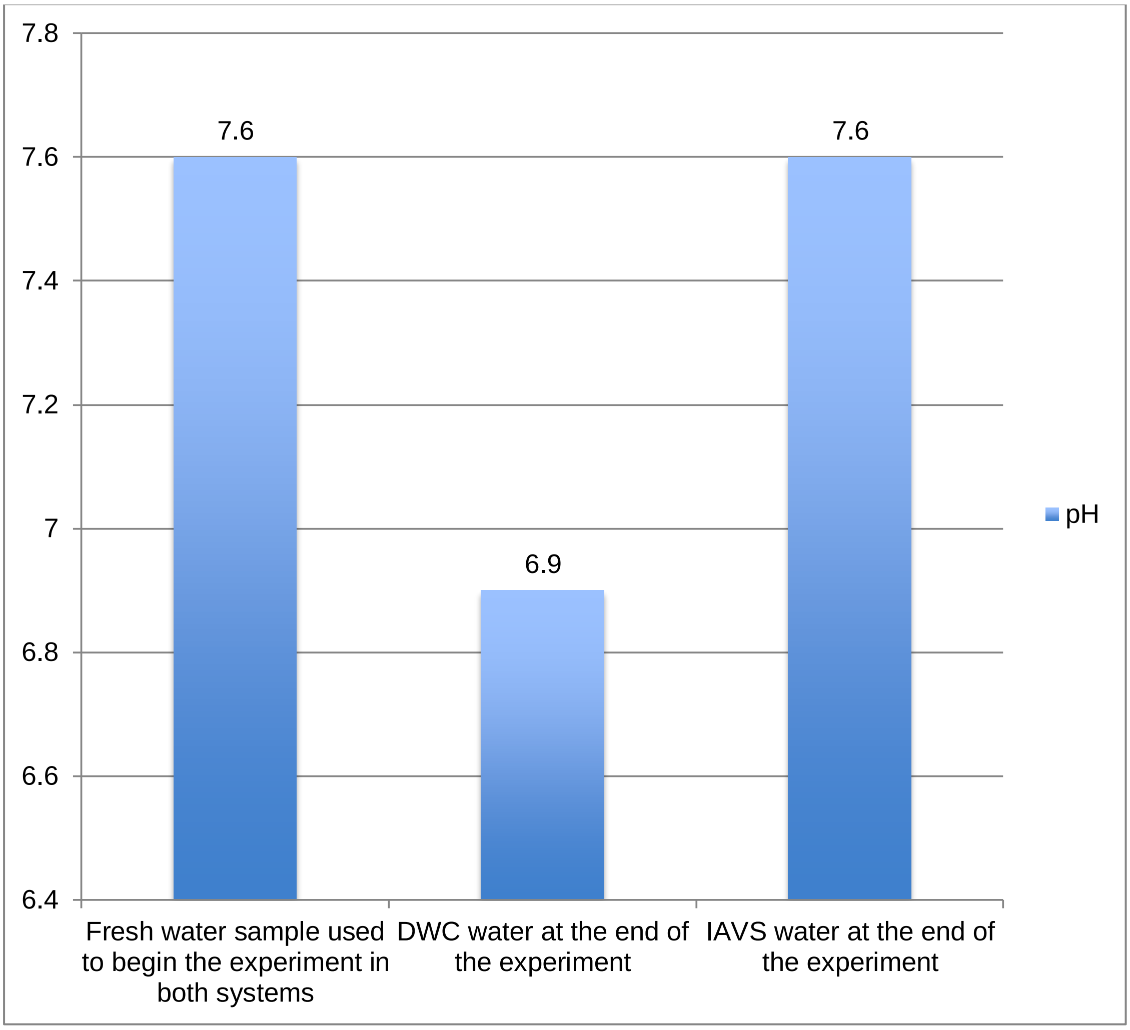

Figure 76: DWC has the lowest pH after the experiment, 6.9 ppm.

Figure 77, Figure 78 and Table 7 show Phosphorus in the DWC is 31.624 mg/L and 4.574 mg/L in the IAVS.

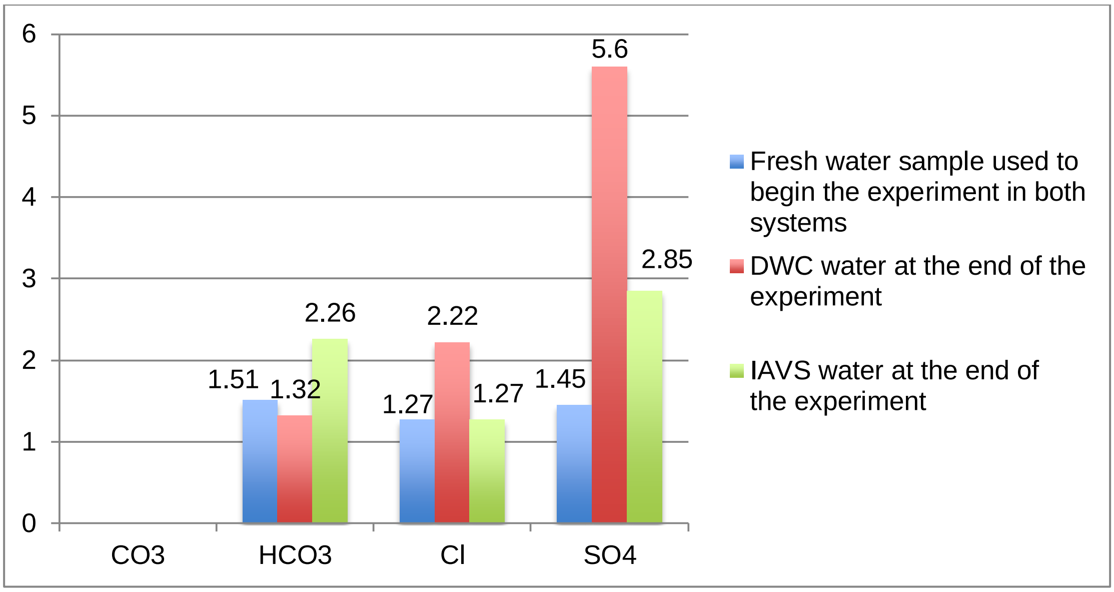

Figure 77: DWC has the highest SO4, 5.6meq/L

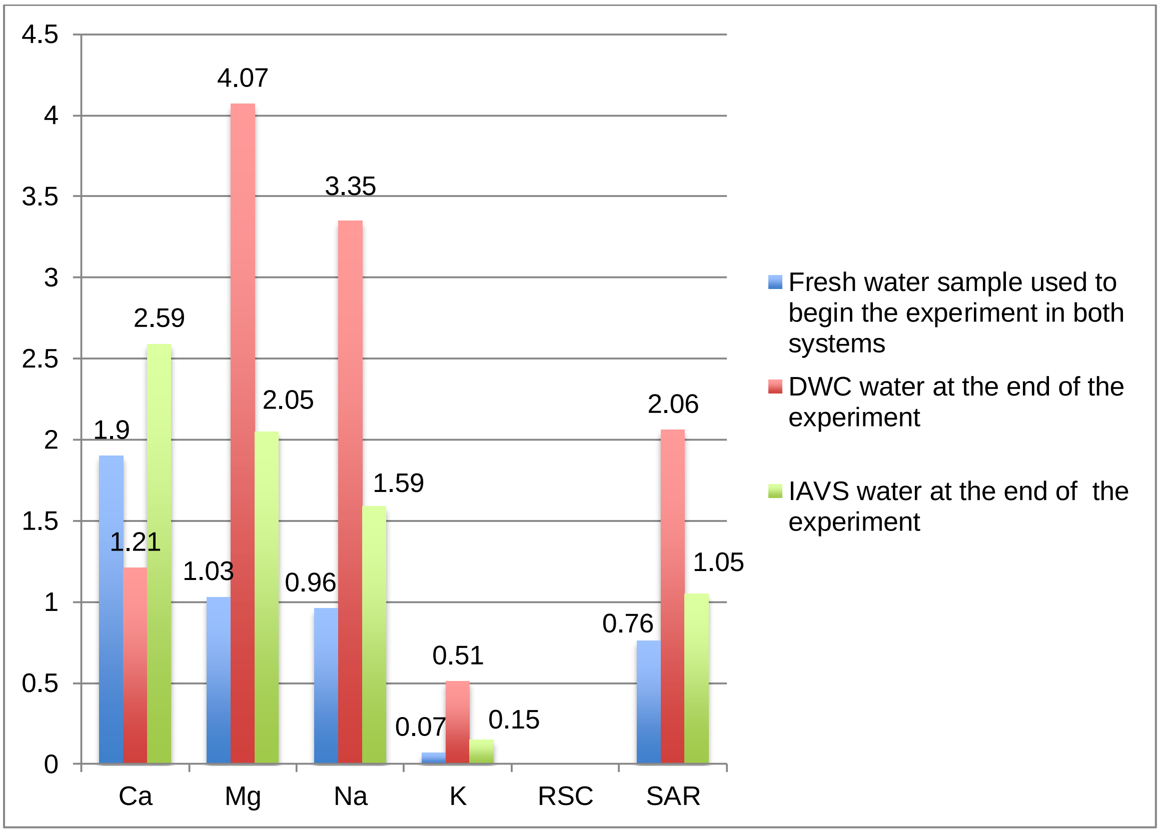

Figure 78: DWC has the highest Mg with 4.07, Na with 3.35, k with 0.51 and SAR with 2.06. While Ca is highest in DWC with 1.9 meq/L

Table 7: Water elements Concentrations (mg/L)

Concentrations (mg/1)	NH4	NO3	P	Fe	Mn	Zn	CU	B	C0	Cd	Cr	NI	Pb	Si	As
Fresh water sample from beginning of the experiment in both systems	0	10.01	0.317	0.169	0.145	0.155	0.0147	0.079	0	0	0	0	0	0	0
DWC water at the end of the experiment	0	6.30	31.624	3.824	0.165	0.210	0.151	0.185	0	0	0	0.001	0	36.14	0.423
IAVS water at the end of the experiment	2.1	17.01	4.574	0.225	0.149	0.151	0.145	0.083	0	0	0	0	0	39.18	0.405

4.6 IAVS Sand test before and after the experiment

A soil analysis was completed on sand samples from the IAVS before and after the experiment. This was done in order to understand the changes to the sand elements during the experiment, which affects plants in the IAVS system.

The sand used in the IAVS was moderately alkaline with a pH of 7.8 before the experiment, while was slightly alkaline after the experiment with a pH of 7.2.

The saturation percentage (SP) of the soil equals the weight of water required to saturate the pore space divided by the weight of the dry sand. The SP is useful for characterizing the sand’s texture, as shown in Figure 79. Very sandy soils have SP of less than 20 percent; whereas, sandy loam-to-loam soil SP ranges are between 20 – 35 percent. The IAVS SP rose to 22 percent after the experiment.

Figure 80, Figure 81, Figure 82 and Figure 83 show the chemical analysis of saturated soil paste, also show total and available macro/micronutrients and heavy metal content of the sand samples from the IAVS before and after the experiment.

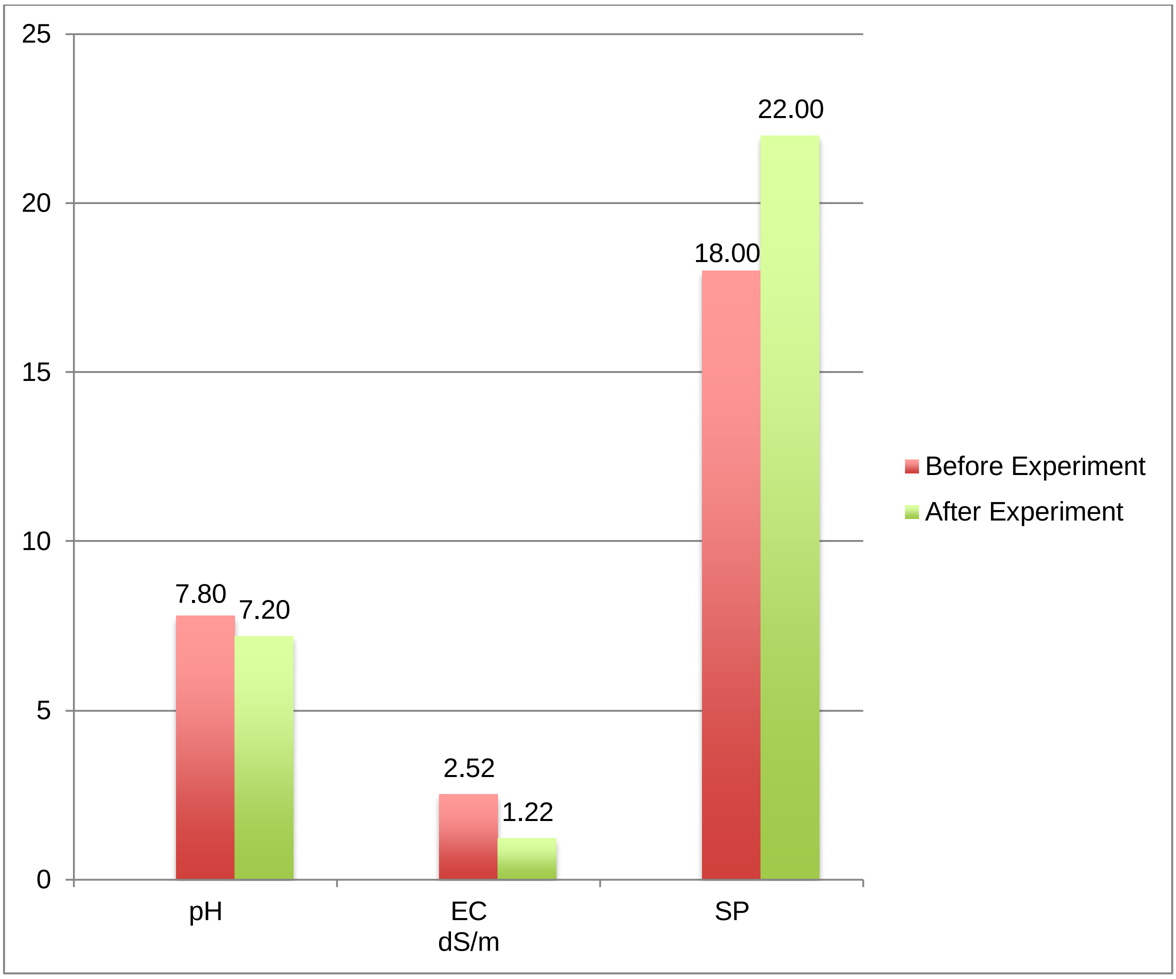

Figure 79: EC, pH and SP in IAVS before and after the experiment

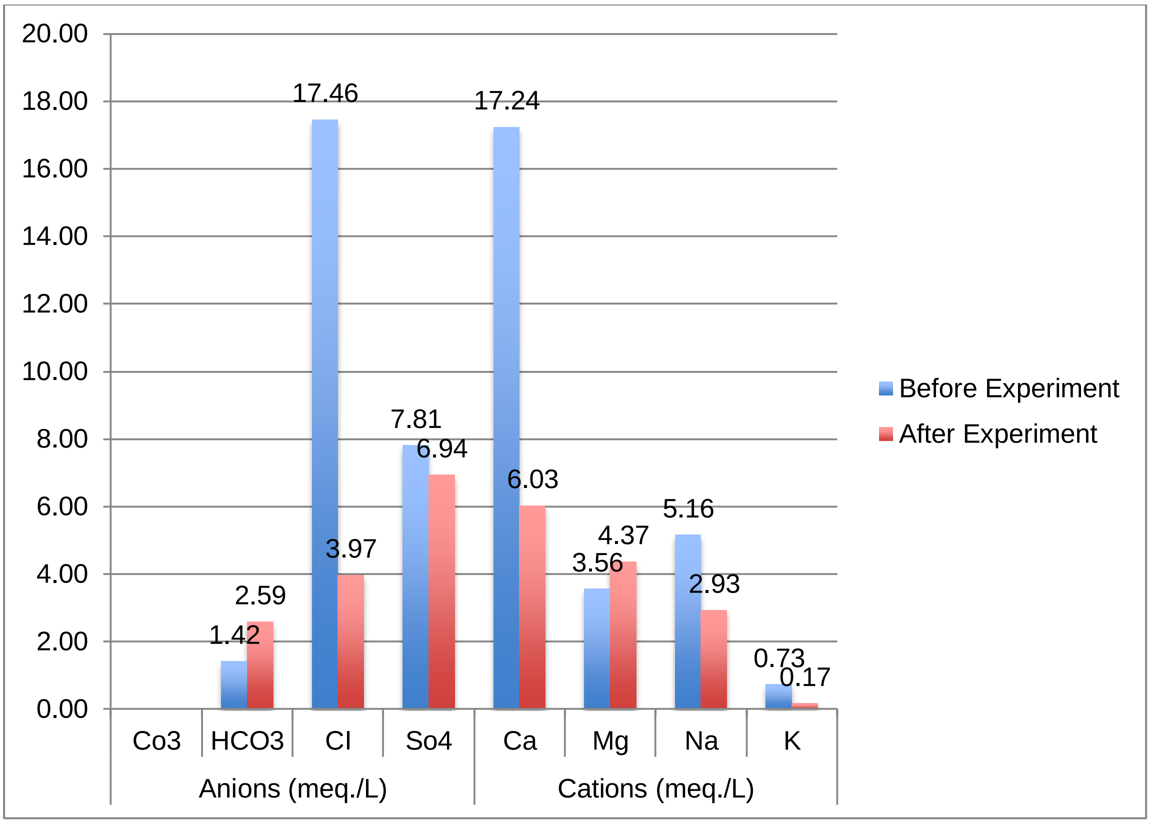

Figure 80: Anions and Cations in IAVS before and after the experiment

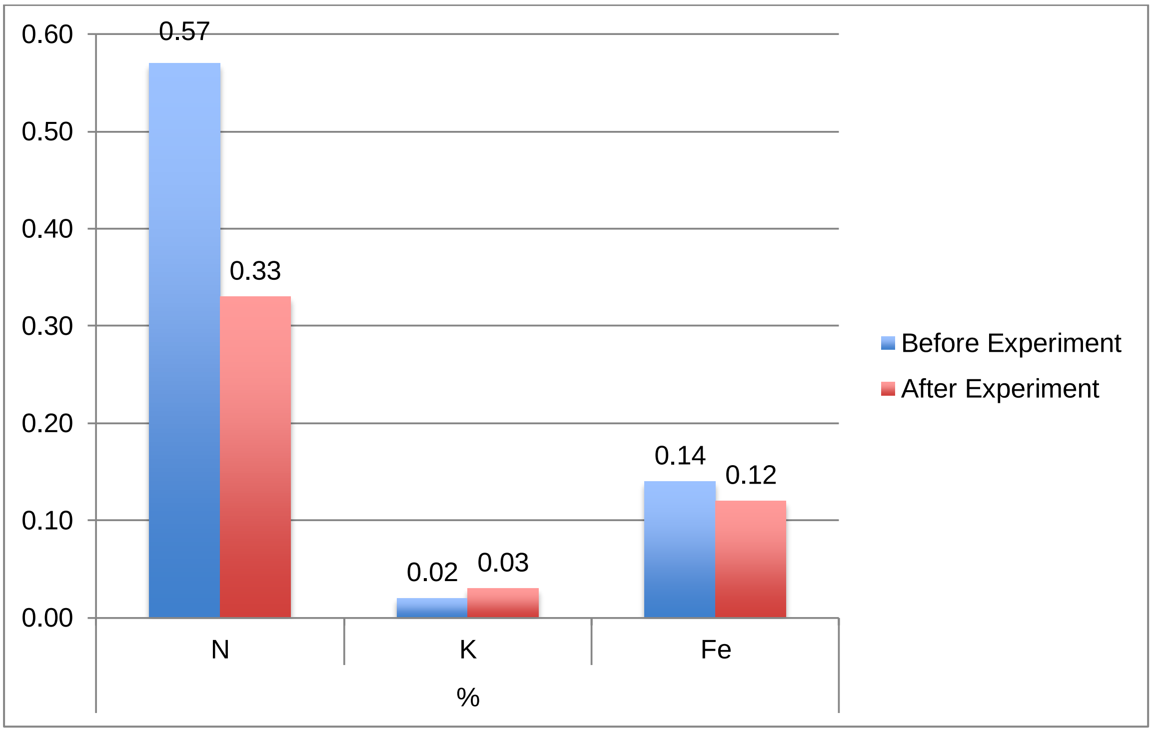

Figure 81: Total Nitrogen and Iron percentages dropped after the experiment. Note no iron was added to the IAVS during the experiment contrary to the DWC system.

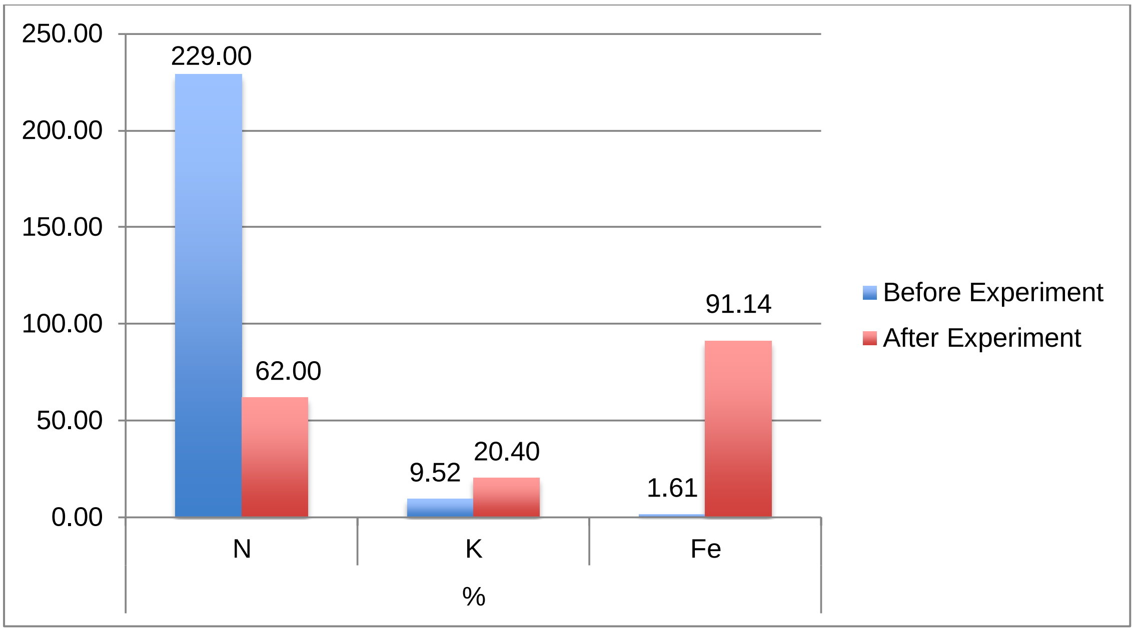

Figure 82: Available Nitrogen and Iron percentages dropped after the experiment. Note that no Iron was added to the IAVS during the experiment in contrary to DWC system.

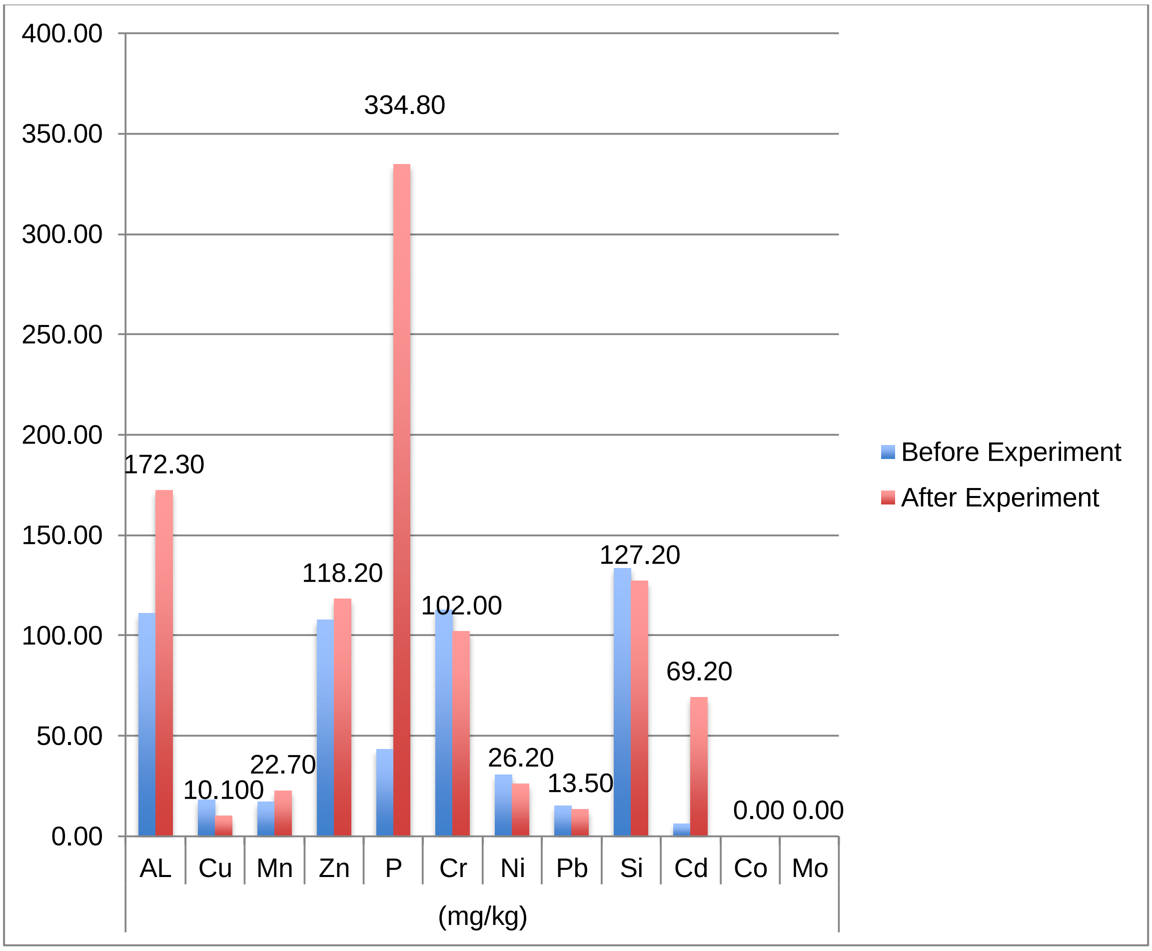

Figure 83: Total macro/micronutrients and heavy metal content of the sand samples, showing high phosphorus showing the noticeable eutrophication phenomena.

Figure 84 shows the Phosphorus content in the sand from the IAVS after the experiment has a very high concentration of 334.8 mg/kg and available 162.4 mg/kg.

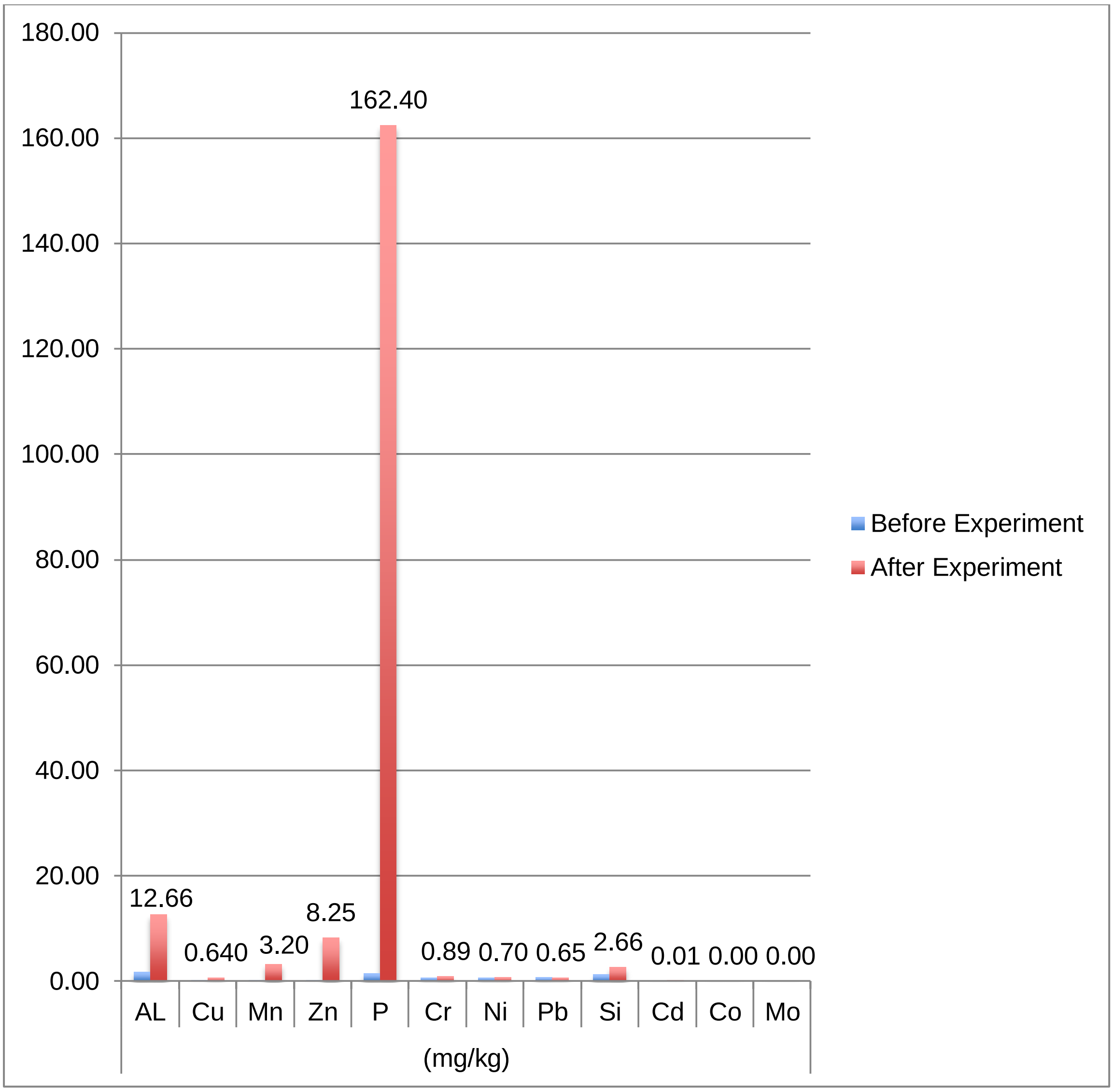

Figure 84: Available macro/micronutrients and heavy metal content of the sand samples, showing high phosphorus showing the noticeable eutrophication phenomena.

Figure 85 shows the IAVS sand condition before and after the experiment. The picture on the right shows the contamination of the algae due to utrophication on the surface of the IAVS sand on the last day of the experiment. This is caused by the high phosphorus rates in the sand analysis. Eutrophication caused the death of the fish in the IAVS tank.

Figure 85: Left, the IAVS sand on the first day and on the right, the sand on the last day of the experiment.

4.7 DWC and IAVS microbiological water analysis after the experiment

Salmonella and fecal coliform are bacteria whose presence can indicate water contaminated by human or animal wastes, which can cause short-term health effects. They may also pose a greater risk to people with severely weakened immune systems such as the elderly and young children. After the experiment, indicators, in both DWC and IAVS water, are showing normal rates (See Figure 86, Figure 87 and Figure 88). Also, it is noted that three cells of the Salmonella and Shigella bacteria were detected per milliliter caused by the stools of a rodent. These rates are not significant and do not affect the water quality.

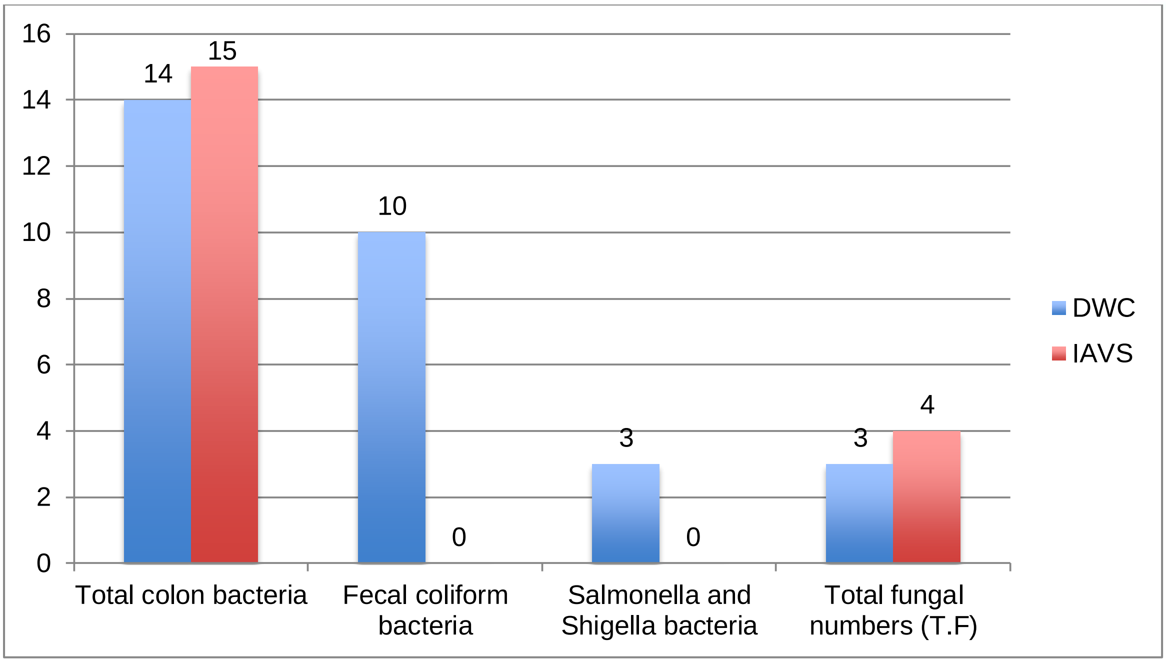

Figure 86: The graph shows the harmful bacteria in DWC and IAVS water – cell per milliliter.

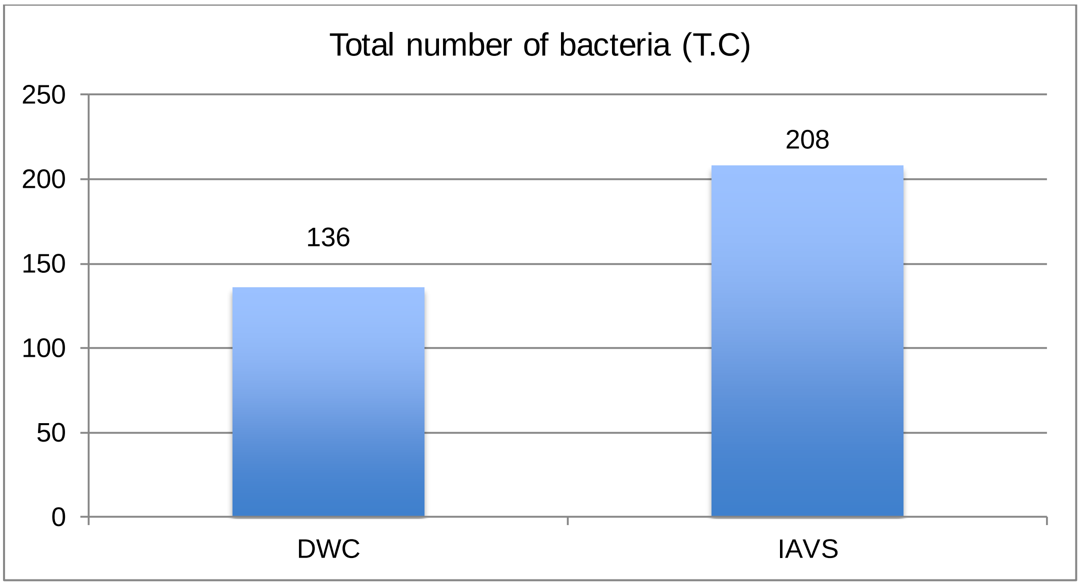

Figure 87: The graph shows the total number of bacteria in the DWC and IAVS (T.C)

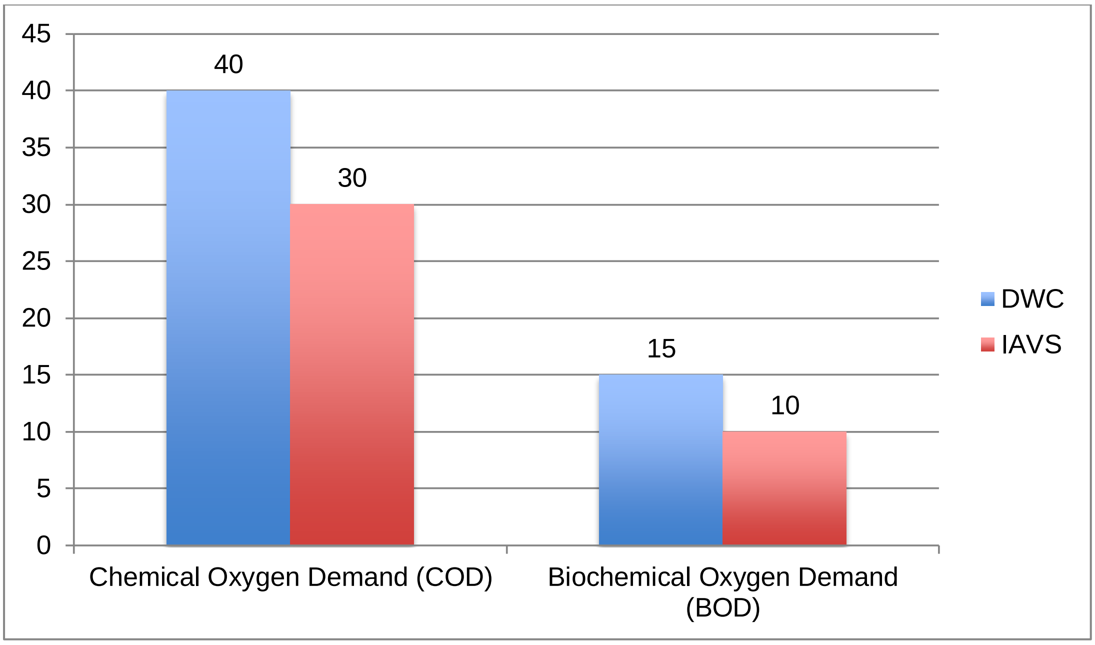

Figure 88: The graph shows COD and BOD in the DWC and IAVS.

4.8 DWC and IAVS Molokheya samples productivity analysis:

A comparison was made between Molokheya samples from the DWC, IAVS and organic Molokheya from Metro market. After analyzing the results from the Molokheya samples from the DWC and IAVS, no pesticides were detected as shown in Figure 89, while Organic Molokheya from the market showed insignificant traces of pesticides at 0.01 mg/kg.

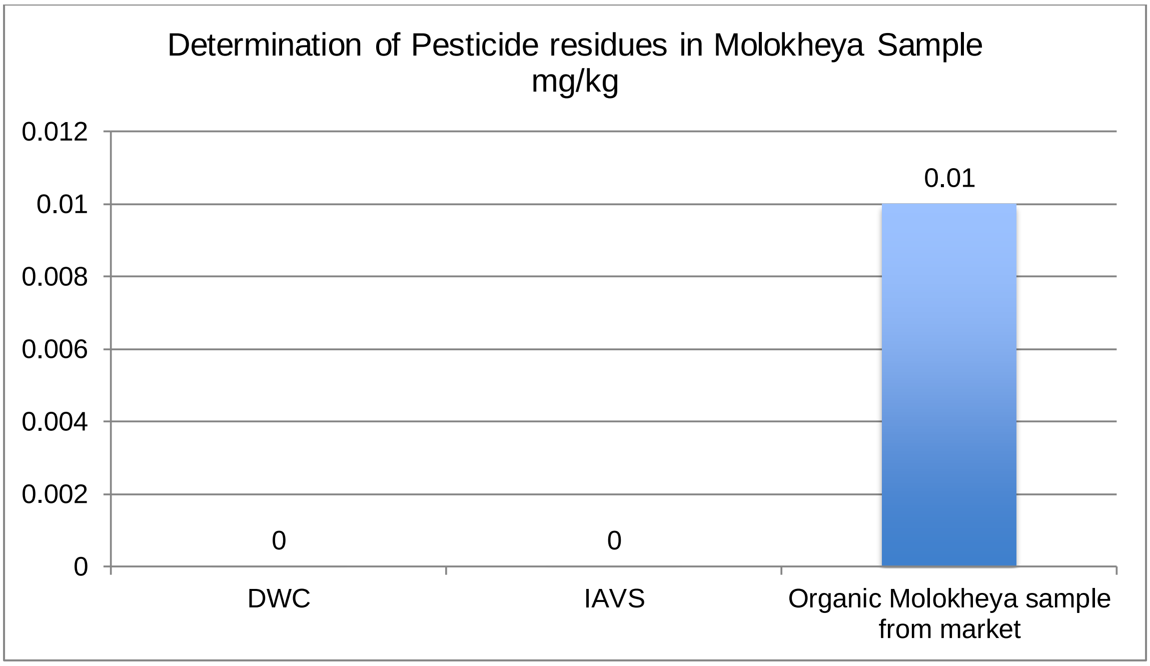

Figure 89: Pesticide traces found in Molokheya from the DWC and IAVS.

The elemental analysis of Molokheya samples from the DWC, IAVS, and organic Molokheya from the market shows close results. The organic Molokehya has higher manganese, copper and zinc. DWC is slightly richer than IAVS in these elements, as shown in Table 8.

The water content was higher in the organic Molokheya sample, compared to the samples from the IAVS and DWC, as shown in Figure 90.

Table 8: Elemental analysis of the Molokheya from the DWC and IAVS

Elemental Analysis for Molokheya mg/kg	Mercury	Antimony	Cadmium	Lead	Tin	Manganese	Copper	Zinc	Nickel	Cobalt	Chromium
DWC	0	0.53	0.05	0.09	0	10.3	2	7	0	0	0
IAVS	0	0.63	0.05	0	0	9.2	2.8	6	0	0	0
Organic Molokheya Sample from the market	0	0	0.05	0	0	12.4	3.5	7.8	0	0	0

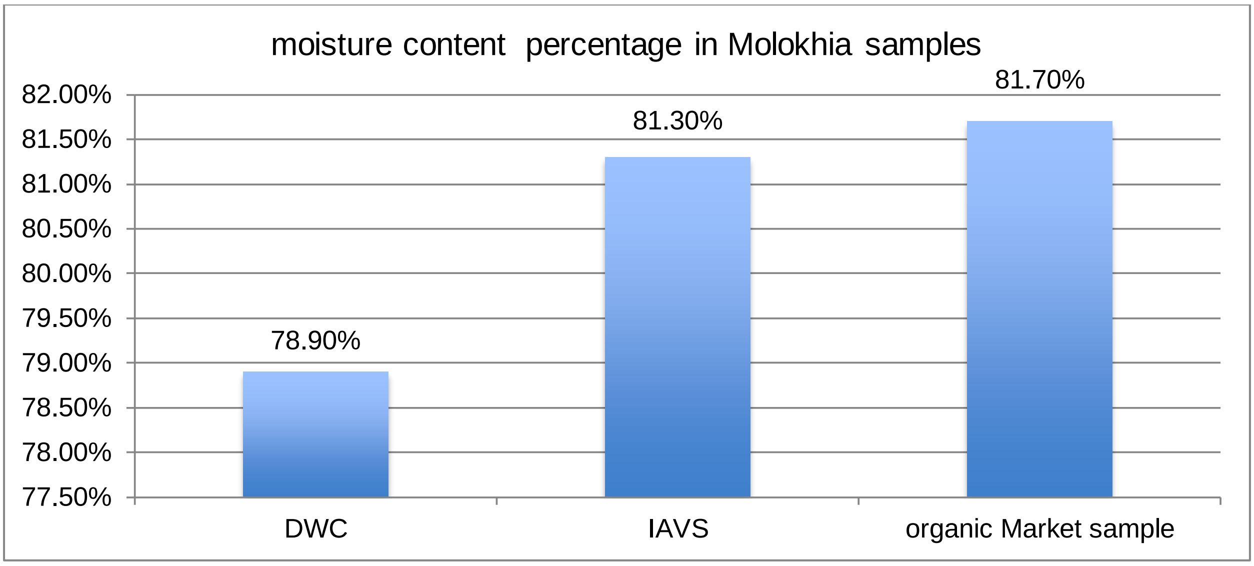

Figure 90: Moisture content percentage in Molokheya samples

Calcium content in the Molokheya is highest in samples from the IAVS and lowest in the organic sample from market, as shown in Figure 91.

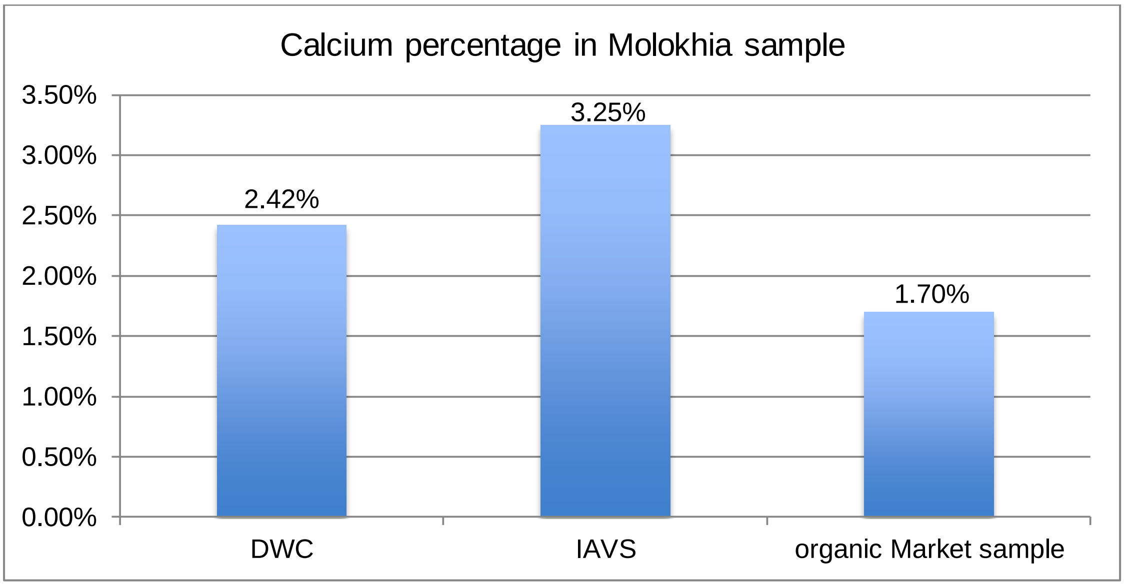

Figure 91: Ca percentage in Molokheya samples.

The organic sample is very rich in iron compared to the DWC and IAVS samples, shown in Figure 92.

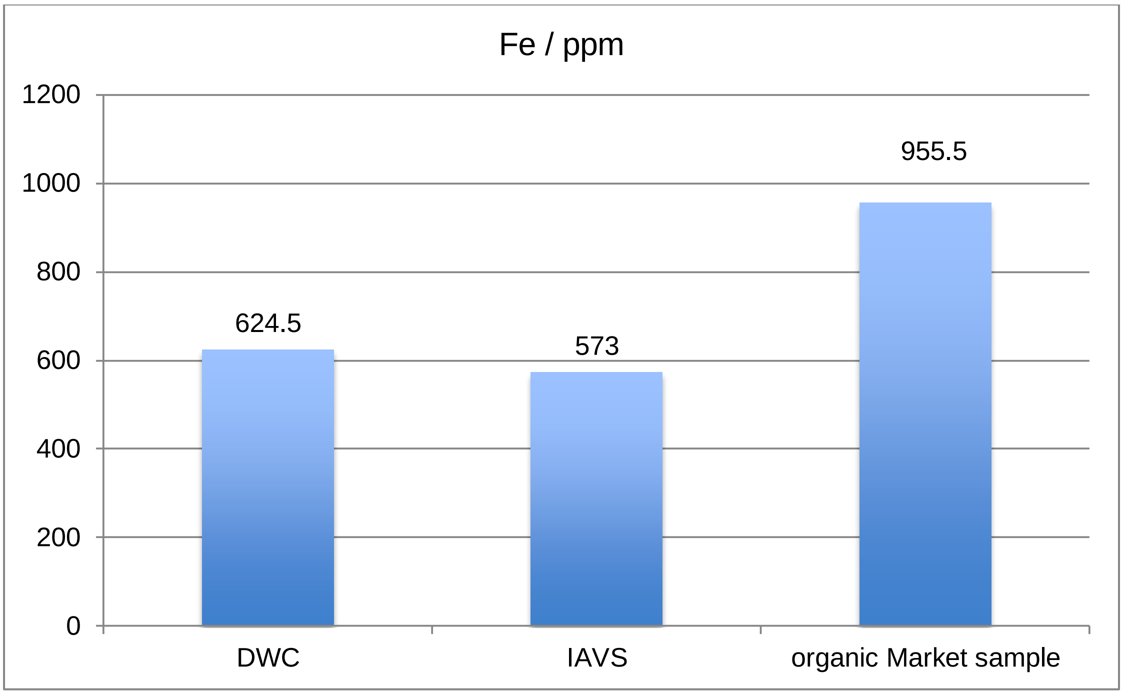

Figure 92: Fe percentages in Molokheya samples.

Figure 93 show the Vitamin A (Beta-carotene) content in the Molokheya samples. Organic sample from market is richest in Vitamin A compared to the IAVS DWC samples. The sample from the IAVS is significantly richer in Vitamin A than the DWC sample.

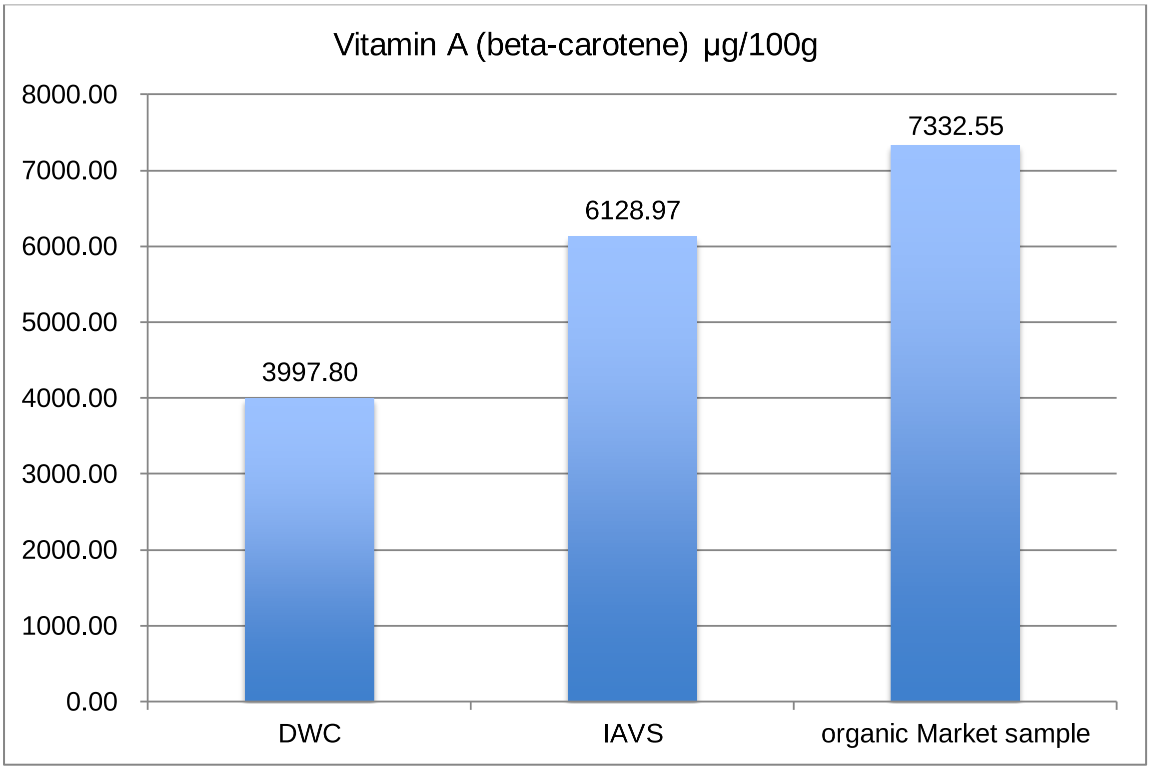

Figure 93: Vitamin A (Beta-carotene) content in Molokheya samples.

5 Chapter 5: Summary Discussion, Conclusions, and Recommendations

5.1 Summary Discussion and Conclusions

The source of water that is used at the beginning of the experiment in both systems is dechlorinated tap water as tap water is often treated with chlorine and chloramines to remove bacteria and pathogens to be potable water. Chlorine and chloramines are toxic to fish, plants and nitrifying bacteria. Thereby, Tap water that was used in the experiment was stored before use to allow all and chloramines to dispel into the atmosphere. This way takes up to 48 hours to have stored dechlorinated tap water to be used in the aquaponics experiment. This process also can be occurred faster if the water is aerated with air stones that are connected to the air pump in the aquaponics (FAO, 2015).

The dechlorinated tap water that is used in the experiment was naturally rich in nitrate as shown in Table 7. The high nitrate levels in the water source impacted ammonia levels in both systems. Ammonia has harmful effects on fish growth and plant stress. Ammonia at concentrations of 0.07 mg/L causes tissue damage and slow fish growth. The acceptable ranges for toxic ammonia for fish is 0-2 mg (Rakocy, Bailey, Shultz, & Thoman, 2004).
Ammonia level was already high in IAVS system from the most beginning when the experiment was launched.
Nutrient-rich water can lead to eutrophication (FAO, 2015). The increase of nutrients in water affects the ecosystem, increasing algae blooms and decreasing the dissolved oxygen causing Eutrophication process (Aguilara-Titus et al., 2014).

Additionally, Eutrophication problem contributed also in increasing ammonia level in IAVS. Therefore, installing a mechanical filter will be inevitable in mitigating the high concentration of Ammonia through preventing the accumulation of solid waste in IAVS, due to the decomposition of solid waste. While on the other side, the ammonia concentration remained at its normal rate in DWC. As a result, high Ammonia level has negative impact on fish health and appetite, which was apparently noticeable in the IVAS experiment.

TDS was originally low at the beginning of the experiments as stated before in Figure 75. It was notable that TDS in DWC was doubled in comparison to IVAS, due to the accumulation of the soluble elements from fish feed, which was mainly because of better fish nutrition, as ammonia levels were lower which caused fish appetite to grow. Fish appetite in IAVS was declining till fish stop feeding. Fish feeding behavior is very important as good fish appetite is a major indicator of healthy fish in aquaponics. If fish appetite decline or if the stop feeding, this is a sign of poor quality water in the Aquaponic. (FAO, 2015)

Plants need to absorb thirteen nutrients from the water. These nutrients are: boron, calcium, chlorine, copper, iron, magnesium, molybdenum, nitrogen, potassium, phosphorus, sulfur and zinc (Aguilara-Titus et al., 2014). While phosphorus rates were high in both systems which it can be inferred that fish intensification production of waste is higher than the capacity of the current grow beds in the experiment. Larger grow beds in both systems could be used in future experiments to grow more crops and produce more food with the same fish tanks and fish amounts.

The cause of many algae blooms is also phosphorus. Algae, often inhibited by lack of phosphorus, blooms, consumes oxygen, and turns once vibrant, ecologically diverse waters into green, dead sludge.
High Phosphorus rates cause a Hypertrophication or Eutrophication phenomena, which is an enrichment of the water from minerals like phosphorus. This causes an increased production of algae that will cause the depletion of fish as the water quality deteriorates (Aure & Stigebrandt, 1990).

Phosphorus was much higher in DWC due to the accumulation of the soluble elements from fish feed as well as and larger fish feed portions to meet the increased fish appetite.
The exposure of fish tanks of both systems and the mechanical filter of the DWC to sunlight resulted in algae flourish. Thus, it is recommended to cover the tanks and limit sunlight exposure control algae effect in eutrophication process.

Ultraviolet (UV) light from the sun is also a problem for nitrifying bacteria as these bacteria are photosensitive organisms. UV affects the Nitrifying bacteria negatively and this also affects the nitrification process in the aquaponics systems (FAO, 2015). Covering fish tanks can be a simple solution for this, also the rafts in the DWC system is preventing direct UV effect on the nitrifying bacteria in the water grow beds. IAVS fish tanks can be also covered, while IAVS sand grow beds is exposed to UV without cover, and this can be a threat for the nitrification process in IAVS grow beds.

Iron is a necessary supplement that should be added to DWC system (Rakocy, Bailey, Shultz, & Thoman, 2004). Iron is added to DWC system at a concentration of 2 mg/L once every two to three weeks. While in IAVS system, iron levels increased significantly in the system and the crops without any involvement. This is one of the main strength points in IAVS systems, as IAVS doesn't need any supplements to grow high quality crops.

DWC and IAVS are completely safe. There are no concerns regarding the integration between fish and plant that could cause food safety problems.
Regarding IAVS soil analysis, there was elements accumulation which blocks water leakage, resulting in losing sand porosity which is one of the IAVS system advantages. Sand porosity is essential in allowing oxygen to reach the plants for respiration. Thus, a well-aerated soil is crucial for the whole process success.
It is also vital to eliminate any heavy metals in fish feed like antimony, caladium, or lid in order not hinder self-water recycling process in aquaponics system because these metals would remain in the closed water cycle of Aquaponics even if in very low traces.

The results answers the research questions as Aquaponics can be considered a strategic ally to conventional agriculture in Egypt today and to be a strong alternative to land reclamation and traditional farming methods in the future. On the short term, aquaponics has one major drawback which is the high CAPEX and OPEX compared with those of conventional agriculture. However, on the long term it could save the huge amounts of water wasted by conventional agriculture and land reclamation up to 85 percent (AlShrouf, 2017).

IAVS system is more efficient with less CAPEX and OPEX than DWC. IAVS is also more productive especially in producing more crop variety. Till now DWC systems are capable to produce only leafy vegetables and herbs, despite the fact that Egyptians are not familiar with eating leafy vegetables as main foods like other European countries

(Soethoudt, 2016). IAVS system shows that it can provide diversity and variety of crop production.

IAVS can be the suitable aquaponics design solution for Egyptian market, since IAVS systems cost about 20% less than DWC aquaponics system, while DWC is used to be known as the most successful commercial aquaponics system.

IAVS also solves the plants and products variety issue in Aquaponics. The experiment and the thesis proven that most of the crops grew better and produced better in IAVS than DWC. The availability of sand in Egypt will make the CAPEX and OPEX less, and will enable a bigger scale models for mass production.

The comparison between DWC and IAVS systems showed that the major differences were not in quality but quantity. Food production quality is slightly higher in DWC but not significantly; both systems produce high quality organic food. However, IAVS is producing more amounts and wider varieties of crops with less CAPEX and OPEX. Both DWC and IAVS are consuming much less water than conventional agriculture. Fish production was more by 8% in DWC.

It is highly recommended to give the IAVS a try and more research as this system can help Egyptians in areas that are suffering from water scarce to produce high quality various food. Fish production results were so close in both systems and slightly more in DWC. More research and work are needed for new designs of IAVS with more efficient materials to lower the CAPEX and OPEX. It will be very useful to research more on the reasons for the rapid amounts of phosphorus that were found in both DWC water and IAVS sand. Also more research about The Eutrophication phenomena in Aquaponics will help a lot in producing more food either plant of fish.

5.2 Limitations, Recommendations and Future work:

One of the main remarks was the death of fish in IAVS fish tank. Fish tanks were exposed to sunlight that helps in rapid algae blooming. Algae and high concentration of phosphorus in water caused what is known as Eutrophication phenomena that affected fish in IAVS. The flooding/ flushing irrigation system in IAVS allows water to remain in

the sand grow bed exposed to sunlight. Dead algae were noticed on the surface of the IAVS sand grow bed, turning the sand's surface first into green then into black.
It is recommended to make microfilteration (MF) process for water that comes out of grow beds before going back again to the fish tanks. This will help to separate microorganisms and suspended particles from process water through a type of physical filtration process where contaminated water is passed through a special pore-sized membrane. MF can be installed in the last phase of water circulation before it is pumped again into fish tanks. Some aggregates like pebbles could also be used in the IAVS sand grow bed. Pebbles can be put as a first phase after water comes out of the fish tank. When water is flooded from IAVS fish tank by gravity force, it will be full of algae from the fish tank because of the sunlight. Water will fall on the pebbles and algae will remain on the pebbles giving the green look and then it will drain to the sand grow bed in IAVS with the least amount of algae. A mechanical filter could be needed to be added to IAVS.

Aquaponics complexity lies in applying and having the best results especially on a huge scale. Aquaponics systems are nearly closed cycle systems including two organisms with different conditions and needs. Accordingly it is always important to invest in the research and development of Aquaponics' design using the latest efficient technologies, while being also sustainable. This can be achieved using local and recycled materials in order to reduce the Aquaponics' CAPEX and OPEX for the small farmers and startups. Aquaponics' productions are still targeting the niche market asking for high quality organic products. Aquaponics have a high potential to help the Egyptian economy through promoting export. This requires all stakeholders to work together including the Egyptian government to raise awareness and support the new ideas including small Aquaponics' projects. Egypt highly depends on conventional agriculture and land reclamation, which inefficiently exploit Egypt's resources. For this reason, Aquaponics can be a strong ally to conventional agriculture and land reclamation in Egypt. Although Aquaponics' cost can be seen expensive, especially for small farmers and startups, yet the profit per acre can reach 30 times more than the profit from land reclamation or conventional agriculture. Fish is also a byproduct that increases the profit.

In accordance, researching Aquaponics' new technologies and new techniques is highly recommended. Aquaponics' designs include commercial scales such as low budgets technologies versus high budgets technologies. It is important to choose the right scale and design of Aquaponics to reach optimum results.

On another side, more research and experiments are required to design more efficient aquaponics. In the near future, it will be important to use product design techniques with aquaponics and integrate aquaponics more with home appliances. Many people will be able to purchase the new customized aquaponics at home to produce clean and organic vegetables and protein. While researchers will need to work more on reducing the high CAPEX and OPEX of aquaponics and to apply more practical and economical designs, to enable aquaponics to be a part of everyone's life style in the near future.

6 References

1.5 million Feddan Project-SIS. (2016). Retrieved January 16, 2017, from http://www.sis.gov.eg/section/352/4996?lang=

Abou Amra, M. (2015, June 3). Exclusive “ministry of Agriculture”: The cost of one feddan of “Million and half feddan” project equals 185 thousand Egyptian pounds [Newspaper]. Retrieved June 5, 2017, from http://www.elwatannews.com/news/details/743327

Adriansen, H. K. (2009). Land reclamation in Egypt: A study of life in the new lands. *Geoforum*, *40*(4), 664–674. https://doi.org/10.1016/j.geoforum.2009.05.006

Aguilara-Titus, J., Cao, Y., Kazyak, E., Kumar, K., Li, K., Louie, A., … others. (2014). EVALUATING ALTERNATIVE NUTRIENT SOURCES IN SUBSISTENCE-LEVEL AQUAPONIC SYSTEMS. Retrieved from http://drum.lib.umd.edu/handle/1903/15533

Ahmed, M. T. (2010). Life Cycle Analysis in Wastewater: A Sustainability Perspective. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 125–154). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_75

AlShrouf, A. (2017). Hydroponics, Aeroponic and Aquaponic as Compared with Conventional Farming. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *27*, 247–255.

Aly, A. A. A.-R. (2007). THE SUGGESTED CROPPING PATTERNS FOR DESERT LANDS ON THE CONTEXT OF GROUNDWATER LIMITATION. Retrieved from http://www.iwtc.info/2007_pdf/1-1.pdf

Aure, J., & Stigebrandt, A. (1990). Quantitative estimates of the eutrophication effects of fish farming on fjords. *Aquaculture*, *90*(2), 135–156. https://doi.org/10.1016/0044-8486(90)90337-M

Barceló, D., Petrovic, M., & Alemany, J. (2010). Problems and Needs of Sustainable Water Management in the Mediterranean Area: Conclusions and Recommendations. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 295–305). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_92

Baudoin, W., Nono-Womdim, R., Lutaladio, N., & Hodder, A. (2013). *Good Agricultural Practices for greenhouse vegetable crops - Principles for Mediterranean climate areas* (p. 640). Rome: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS. Retrieved from http://www.fao.org/3/a-i3284e.pdf

Bernstein, S. (2011). *Aquaponic Gardening: A Step-By-Step Guide to Raising Vegetables and Fish Together*. New Society Publishers.

Beyene, T., Lettenmaier, D. P., & Kabat, P. (2010). Hydrologic impacts of climate change on the Nile River Basin: implications of the 2007 IPCC scenarios. *Climatic Change*, *100*(3–4), 433–461. https://doi.org/10.1007/s10584-009-9693-0

Bizikova, L., Roy, D., Swanson, D., Venema, H. D., & McCandless, M. (2013). *The water-energy-food security nexus: Towards a practical planning and decision-support framework for landscape investment and risk management*. International Institute for Sustainable Development. Retrieved from http://empoderamiento.info/biblioteca/files/original/8e66ac686bf713f8c49a55d85db1e8fa.pdf

Browne, C., DI BATTISTA, A., GEIGER, T., & GUTKNECHT, T. (2014). The executive opinion survey: The voice of the business community. *The Global Competitiveness Report 2014–2015*, 69–78.

Chenini, F. (2010a). Evaluation of the Three Decades of Treated Wastewater Reuse in Tunisia. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 215–227). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_65

Chenini, F. (2010b). Overview of New Practices in the Reclaimed Water Reuses in the Mediterranean Countries. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 43–62). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_61

Choukr-Allah, R. (2010). Innovative Wastewater Treatments and Reuse Technologies Adapted to Southern Mediterranean Countries. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 29–41). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_87

Conway, D. (1996). The Impacts of Climate Variability and Future Climate Change in the Nile Basin on Water Resources in Egypt. *International Journal of Water Resources Development*, *12*(3), 277–296. https://doi.org/10.1080/07900629650178

Dillon, J. L., & Hardaker, J. B. (1980). *Farm management research for small farmer development*. Rome: Food and Agriculture Organization of the United Nations.

Diver, S. (2006). *Aquaponics-Integration of hydroponics with aquaculture*. Attra. Retrieved from http://cichlidfish.net/Ebooks/aquaponic.pdf

EEAA. (2010). *Egypt State of Environment 2010* (p. 353). Retrieved from http://www.eeaa.gov.eg/portals/0/eeaaReports/SoE2011en/completereport/SOE-2010-En.pdf

El-Ramady, H. R., El-Marsafawy, S. M., & Lewis, L. N. (2013). Sustainable Agriculture and Climate Changes in Egypt. In E. Lichtfouse (Ed.), *Sustainable Agriculture Reviews* (pp. 41–95). Springer Netherlands. https://doi.org/10.1007/978-94-007-5961-9_2

Essa, M. A., Goda, A., Hanafy, M. A., El-Shebly, A. A., Mohamed, R. A., & El-Ebiary, E. H. (2008). Small-scale fish culture: guiding models of aquaponics and net-enclosures fish farming in Egypt. *Egyptian Journal of Aquatic Research*, *34*(3), 320–337.

FAO (Ed.). (2015). *Meeting the 2015 international hunger targets: taking stock of uneven progress*. Rome: FAO.

Fuerhacker, M., & Haile, T. M. (2010). Treatment and Reuse of Sludge. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 63–92). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_60

Gomaa, R. (2017, April 21). Aquaponics CAPEX and OPEX in Egypt.

Guerrero, J., Edwards, C. F., Wan, D. Y., & Sheth, V. (2013). Using Wireless Sensor Network Controls to Monitor an Indoor Aquaponics System. *RET: Research Experiences for Teachers on Sensor Networks*. Retrieved from http://www.teo.unt.edu/ret/pdf2013/Aquaponics-report.pdf

Hanlon, P., Madel, R., Olson-Sawyer, K., Rabin, K., Rose, J., Demaline, K., … Sweetman, K. (2013). Food, Water and Energy.

Hanna, F., & Osman, M. A. G. (1995). Agricultural land resources and the future of land reclamation and development in Egypt. *Egyptian Agriculture Profile. CIHEAM Options Méditerr. Sér. B. Etud. Rech*, *9*, 15–32.

Hassanen, M. (2017, May 24). Big scale aquaponics CAPEX and OPEX.

Hendrickson, M. K., & Porth, M. (2012). Urban agriculture—best practices and possibilities. *University of Missouri*, 1–52.

Heshmati, G. A., & Squires, V. R. (Eds.). (2013). *Combating Desertification in Asia, Africa and the Middle East*. Dordrecht: Springer Netherlands. Retrieved from http://link.springer.com/10.1007/978-94-007-6652-5

Hinkel, J., Brown, S., Exner, L., Nicholls, R. J., Vafeidis, A. T., & Kebede, A. S. (2012). Sea-level rise impacts on Africa and the effects of mitigation and adaptation: an application of DIVA. *Regional Environmental Change*, *12*(1), 207–224. https://doi.org/10.1007/s10113-011-0249-2

Howland, A., Kim, N., & Marks, A. (2012). ADVANCED FOOD TECHNOLOGIES. In *Advanced Seminar in Landscape+ Urbanism, Spring*.

Hussain, A., Iqbal, K., Aziem, S., Mahato, P., & Negi, A. K. (2014). A Review On The Science Of Growing Crops Without Soil (Soilless Culture)-A Novel Alternative For Growing Crops. *International Journal of Agriculture and Crop Sciences*, *7*(11), 833.

iAVs Layout Options | iAVs. (2017). Retrieved October 6, 2017, from http://iavs.info/backyard/iavs-layout-options/

Iglesias, A., Garrote, L., Flores, F., & Moneo, M. (2007). Challenges to Manage the Risk of Water Scarcity and Climate Change in the Mediterranean. *Water Resources Management*, *21*(5), 775–788. https://doi.org/10.1007/s11269-006-9111-6

IRENA. (2015). *RENEWABLE ENERGY IN THE WATER, ENERGY & FOOD NEXUS* (p. 128). Abu Dhabi, United Arab: International Renewable Energy Agency. Retrieved from http://www.irena.org/documentdownloads/publications/irena_water_energy_food_nexus_2015.pdf

Jones, S. (2002). Evolution of Aquaponics. *Aquaponics Journal*, *VI*, *No. 1*. Retrieved from http://aquaponics.com/wp-content/uploads/articles/evoluton-of-Aquaponics.pdf

Jr, J. B. J. (2016). *Hydroponics: A Practical Guide for the Soilless Grower*. CRC Press.

Kampa, E., Choukr-Allah, R., Ahmed, M. T., & Fürhacker, M. (2010). Constraints of Application of Wastewater Treatment and Reuse in Mediterranean Partner Countries. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 93–124). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_62

Khakyzadeh, V., Luque, R., Zolfigol, M. A., Vahidian, H. R., Salehzadeh, H., Moradi, V., … Xu, K. (2015). Waste to wealth: a sustainable aquaponic system based on residual nitrogen photoconversion. *RSC Adv.*, *5*(5), 3917–3921. https://doi.org/10.1039/C4RA15242E

Khouzam, R. F. (2002). *Economic aspects of wastewater reuse: the Egyptian case*. Cairo, Egypt: Economic Research Forum for the Arab Countries, Iran & Turkey.

Kishk, M. A. (1993). Combating Desertification, is it always Possible? The Case of Small Egyptian Farmers. *GeoJournal*, *31*(1), 77–84.

Klinger-Bowen, R. C., Tamaru, C. S., Fox, B. K., McGovern-Hopkins, K., & Howerton, R. (2011). *Testing your Aquaponic System Water: A Comparison of Commercial Water Chemistry Methods*. Center for Tropical and Subtropical Aquaculture, University of Hawaii.

Loutfy, N. M. (2010). Reuse of Wastewater in Mediterranean Region, Egyptian Experience. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the*

Mediterranean Region (pp. 183–213). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_76

Malato, S., Oller, I., Fernández-Ibáñez, P., & Fuerhacker, M. (2010). Technologies for Advanced Wastewater Treatment in the Mediterranean Region. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 1–28). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_59

McCarl, B. A., Musumba, M., Smith, J. B., Kirshen, P., Jones, R., El-Ganzori, A., … Hynninen, R. (2015). Climate change vulnerability and adaptation strategies in Egypt's agricultural sector. *Mitigation and Adaptation Strategies for Global Change*, *20*(7), 1097–1109. https://doi.org/10.1007/s11027-013-9520-9

McMurtry, M., Nelson, P. V., Sanders, D. C., & Hodges, L. (1990). Sand Culture of Vegetables Using Recirculated Aquaculture Effluents. *Applied Agricultural Research, Vol. 5, No. 4*, 280–284.

Menon, R., Sahana, G. V., Shruthi, V., & Suganya, R. (2013). Small Scale Aquaponic System. Retrieved from http://www.ripublication.com/ijafst_spl/ijafstv4n9spl_15.pdf

Monica, 1776 Main Street Santa, & 90401-3208, C. (n.d.). Population Growth in Egypt - A Continuing Policy Challenge | RAND. Retrieved January 16, 2017, from http://www.rand.org/pubs/issue_papers/IP183/index2.html

NICOLAE, C., POPA, D., RAHOVEANU, A., DUMITRACHE, F., MOCUȚA, D., & ELIA, E. (2015). LOW-TECH AQUAPONIC SYSTEM BASED ON AN ORNAMENTAL AQUARIUM. *Scientific Papers*, *LVIII*, 6.

Nigam, S., & Balcom, P. (2016). Project OASIS: Optimizing Aquaponic Systems to Improve Sustainability. *Honors Theses and Capstones*. Retrieved from http://scholars.unh.edu/honors/272

Nigatu, G., & Dinar, A. (2011). Modeling efficiency, equity and externality in the Eastern Nile River basin. *Water Science Policy Center. University of California, Riverside. See: Http://Wspc. Ucr. Edu/Working_papers/WSPC_WP_02_0611_Modeling% 20Nile. Pdf*.

No Progress on Egypt-Ethiopia Dam Negotiations. (2014, May 14). Retrieved September 18, 2017, from https://eastafricawatch.wordpress.com/2014/05/14/no-progress-on-egypt-ethiopia-dam-negotiations/

Onyeji, S. C., & Fischer, G. (1994). An economic analysis of potential impacts of climate change in Egypt. *Global Environmental Change*, *4*(4), 281–299. https://doi.org/10.1016/0959-3780(94)90029-9

Pérez, S., Köck, M., Tong, L., Ginebreda, A., López-Serna, R., Postigo, C., … Barceló, D. (2010). Wastewater Reuse in the Mediterranean Area of Catalonia, Spain: Case Study of Reuse of Tertiary Effluent from a Wastewater Treatment Plant at el Prat de Llobregat (Barcelona). In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 249–294). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_88

Pfeiffer, A., Silva, E., & Colquhoun, J. (2015). Innovation in urban agricultural practices: Responding to diverse production environments. *Renewable Agriculture and Food Systems*, *30*(01), 79–91. https://doi.org/10.1017/S1742170513000537

Radwan, H. (2013). Sensitivity Analysis of Head Loss Equations on the Design of Improved Irrigation On-Farm System In Egypt. *International Journal of Advancements in Research & Technology*, *Volume 2*(Issue1), 9.

Rakocy, J. E., Bailey, D. S., Shultz, R. C., & Thoman, E. S. (2004). Update on tilapia and vegetable production in the UVI aquaponic system. In *New Dimensions on Farmed Tilapia: Proceedings of the Sixth International Symposium on Tilapia in Aquaculture, Held September* (pp. 12–16). Retrieved from https://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/676.pdf

Sadek, S. (2010). An overview on desert aquaculture in Egypt. In *Aquaculture in desert and arid lands: developmental constraints and opportunities. FAO technical workshop* (pp. 6–8). Retrieved from http://www.fao.org/3/a-ba0114e/ba0114e08.pdf

Samhan, S., Al-Sa'ed, R., Assaf, K., Friese, K., Afferden, M., Muller, R., … Zimmo, O. (2010). Wastewater Management Overview in the Occupied Palestinian Territory. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 229–248). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_64

Savidov, N. A. (2011). Aquaponics: Protein and vegetables for developing countries. Michael A Nichols Institute of Natural Resources, Massey University, Private Bag 11-222, Palmerston North, New Zealand. Retrieved from http://users.ugent.be/~sdeneve/Full%20paper/Nichols_full.docx

SDS Egypt 2030. (2016). Egypt 2030 - SDS Egypt 2030. Retrieved March 26, 2017, from http://sdsegypt2030.com?lang=en

Seada, T., Mohamed, R., Fletscher, T., Abouleish, H., & Abouleish-Boes, M. (2016). *The Future of Agriculture in Egypt* (No. 1.0) (p. 24). Sekem, Egypt: Heliopolis University. Retrieved from http://www.sekem.com/assets/the-future-of-agriculture-in-egypt.pdf

Shamrukh, M., Corapcioglu, M. Y., & Hassona, F. A. A. (2001). Modeling the Effect of Chemical Fertilizers on Ground Water Quality in the Nile Valley Aquifer, Egypt. *Ground Water*, *39*(1), 59–67. https://doi.org/10.1111/j.1745-6584.2001.tb00351.x

Soethoudt, J. M. (2016). Opportunities hydro-and aquaponics in Egypt. Retrieved from http://www.agroberichtenbuitenland.nl/cairo/wp-content/uploads/sites/3/2016/04/WUR-Opportunities-for-hydro-and-aquaponics-in-Egypt-Han-Soethoudt.pdf

Somerville, C., & Food and Agriculture Organization of the United Nations. (2015). *Small-scale aquaponic food production: integrated fish and plant farming*.

Szirmai, A. (2012). Industrialisation as an engine of growth in developing countries, 1950–2005. *Structural Change and Economic Dynamics*, *23*(4), 406–420. https://doi.org/10.1016/j.strueco.2011.01.005

Tate, B., & Verdonk, R. (2016). *Egypt: Egyptian Land Reclamation Efforts | USDA Foreign Agricultural Service*. Retrieved from http://www.fas.usda.gov/data/egypt-egyptian-land-reclamation-efforts

The World Factbook — Central Intelligence Agency. (2016). Retrieved November 10, 2016, from https://www.cia.gov/library/publications/the-world-factbook/geos/eg.html

Tortajada, C. (2008). *Water as a Human Right for the Middle East and North Africa*. London, CA: Routledge. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10255099

UNEP Year Book 2012. (2012). *Sustainable Futures: Multi-Disciplinary Perspectives on Multi-Level Transitions*, *2*, 149. https://doi.org/10.1016/j.envdev.2012.03.004

Voll, S. P. (1980). Egyptian Land Reclamation since the Revolution. *Middle East Journal*, *34*(2), 127–148.

Wahaab, R. A. (2003). Sustainable Development and Environmental Impact Assessment in Egypt: Historical Assessment. *Environmentalist*, *23*(1), 49–70. https://doi.org/10.1023/A:1022991509577

Yates, D. N., & Strzepek, K. M. (1998). An Assessment of Integrated Climate Change Impacts on the Agricultural Economy of Egypt. *Climatic Change*, *38*(3), 261–287. https://doi.org/10.1023/A:1005364515266

Zaki, M. H. (2011, October 30). Lettuce agricutlre in Egypt [Blog]. Retrieved June 5, 2017, from http://www.agricultureegypt.com/ArticleDetails.aspx?CatID=e533c309-c8b1-4606-a3b0-5a115362ee0b&ID=5f401db9-13c7-435b-b7c1-55d861695583

Zeinobia. (2013, June 17). Egyptian Chronicles: Cairo University’s report on Ethiopia’s Great Renaissance Dam. Retrieved from http://egyptianchronicles.blogspot.com.eg/2013/06/cairo-universitys-report-on-ethiopias.html

Zhang Ying, Block Paul, Hammond Michael, & King Andrew. (2015). Ethiopia's Grand Renaissance Dam: Implications for Downstream Riparian Countries. *Journal of Water Resources Planning and Management*, *141*(9), 05015002. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000520

Zimmo, O. R., & Imseih, N. (2010). Overview of Wastewater Management Practices in the Mediterranean Region. In D. Barceló & M. Petrovic (Eds.), *Waste Water Treatment and Reuse in the Mediterranean Region* (pp. 155–181). Springer Berlin Heidelberg. https://doi.org/10.1007/698_2010_63

7 Appendix

وزارة الزراعة واستصلاح الاراضى
Ministry of Agriculture and Land Reclamation
ARC
مركز البحوث الزراعية
Agricultural Research Center

S.W.E.R.I
معهد بحوث الاراضى والمياه والبيئة
Soils, Water & Environment Res. Ins. (SWERI)
وحدة الأراضى والمياه والبيئة
مكون التحاليل والدراسات

From : Unit of Soils, Water and Environment.
Analyses and Studies Component.

To : Centre For Sustainable development (AUC)-Code. (DWC) – Receipt No.(2207).

Subject : Chemical analysis, macro and micro nutrients as well as, heavy metals Content of water sample which delivered by yours.

EC (dS/m)	0.85	**Concentration (mg/l)**	
ppm	544.0	NH_4^+	0.00
pH	6.9	NO_3^-	6.30
Soluble Anions (meq./l)		P	31.624
$CO_3^=$	-	Fe	3.824
HCO_3^-	1.32	Mn	0.165
Cl^-	2.22	Zn	0.210
$SO_4^=$	5.60	Cu	0.151
Soluble Cations (meq./l)		B	0.185
Ca^{++}	1.21	CO	0.00
Mg^{++}	4.07	Cd	0.00
Na^+	3.35	Cr	0.00
K^+	0.51	Ni	0.001
RSC	-	Pb	0.00
SAR	2.06	Si	36.14
		As	0.423

With Our Best Regards,

مركز البحوث الزراعية
وحدة الأراضى والمياه والبيئة

المشرف
على مكون التحاليل والدراسات
٢٠١٧/٩/٥
أ.د نبيل قنديل

مدير تنفيذى
أ.د. محمد الخولى

رئيس مجلس الإدارة
ومدير المعهد
أ.د. محمد إسماعيل

Address : 9 Cairo Univ. Street, Giza, Egypt
Area Code : 12112
P.O. Box : 175 El-Orman, Egypt
Tel : 02 35724269 - 02 35720608
Fax : 02 35720608

العنـــــوان : ٩ ش جامعة القاهرة - الجيزة - مصر
رمز بريدى : ١٢١١٢
ص.ب : ١٧٥ الأورمان - مصر
تليفـــــون : ٠٢ ٣٥٧٢٤٢٦٩ - ٠٢ ٣٥٧٢٠٦٠٨
فاكـــــس : ٠٢ ٣٥٧٢٠٦٠٨

Website : www.sweri-eg.com
e-mail : sweri@arc.sci.eg

Chemical analysis, Macro and micro nutrients as well as Heavy metals content of water sample of DWC Aquaponics system during the experiment

وزارة الزراعة واستصلاح الأراضي
Ministry of Agriculture and Land Reclamation
ARC
مركز البحوث الزراعية
Agricultural Research Center

S.W.E.RI
معهد بحوث الأراضي والمياه والبيئة
Soils, Water & Environment Res. Ins. (SWERI)
وحدة الأراضي والمياه والبيئة
مكون التحاليل والدراسات

From : Unit of Soils, Water and Environment.
Analyses and Studies Component.

To : Centre For Sustainable development (AUC)-Code. (IAVS) – Receipt No.(2207).

Subject : Chemical analysis, macro and micro nutrients as well as , heavy metals Content of water sample which delivered by yours.

EC (dS/m)	0.59
ppm	377.0
pH	7.6
Soluble Anions (meq./l)	
$CO_3^{=}$	-
HCO_3^-	2.26
Cl^-	1.27
$SO_4^{=}$	2.85
Soluble Cations (meq./l)	
Ca^{++}	2.59
Mg^{++}	2.05
Na^+	1.59
K^+	0.15
RSC	-
SAR	1.05

Concentration (mg/l)	
NH_4^+	2.10
NO_3^-	17.01
P	4.574
Fe	0.225
Mn	0.149
Zn	0.151
Cu	0.145
B	0.083
CO	0.00
Cd	0.00
Cr	0.00
Ni	0.00
Pb	0.00
Si	39.18
As	0.405

With Our Best Regards,

المشرف على مكون التحاليل والدراسات
٠١٧/٩/٥
أ.د نبيل قنديل

مدير تنفيذي
أ.د. محمد الخولي

مركز البحوث الزراعية
وحدة الأراضي والمياه والبيئة
رئيس مجلس الإدارة ومدير المعهد
أ.د. محمد إسماعيل

Address : 9 Cairo Univ. Street, Giza, Egypt
Area Code : 12112
P.O. Box : 175 El-Orman, Egypt
Tel : 02 35724269 - 02 35720608
Fax : 02 35720608
العنوان : ٩ ش جامعة القاهرة - الجيزة - مصر
رمز بريدي : ١٢١١٢
ص.ب : ١٧٥ الأورمان - مصر
تليفون : ٠٢ ٣٥٧٢٤٢٦٩ - ٠٢ ٣٥٧٢٠٦٠٨
فاكس : ٠٢ ٣٥٧٢٠٦٠٨
Website : www.sweri-eg.com
e-mail : sweri@arc.sci.eg

Chemical analysis, Macro and micro nutrients as well as Heavy metals content of water sample of IAVS Aquaponics system during the experiment

وزارة الزراعة واستصلاح الأراضي
Ministry of Agriculture and Land Reclamation
ARC
مركز البحوث الزراعية
Agricultural Research Center

معهد بحوث الأراضي والمياه والبيئة
Soils, Water & Environment Res. Ins. (SWERI)
وحدة الأراضي والمياه والبيئة
مكون التحاليل والدراسات

From :Unit of Soils, Water and Environment.
Analyses and Studies Component.

To: Centre For Sustainable development (AUC)-Code. (Tap Water) – Receipt No.(2207).

Subject :Chemical analysis, macro and micro nutrients Content of water sample which delivered by yours.

EC (dS/m)	0.41	**Concentration (mg/l)**	
ppm	262.0	**NH_4^+**	0.00
pH	7.6	**NO_3^-**	10.01
Soluble Anions (meq./l)		**P**	0.317
$CO_3^=$	-	**Fe**	0.169
HCO_3^-	1.51	**Mn**	0.145
Cl^-	1.27	**Zn**	0.155
$SO_4^=$	1.45	**Cu**	0.0147
Soluble Cations (meq./l)		**B**	0.079
Ca^{++}	1.90		
Mg^{++}	1.30		
Na^+	0.96		
K^+	0.07		
RSC	-		
SAR	0.76		

With Our Best Regards,

المشرف
على مكون التحاليل والدراسات
أ.د نبيل قنديل

مدير تنفيذي
أ.د. محمد الخولي

أ.د. محمد إسماعيل

Address : 9 Cairo Univ. Street, Giza, Egypt
Area Code : 12112
P.O. Box : 175 El-Orman, Egypt
Tel : 02 35724269 - 02 35720608
Fax : 02 35720608
Website : www.sweri-eg.com
e-mail : sweri@arc.sci.eg

العنوان : ٩ ش جامعة القاهرة - الجيزة - مصر
رمز بريدي : ١٢١١٢
ص.ب : ١٧٥ الأورمان - مصر
تليفون : ٠٢ ٣٥٧٢٤٢٦٩ - ٠٢ ٣٥٧٢٠٦٠٨
فاكس : ٠٢ ٣٥٧٢٠٦٠٨

Chemical analysis, Macro and micro nutrients as well as Heavy metals content of water sample of the water source that is used in both DWC and IAVS Aquaponics system before the experiment

Table(1): Chemical analysis of saturated soil paste.

Code	pH	EC	SP	Anions (meq. / L)				Cations (meq. / L)			
	1:2.5	dS/m		$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
PRE	7.80	2.52	18.0	-	1.42	17.46	7.81	17.24	3.56	5.16	0.73
POST	7.20	1.22	22.0	-	2.59	3.97	6.94	6.03	4.37	2.93	0.17

Table (2): Total macro, micronutrients and heavy metal content of the soil samples.

Code	%			(mg/kg)												
	N	K	Fe	Al	Cu	Mn	Zn	P	Cr	Ni	Pb	Si	Cd	Co	Mo
PRE	0.57	0.02	0.14	111.1	18.20	17.20	107.80	43.00	112.80	30.60	15.10	133.5	6.10	0.00	0.00
POST	0.33	0.03	0.12	172.3	10.10	22.70	118.20	334.80	102.0	26.20	13.50	127.2	69.20	0.00	0.00

Table (3): Available macro, micronutrients & heavy metal content of the soil samples.

Code	(mg/kg)														
	N	K	Fe	Al	Cu	Mn	Zn	P	Cr	Ni	Pb	Si	Cd	Co	Mo
PRE	229.0	9.52	1.61	1.72	0.018	0.04	0.11	1.47	0.67	0.67	0.72	1.26	0.00	0.00	0.00
POST	62.0	20.4	91.14	12.66	0.640	3.20	8.25	162.40	0.89	0.70	0.65	2.66	0.01	0.00	0.00

Chemical analysis of saturated soil paste, as well as total and available macro, micronutrient and heavy metal contents in sand media in IAVS.

وزارة الزراعة
مركز البحوث الزراعية
المركز الاقليمي للاغذية والاعلاف

شهادة تحليل تخصصية

اسم العميل: مركز التنمية المستدامة بالجامعة الامريكية بالقاهرة (مداولة /هشام العيسوى) التاريخ :٢٠١٧/٩/١٨

رقم العينة	نوع العينة	حديد جزء في المليون	كالسيوم	-----
١٢٠٠	ملوخية (١) DWC	٦٢٤,٥٠	%٢,٤٢	--------------
١٢٠١	ملوخية (٢) LAVS	٥٧٣,٠	%٣,٢٥	--------------
١٢٠٢	ملوخية (٣)MARKET	٩٥٥,٥٠	%١,٧٠	-----------

ملخص النتائج : النتيجة تمثل العينة الواردة للمعمل فقط

تم التحليل بعد التجفيف

مدير المركز الاقليمي

"د.اشرف هاشم جمعة "

٩ش الجامعة ـ الجيزة . ت: 5731989 – 5732280 ـ فاكس : 5732280 ص.ب 588 الأورمان e-mail ; clff@intouch.com

Iron and Calcium elemental analysis for Molokheya samples from DWC, IAVS and organic sample from market.

وزارة الزراعة
مركز البحوث الزراعية
المركز الأقليمي للأغذية والأعلاف

اسم العميل : مركز التنمية المستدامة بالجامعة الأمريكية بالقاهرة (مناولة/ هشام العيسوى)   التاريخ : ٢٠١٧/٩/١٢

رقم العينة	نوع العينـة	دهن %	ألياف %	رطوبة %	رماد %	------	----
١٢٠٠	ملوخية (١) DWC	--------	-------	٧٨,٩	----------	--------	------
١٢٠١	ملوخية (٢)LAVS	--------	-------	٨١,٣	----------	--------	------
١٢٠٢	ملوخية (٣)MARKET	--------	-------	٨١,٧	----------	---	----

ملخص النتائج :النتيجة تمثل العينة الواردة للمعمل فقط

مدير المركز الاقليمى

" د . أشرف هاشم جمعة "

٩ش الجامعة ـ الجيزة ـ ت: ٥٧٣١٩٨٩ ـ ٥٧٣٢٢٨٠ ـ فاكس :٥٧٣٢٢٨٠ ص.ب ٥٨٨ الأورمان e-mail : clff@intouch.com

Water content analysis for Molokheya samples from DWC, IAVS and organic sample from market.

٢٠١٧/٦/١٣ ١٠٥

RCFF

ACCREDITED
CERTIFICATE

مركز البحوث الزراعية
المركز الإقليمي للأغذية والأعلاف

مسلسل رقم :٨

مرفق (١)
شهادة تحليل الفيتامينات
Certificate of Vitamins analysis

العنوان :القاهرة
رقم العينة :١١٩٩
تاريخ انتهاء التحليل :٢٠١٧/٩/١٧

العميل : مركز التنمية المستدامة بالجامعة الأمريكية (مناولة /هشام العيسوى)
نوع العينة : ملوخية (٣) MARKET
تاريخ استلام العينة :٢٠١٧/٩/١٠
حالة العينة :فريش

Type of Vitamin	Result	Unit	Estimated Uncertainty (U)
Vit(A) B-carotene	3997.8	µg/100g	±103.94

- تمثل العينة الواردة للمركز الإقليمي للأغذية والأعلاف
- البيانات الخاصة بالعينة طبقا لما ورد بطلب التحليل الخاص بالعميل
*نتائج خارج الأيزو

طرق الاختبارات :

- Vitamin A, Danish official, HPLC method No. AF 255.1, 3rd ed .1996 National food Agency of Denmark
- Vitamin B_1 &B_2, Danish official, HPLC method No. AB 189.2 (1996) – National food Agency of Denmark.
- Vitamin C, Danish official, HPLC method No. AB 113.2, journal of chroma tography B 730(1999) pp101-111
- This uncertainty represents an expanded uncertainty (type A) expressed at approximately the 95 % confidence level using a coverage factor of K = 2
- Traceability trace to SI units is achieved through using Certified Reference Material or In House Reference Material, which is traceable to SI units

RCFF

توصيات :

....

....

الراي الفني عن النتائج تكون على مسئولية المركز الإقليمي وليست على مسئولية A2LA

مدير المركز الإقليمي

الاسم : د/ أشرف هاشم جمعة
التوقيع :
التاريخ : ٢٠١٧/٩/١٧

٩ ش الجامعة – جيزة – ت ٣٥٧٣٢٢٢٨٠ـ ٣٥٧٣١٩٨٩ـ فاكس :٣٥٧١٣٢٥٠ ص ٠ ب ٥٨٨ـ أورمان الجيزة
المركز الإقليمي يسعده أن يحصل على آرائكم من أجل التحسين المستمر ويسعده تعاونكم في ملء مرفق قياس رضاء عميل

Vitamin (A) B-carotene analysis for Molokheya sample from market

٢٠١٧/٦/١٣ ف١٠

RCFF

مركز البحوث الزراعية
المركز الإقليمي للأغذية والأعلاف

مسلسل رقم :٧

ACCREDITED
CERTIFICATE

مرفق(أ)
شهادة تحليل الفيتامينات
Certificate of Vitamins analysis

العميـــل : مركز التنمية المستدامة بالجامعة الأمريكية (مناولة /هشام العيسوى)
نوع العينـــة : ملوخية (٢) IAVS
تاريخ استلام العينة : ٢٠١٧/٩/١٠
حالة العينة :فريش

العنوان :القاهرة
رقم العينة :١١٩٨
تاريخ انتهاء التحليل :٢٠١٧/٩/١٧

Type of Vitamin	Result	Unit	Estimated Uncertainty (U)
Vit(A) B-carotene	6128.97	µg/100g	±159.35

- تمثل العينة الواردة للمركز الإقليمي للأغذية والأعلاف
- البيانات الخاصة بالعينة طبقا لما ورد بطلب التحليل الخاص بالعميل

*نتائج خارج الأيزو

طرق الاختبارات :

- Vitamin A, Danish official, HPLC method No. AF 255.1, 3rd ed .1996 National food Agency of Denmark
- Vitamin B_1 &B_2, Danish official, HPLC method No. AB 189.2 (1996) - National food Agency of Denmark,
- Vitamin C, Danish official, HPLC method No. AB 113.2, journal of chroma tography B 730(1999) pp101-111
- This uncertainty represents an expanded uncertainty (type A) expressed at approximately the 95 % confidence level using a coverage factor of K = 2
- Traceability trace to SI units is achieved through using Certified Reference Material or In House Reference Material, which is traceable to SI units

RCFF

توصيات :

....

....

الرأي الفني عن النتائج تكون على مسئولية المركز الإقليمي وليست على مسئولية A2LA

مدير المركز الإقليمي

الاسم : د. / أشرف هاشم جمعة
التوقيع :
التاريخ : ٢٠١٧/٩/١٧

٩ ش الجامعة ـ جيزة ـ ت ٣٥٧٣٢٢٨٠ـ ٣٥٧٣١٩٨٩ـ فاكس :٣٥٧١٣٢٥٠ ص ٠ ب ٥٨٨ـ أورمان الجيزة
المركز الإقليمي يسعده أن يحصل على آرائكم من أجل التحسين المستمر ويسعده تعاونكم في ملء مرفق قياس رضاء عميل

Vitamin (A) B-carotene analysis for Molokheya sample from IAVS

٢٠١٧/٩/١٧ ١٠٥

RCFF

ACCREDITED

مركز البحوث الزراعية
المركز الإقليمي للأغذية والأعلاف

مسلسل رقم : ٦

مرفق (أ)

شهادة تحليل الفيتامينات

Certificate of Vitamins analysis

العميـــل : مركز التنمية المستدامة بالجامعة الأمريكية (مناولة /هشام العيسوى) العنوان : القاهرة
نوع العينـــة : ملوخية (١) DWC رقم العينة : ١١٩٧
تاريخ استلام العينة : ٢٠١٧/٩/١٠ تاريخ انتهاء التحليل : ٢٠١٧/٩/١٧
حالة العينة : طريش

Type of Vitamin	Result	Unit	Estimated Uncertainty (U)
Vit(A)B-carotene	7332.55	μg/100g	±190.64

- تمثل العينة الواردة للمركز الإقليمي للأغذية والأعلاف
- البيانات الخاصة بالعينة طبقا لما ورد بطلب التحليل الخاص بالعميل
- *نتائج خارج الأيزو

طرق الاختبارات :

- Vitamin A, Danish official, HPLC method No. AF 255.1, 3rd ed. 1996 National food Agency of Denmark
- Vitamin B_1 &B_2, Danish official, HPLC method No. AB 189.2 (1996) - National food Agency of Denmark,
- Vitamin C, Danish official, HPLC method No. AB 113.2, journal of chroma tography B 730(1999) pp101-111
- This uncertainty represents an expanded uncertainty (type A) expressed at approximately the 95 % confidence level using a coverage factor of K = 2
- Traceability trace to SI units is achieved through using Certified Reference Material or In House Reference Material, which is traceable to SI units

RCFF

توصيات :

....

....

الرأي الفني عن النتائج تكون على مسئولية المركز الإقليمي وليست على مسئولية A2LA

مدير المركز الإقليمي

الاســم : د. / أشرف هاشم جمعة
التوقيــع :
التاريــخ : ٢٠١٧/٩/١٧

٩ ش الجامعة – جيزة – ت ٣٥٧٣٢٢٨٠ - ٣٥٧٣١٩٨٩ - فاكس : ٣٥٧١٣٢٥٠ ص ب ٥٨٨ - أورمان الجيزة
المركز الإقليمي يسعده أن يحصل على آرائكم من أجل التحسين المستمر ويسعده تعاونكم في ملء مرفق قياس رضاء عميل

Vitamin (A) B-carotene analysis for Molokheya sample from DWC

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP

وزارة الزراعـة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Test Certificate

ilac-MRA

FINAS
Finnish Accreditation Service
T219 (EN ISO/IEC 17025)

Certificate Number: 600916

Sample ID: 2017 - 49074 **Date received:** 10-Sep-2017

Sample: Molokia **Number of sub samples** 0

Total sample weight: kg

Customer : Center For Sustainable Development (CSD)-AUC

Phone: 01111000455 **Fax:**

Protocol Number: Hesham Ahmed Samy **Number of Packages:** 0

Lot number: ------------ **Package size:** 0 kg

Sampling place: 1-DWC **Lot size:** ------------ kg

Destination Country: ------------

Sample ID : 49074 **Sample :** Molokia

Analysis ID : 55526 **Analysis Date :** 12 September, 2017

Method Name : QuEChERS Method

Method Description : Quick and Easy Method (QuEChERS) for Determination of Pesticide Residues in Foods Using LC-MSMS, GC-MSMS

European Standard Method EN 15662:2008

Results of analysis :

Compound or microbe	**Result :**
Pesticide Residues	**Not detected.**

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ± 50%.The list of LOQ's attached to this certificate are tested. (attachment PR-FV-Q1,version 4)

Person in Charge: Dr.Emad Ramadan Mohamed

Page 1 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com Website: www.qcap-egypt.com

٧شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية
تليفون : ٣٧٦٠١٣٩٥ (٢٠٢) - ٣٧٦١١٣٥٥ (٢٠٢)
فاكس : ٣٧٦١١٢١٦ (٢٠٢) - ٣٧٦١١١٠٦ (٢٠٢)

Pesticide residues analysis results for Molokheya sample from DWC

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP
مشروع مراقبة جودة المنتجات الزراعية

وزارة الزراعــة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Sample ID :	**49074**	**Sample :**	Molokia
Analysis ID :	55527	**Analysis Date :**	18 September, 2017
Method Name :	Heavy Metals in Foods (ICP-OES)		
Method Description :	Determination of Heavy Metals in foods by inductively coupled plasma optical emission spectrometry after high pressure microwave digestion *Food additives and contaminants, June 2003, Vol. 20, No. 6, P.543 – 552*		

Results of analysis :

Compound or microbe	**Result :**
Mercury	Not detected.
Antimony	0.53 mg/kg
Cadmium	0.05 mg/kg
Lead	0.09 mg/kg
Tin	< LOQ
Manganese	10.3 mg/kg
Copper	2. mg/kg
Zinc	7. mg/kg
Nickel	< LOQ
Cobalt	< LOQ
Chromium	< LOQ

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ±26%. The list of LOQ's attached to this certificate are tested (attachment HM8)

Person in Charge: Dr. Mona Khorshed

The sample was taken by the customer

Giza, Egypt - Monday, 18 September, 2017

Thank you for using our laboratory

Dr. Ashraf Elmarsafy
Director

Page 2 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com Website: www.qcap-egypt.com

٧شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية
تليفون : ٣٧٦٠١٣٩٥ (٢٠٢) - ٣٧٦١١٣٥٥ (٢٠٢)
فاكس : ٣٧٦١١٢١٦ (٢٠٢) - ٣٧٦١١١٠٦ (٢٠٢)

Heavy metals elemental analysis results for Molokheya sample from DWC

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP
مشروع مراقبة جودة المنتجات الزراعية

وزارة الزراعة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Test Certificate

ilac-MRA
FINAS Finnish Accreditation Service T219 (EN ISO/IEC 17025)

Certificate Number: 600917
Sample ID: 2017 - 49075 **Date received:** 10-Sep-2017
Sample: Molokia **Number of sub samples** 0
Total sample weight: kg
Customer: Center For Sustainable Development (CSD)-AUC
Phone: 01111000455 **Fax:**

Protocol Number: Hesham Ahmed Samy **Number of Packages:** 0
Lot number: ------------ **Package size:** 0 kg
Sampling place: 2 IAVS **Lot size:** ------------ kg
Destination Country: ------------
Sample ID : 49075 **Sample :** Molokia

Analysis ID : 55528 **Analysis Date :** 12 September, 2017
Method Name : QuEChERS Method
Method Description : Quick and Easy Method (QuEChERS) for Determination of Pesticide Residues in Foods Using LC-MSMS, GC-MSMS
European Standard Method EN 15662:2008

Results of analysis :

Compound or microbe	Result :
Pesticide Residues	Not detected.

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ± 50%.The list of LOQ's attached to this certificate are tested. (attachment PR-FV-Q1,version 4)

Person in Charge: Dr.Emad Ramadan Mohamed

This TEST CERTIFICATE shall not be reproduced except in full, without the written approval of the Laboratory.
Test results relate only to the items tested

Page 1 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com

٧ شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية
تليفون : ٣٧٦٠١٣٩٥ (٢٠٢) - ٣٧٦١١٣٥٥ (٢٠٢)
فاكس : ٣٧٦١١٢١٦ (٢٠٢) - ٣٧٦١١١٠٦ (٢٠٢)
Website: www.qcap-egypt.com

Pesticide residues analysis results for Molokheya sample from IAVS

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP
مشروع مراقبة جودة المنتجات الزراعية

وزارة الزراعة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Sample ID :	**49075**	**Sample :**	Molokia
Analysis ID :	55529	**Analysis Date :**	18 September, 2017
Method Name :	Heavy Metals in Foods (ICP-OES)		
Method Description :	Determination of Heavy Metals in foods by inductively coupled plasma optical emission spectrometry after high pressure microwave digestion *Food additives and contaminants, June 2003, Vol. 20, No. 6, P.543 – 552.*		

Results of analysis :

Compound or microbe	**Result :**
Mercury	Not detected.
Antimony	0.63 mg/kg
Cadmium	0.05 mg/kg
Lead	< LOQ
Tin	< LOQ
Manganese	9.2 mg/kg
Copper	2.8 mg/kg
Zinc	6. mg/kg
Nickel	< LOQ
Cobalt	< LOQ
Chromium	< LOQ

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ±26%. The list of LOQ's attached to this certificate are tested (attachment HM8)

Person in Charge: Dr. Mona Khorshed

The sample was taken by the customer

Giza, Egypt - Monday, 18 September, 2017

Thank you for using our laboratory

Dr. Ashraf Elmarsafy
Director

This TEST CERTIFICATE shall not be reproduced except in full, without the written approval of the Laboratory.
Test results relate only to the items tested

Page 2 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com

٧شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية
تليفون : ٣٧٦٠١٣٩٥ (٢٠٢) - ٣٧٦١١٣٥٥ (٢٠٢)
فاكس : ٣٧٦١١٢١٦ (٢٠٢) - ٣٧٦١١١٠٦ (٢٠٢)
Website: www.qcap-egypt.com

Heavy metals elemental analysis results for Molokheya sample from IAVS

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP
مشروع مراقبة جودة المنتجات الزراعية

وزارة الزراعــة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Test Certificate

ilac-MRA

FINAS
Finnish Accreditation Service
T219 (EN ISO/IEC 17025)

Certificate Number: 600918
Sample ID: 2017 - 49076 **Date received:** 10-Sep-2017
Sample: Molokia **Number of sub samples** 0
Total sample weight: kg

Customer : Center For Sustainable Development (CSD)-AUC

Phone: 01111000455 **Fax:**

Protocol Number: Hesham Ahmed Samy **Number of Packages:** 0
Lot number: ———— **Package size:** 0 kg
Sampling place: 3 Market **Lot size:** ———— kg
Destination Country: ————

Sample ID : 49076 **Sample :** Molokia
Analysis ID : 55530 **Analysis Date :** 12 September, 2017
Method Name : QuEChERS Method
Method Description : Quick and Easy Method (QuEChERS) for Determination of Pesticide Residues in Foods Using LC-MSMS, GC-MSMS
European Standard Method EN 15662:2008

Results of analysis :

Compound or microbe	Result :
Boscalid	< LOQ

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ± 50%. The list of LOQ's attached to this certificate are tested. (attachment :PR-FV-Q1, version 4)

Person in Charge: Dr.Emad Ramadan Mohamed

This TEST CERTIFICATE shall not be reproduced except in full, without the written approval of the Laboratory.
Test results relate only to the items tested

Page 1 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com Website: www.qcap-egypt.com

٧شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية

Pesticide residues analysis results for organic Molokheya Sample from the market

Ministry of Agriculture
Agricultural Research Center
Central Laboratory of Residue Analysis
of Pesticides and Heavy Metals in Food

QCAP
مشروع مراقبة جودة المنتجات الزراعية

وزارة الزراعـة
مركز البحوث الزراعية
المعمل المركزى لتحليل متبقيات المبيدات
والعناصر الثقيلة فى الأغذية

Sample ID : 49076 **Sample :** Molokia

Analysis ID : 55531 **Analysis Date :** 18 September, 2017

Method Name : Heavy Metals in Foods (ICP-OES)

Method Description : Determination of Heavy Metals in foods by inductively coupled plasma optical emission spectrometry after high pressure microwave digestion

Food additives and contaminants, June 2003, Vol. 20, No. 6, P.543 – 552.

Results of analysis :

Compound or microbe	Result :
Mercury	Not detected.
Antimony	< LOQ
Cadmium	0.05 mg/kg
Lead	< LOQ
Tin	< LOQ
Manganese	12.4 mg/kg
Copper	3.5 mg/kg
Zinc	7.8 mg/kg
Nickel	< LOQ
Cobalt	< LOQ
Chromium	< LOQ

The measurement uncertainty expressed as expanded uncertainty (at 95% confidence level) is within the range ±26%. The list of LOQ's attached to this certificate are tested (attachment HM8)

Person in Charge: Dr. Mona Khorshed

The sample was taken by the customer

Giza, Egypt - Monday, 18 September, 2017

Thank you for using our laborato[ry]

Dr. Ashraf Elmarsafy
Director

This TEST CERTIFICATE shall not be reproduced except in full, without the written approval of the Laboratory.
Test results relate only to the items tested

Page 2 (2)

7 Nadi El-said St. - Dokki - Giza - Egypt
Phone: Int +(202) 37601 395 - (202) 36711 355
Fax: Int + (202) 37611 216 - (202) 37611 106
E-mail: info@qcap-egypt.com Website: www.qcap-egypt.com

٧ شارع نادى الصيد - الدقى - الجيزة - جمهورية مصر العربية
تليفون : ٣٧٦٠١٣٩٥ (٢٠٢) - ٣٦٧١١٣٥٥ (٢٠٢)
فاكس : ٣٧٦١١٢١٦ (٢٠٢) - ٣٧٦١١١٠٦ (٢٠٢)

Heavy metals elemental analysis results for organic Molokheya sample from market

QCAP
Central Lab of Residue Analysis of Pesticides & Heavy Metals in Food

Heavy Metals attachement in Food
Attachement Code: HM 8 Version: 2

Heavy Metals in Food ICP – OES (attachment HM 8)

The elements detected in food using ICP-OES and their practical limits of quantification (LOQ) in food (mg/kg)

SN	Compound	LOQ (mg/kg)
1	Copper (Cu)	1
2	Iron (Fe)	1
3	Zinc (Zn)	1
4	Chromium (Cr)	1
5	Manganese (Mn)	1
6	Tin (Sn)	1
7	Cobalt (Co)	1
8	Nickel (Ni)	1
9	Antimony (Sb)	0.4
10	Cadmium (Cd)	0.02
11	Lead (Pb)	0.05
12	Mercury (Hg)	0.03

Mona Khorshed
8/1/2017

7 Nadi El-said street, Dokki, Giza, Egypt. P.O. Box: 2311
Web: www.qcap-egypt.com
e-mail: info@qcap-egypt.com
Tel: (+202) 37611355 - 37611282 - 37611106 - 37601395
Fax: (+202) 37611355 - 37611216
Page 1 of 1 [total no. of pages: 1]

Elements detected in food using ICP-OES method and their practical Limits of quantification (LOQ) in food (mg/kg) by QCAP

►B **COMMISSION REGULATION (EC) No 1881/2006**

of 19 December 2006

setting maximum levels for certain contaminants in foodstuffs

(Text with EEA relevance)

(OJ L 364, 20.12.2006, p. 5)

Amended by:

		Official Journal		
		No	page	date
►M1	Commission Regulation (EC) No 1126/2007 of 28 September 2007	L 255	14	29.9.2007
►M2	Commission Regulation (EC) No 565/2008 of 18 June 2008	L 160	20	19.6.2008
►M3	Commission Regulation (EC) No 629/2008 of 2 July 2008	L 173	6	3.7.2008
►M4	Commission Regulation (EU) No 105/2010 of 5 February 2010	L 35	7	6.2.2010
►M5	Commission Regulation (EU) No 165/2010 of 26 February 2010	L 50	8	27.2.2010
►M6	Commission Regulation (EU) No 420/2011 of 29 April 2011	L 111	3	30.4.2011
►M7	Commission Regulation (EU) No 835/2011 of 19 August 2011	L 215	4	20.8.2011
►M8	Commission Regulation (EU) No 1258/2011 of 2 December 2011	L 320	15	3.12.2011
►M9	Commission Regulation (EU) No 1259/2011 of 2 December 2011	L 320	18	3.12.2011
►M10	Commission Regulation (EU) No 219/2012 of 14 March 2012	L 75	5	15.3.2012
►M11	Commission Regulation (EU) No 594/2012 of 5 July 2012	L 176	43	6.7.2012
►M12	Commission Regulation (EU) No 1058/2012 of 12 November 2012	L 313	14	13.11.2012

Commission regulation (EC) - Setting maximum levels for certain contaminants in foodstuffs

▼B

COMMISSION REGULATION (EC) No 1881/2006

of 19 December 2006

setting maximum levels for certain contaminants in foodstuffs

(Text with EEA relevance)

THE COMMISSION OF THE EUROPEAN COMMUNITIES,

Having regard to the Treaty establishing the European Community,

Having regard to Council Regulation (EEC) No 315/93 of 8 February 1993 laying down Community procedures for contaminants in food ([1]), and in particular Article 2(3) thereof,

Whereas:

(1) Commission Regulation (EC) No 466/2001 of 8 March 2001 setting maximum levels for certain contaminants in foodstuffs ([2]) has been amended substantially many times. It is necessary to amend again maximum levels for certain contaminants to take into account new information and developments in Codex Alimentarius. At the same time, the text should, where appropriate, be clarified. Regulation (EC) No 466/2001 should therefore be replaced.

(2) It is essential, in order to protect public health, to keep contaminants at levels which are toxicologically acceptable.

(3) In view of disparities between the laws of Member States and the consequent risk of distortion of competition, for some contaminants Community measures are necessary in order to ensure market unity while abiding by the principle of proportionality.

(4) Maximum levels should be set at a strict level which is reasonably achievable by following good agricultural, fishery and manufacturing practices and taking into account the risk related to the consumption of the food. In the case of contaminants which are considered to be genotoxic carcinogens or in cases where current exposure of the population or of vulnerable groups in the population is close to or exceeds the tolerable intake, maximum levels should be set at a level which is as low as reasonably achievable (ALARA). Such approaches ensure that food business operators apply measures to prevent and reduce the contamination as far as possible in order to protect public health. It is furthermore appropriate for the health protection of infants and young children, a vulnerable group, to establish the lowest maximum levels, which are achievable through a strict selection of the raw materials used for the manufacturing of foods for infants and young children. This strict selection of the raw materials is also appropriate for the production of some specific foodstuffs such as bran for direct human consumption.

([1]) OJ L 37, 13.2.1993, p. 1. Regulation as amended by Regulation (EC) No 1882/2003 of the European Parliament and of the Council (OJ L 284, 31.10.2003, p. 1).

([2]) OJ L 77, 16.3.2001, p. 1. Regulation as last amended by Regulation (EC) No 199/2006 (OJ L 32, 4.2.2006, p. 32).

▼B

(5) To allow maximum levels to be applied to dried, diluted, processed and compound foodstuffs, where no specific Community maximum levels have been established, food business operators should provide the specific concentration and dilution factors accompanied by the appropriate experimental data justifying the factor proposed.

(6) To ensure an efficient protection of public health, products containing contaminants exceeding the maximum levels should not be placed on the market either as such, after mixture with other foodstuffs or used as an ingredient in other foods.

(7) It is recognised that sorting or other physical treatments make it possible to reduce the aflatoxin content of consignments of groundnuts, nuts, dried fruit and maize. In order to minimise the effects on trade, it is appropriate to allow higher aflatoxin contents for those products which are not intended for direct human consumption or as an ingredient in foodstuffs. In these cases, the maximum levels for aflatoxins should be fixed taking into consideration the effectiveness of the above-mentioned treatments to reduce the aflatoxin content in groundnuts, nuts, dried fruit and maize to levels below the maximum limits fixed for those products intended for direct human consumption or use as an ingredient in foodstuffs.

(8) To enable effective enforcement of the maximum levels for certain contaminants in certain foodstuffs, it is appropriate to provide for suitable labelling provisions for these cases.

(9) Because of the climatic conditions in some Member States, it is difficult to ensure that the maximum levels are not exceeded for fresh lettuce and fresh spinach. These Member States should be allowed for a temporary period to continue to authorise the marketing of fresh lettuce and fresh spinach grown and intended for consumption in their territory with nitrate contents exceeding the maximum levels. Lettuce and spinach producers established in the Member States which have given the afore-mentioned authorisations should progressively modify their farming methods by applying the good agricultural practices recommended at national level.

(10) Certain fish species originating from the Baltic region may contain high levels of dioxins and dioxin-like PCBs. A significant proportion of these fish species from the Baltic region will not comply with the maximum levels and would therefore be excluded from the diet. There are indications that the exclusion of fish from the diet may have a negative health impact in the Baltic region.

▼B

(11) Sweden and Finland have a system in place which has the capacity to ensure that consumers are fully informed of the dietary recommendations concerning restrictions on consumption of fish from the Baltic region by identified vulnerable groups of the population in order to avoid potential health risks. Therefore, it is appropriate to grant a derogation to Finland and Sweden to place on the market for a temporary period certain fish species originating in the Baltic region and intended for consumption in their territory with levels of dioxins and dioxin-like PCBs higher than those set in this Regulation. The necessary measures must be implemented to ensure that fish and fish products not complying with the maximum levels are not marketed in other Member States. Finland and Sweden report every year to the Commission the results of their monitoring of the levels of dioxins and dioxin-like PCBs in fish from the Baltic region and the measures to reduce human exposure to dioxins and dioxin-like PCBs from the Baltic region.

(12) To ensure that the maximum levels are enforced in a uniform way, the same sampling criteria and the same analysis performance criteria should be applied by the competent authorities throughout the Community. It is furthermore important that analytical results are reported and interpreted in a uniform way. The measures as regards sampling and analysis specified in this Regulation provide for uniform rules on reporting and interpretation.

(13) For certain contaminants, Member States and interested parties should monitor and report levels, as well report on the progress with regard to application of preventative measures, to allow the Commission to assess the need to modify existing measures or to adopt additional measures.

(14) Any maximum level adopted at Community level can be subject to a review to take account of the advance of scientific and technical knowledge and improvements in good agricultural, fishery and manufacturing practices.

(15) Bran and germ can be marketed for direct human consumption and it is therefore appropriate to establish a maximum level for deoxynivalenol and zearalenone in these commodities.

(16) Codex Alimentarius has recently set a maximum level for lead in fish which the Community accepted. It is therefore appropriate to modify the current provision for lead in fish accordingly.

(17) Regulation (EC) No 853/2004 of the European Parliament and Council of 29 April 2004 laying down specific hygiene rules for food of animal origin [1] defines foodstuffs of animal origin, and consequently the entries as regards foodstuffs of animal origin should be amended in some cases according to the terminology used in that Regulation.

[1] OJ L 139, 30.4.2004, p. 55, as corrected by OJ L 226, 25.6.2004, p. 22. Regulation as last amended by Regulation (EC) No 1662/2006 (OJ L 320, 18.11.2006, p. 1).

▼B

(18) It is necessary to provide that the maximum levels for contaminants do not apply to the foodstuffs which have been lawfully placed on the Community market before the date of application of these maximum levels.

(19) As regards nitrate, vegetables are the major source for the human intake of nitrate. The Scientific Committee on Food (SCF) stated in its opinion of 22 September 1995 (1) that the total intake of nitrate is normally well below the acceptable daily intake (ADI) of 3,65 mg/kg body weight (bw). It recommended, however, continuation of efforts to reduce exposure to nitrate via food and water.

(20) Since climatic conditions have a major influence on the levels of nitrate in certain vegetables such as lettuce and spinach, different maximum nitrate levels should therefore be fixed depending on the season.

(21) As regards aflatoxins, the SCF expressed in its opinion of 23 September 1994 that aflatoxins are genotoxic carcinogens (2). Based on that opinion, it is appropriate to limit the total aflatoxin content of food (sum of aflatoxins B_1, B_2, G_1 and G_2) as well as the aflatoxin B_1 content alone, aflatoxin B_1 being by far the most toxic compound. For aflatoxin M_1 in foods for infants and young children, a possible reduction of the current maximum level should be considered in the light of developments in analytical procedures.

(22) As regards ochratoxin A (OTA), the SCF adopted a scientific opinion on 17 September 1998 (3). An assessment of the dietary intake of OTA by the population of the Community has been performed (4) in the framework of Council Directive 93/5/EEC of 25 February 1993 on assistance to the Commission and cooperation by the Member States in the scientific examination of questions relating to food (5) (SCOOP). The European Food Safety Authority (EFSA) has, on a request from the Commission, adopted an updated scientific opinion relating to ochratoxin A in food on 4 April 2006 (6), taking into account new scientific information and derived a tolerable weekly intake (TWI) of 120 ng/kg bw.

(1) Reports of the Scientific Committee for Food, 38th series, Opinion of the Scientific Committee for Food on nitrates and nitrite, p. 1, http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_38.pdf
(2) Reports of the Scientific Committee for Food, 35th series, Opinion of the Scientific Committee for Food on aflatoxins, ochratoxin A and patulin, p. 45, http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_35.pdf
(3) Opinion of the Scientific Committee on Food on Ochratoxin A (expressed on 17 September 1998) http://ec.europa.eu/food/fs/sc/scf/out14_en.html
(4) Reports on tasks for scientific cooperation, Task 3.2.7 'Assessment of dietary intake of Ochratoxin A by the population of EU Member States'. http://ec.europa.eu/food/food/chemicalsafety/contaminants/task_3-2-7_en.pdf
(5) OJ L 52, 4.3.1993, p. 18.
(6) Opinion of the Scientific Panel on contaminants in the Food Chain of the EFSA on a request from the Commission related to ochratoxin A in food. http://www.efsa.europa.eu/etc/medialib/efsa/science/contam/contam_opinions/1521.Par.0001.File.dat/contam_op_ej365_ochratoxin_a_food_en1.pdf

▼B

(23) Based on these opinions, it is appropriate to set maximum levels for cereals, cereal products, dried vine fruit, roasted coffee, wine, grape juice and foods for infants and young children, all of which contribute significantly to general human exposure to OTA or to the exposure of vulnerable groups of consumers such as children.

(24) The appropriateness of setting a maximum level for OTA in foodstuffs such as dried fruit other than dried vine fruit, cocoa and cocoa products, spices, meat products, green coffee, beer and liquorice, as well as a review of the existing maximum levels, in particular for OTA in dried vine fruit and grape juice, will be considered in the light of the recent EFSA scientific opinion.

(25) As regards patulin, the SCF endorsed in its meeting on 8 March 2000 the provisional maximum tolerable daily intake (PMTDI) of 0,4 µg/kg bw for patulin (1).

(26) In 2001, a SCOOP-task 'Assessment of the dietary intake of patulin by the population of EU Member States' in the framework of Directive 93/5/EEC was performed (2).

(27) Based on that assessment and taking into account the PMTDI, maximum levels should be set for patulin in certain foodstuffs to protect consumers from unacceptable contamination. These maximum levels should be reviewed and, if necessary, reduced taking into account the progress in scientific and technological knowledge and the implementation of Commission Recommendation 2003/598/EC of 11 August 2003 on the prevention and reduction of patulin contamination in apple juice and apple juice ingredients in other beverages (3).

(28) As regards Fusarium toxins, the SCF has adopted several opinions evaluating deoxynivalenol in December 1999 (4) establishing a tolerable daily intake (TDI) of 1 µg/kg bw, zearalenone in June 2000 (5) establishing a temporary TDI of 0,2 µg/kg bw, fumonisins in October 2000 (6) (updated in April 2003) (7) establishing a TDI of 2 µg/kg bw, nivalenol in October

(1) Minutes of the 120th Meeting of the Scientific Committee on Food held on 8 and 9 March 2000 in Brussels, Minute statement on patulin. http://ec.europa.eu/food/fs/sc/scf/out55_en.pdf

(2) Reports on tasks for scientific cooperation, Task 3.2.8, 'Assessment of dietary intake of Patulin by the population of EU Member States'. http://ec.europa.eu/food/food/chemicalsafety/contaminants/3.2.8_en.pdf

(3) OJ L 203, 12.8.2003, p. 34.

(4) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 1: Deoxynivalenol (DON), (expressed on 2 December 1999) http://ec.europa.eu/food/fs/sc/scf/out44_en.pdf

(5) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 2: Zearalenone (ZEA), (expressed on 22 June 2000) http://ec.europa.eu/food/fs/sc/scf/out65_en.pdf

(6) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 3: Fumonisin B_1 (FB_1) (expressed on 17 October 2000) http://ec.europa.eu/food/fs/sc/scf/out73_en.pdf

(7) Updated opinion of the Scientific Committee on Food on Fumonisin B_1, B_2 and B_3 (expressed on 4 April 2003) http://ec.europa.eu/food/fs/sc/scf/out185_en.pdf

▼B

2000 (1) establishing a temporary TDI of 0,7 µg/kg bw, T-2 and HT-2 toxin in May 2001 (2) establishing a combined temporary TDI of 0,06 µg/kg bw and the trichothecenes as group in February 2002 (3).

(29) In the framework of Directive 93/5/EEC the SCOOP-task 'Collection of occurrence data on Fusarium toxins in food and assessment of dietary intake by the population of EU Member States' was performed and finalised in September 2003 (4).

(30) Based on the scientific opinions and the assessment of the dietary intake, it is appropriate to set maximum levels for deoxynivalenol, zearalenone and fumonisins. As regards fumonisins, monitoring control results of the recent harvests indicate that maize and maize products can be very highly contaminated by fumonisins and it is appropriate that measures are taken to avoid such unacceptably highly contaminated maize and maize products can enter the food chain.

(31) Intake estimates indicate that the presence of T-2 and HT-2 toxin can be of concern for public health. Therefore, the development of a reliable and sensitive method, collection of more occurrence data and more investigations/research in the factors involved in the presence of T-2 and HT-2 toxin in cereals and cereal products, in particular in oats and oat products, is necessary and of high priority.

(32) It is not necessary due to co-occurrence to consider specific measures for 3-acetyl deoxynivalenol, 15-acetyl deoxynivalenol and fumonisin B_3, as measures with regard to in particular deoxynivalenol and fumonisin B_1 and B_2 would also protect the human population from an unacceptable exposure from 3-acetyl deoxynivalenol, 15-acetyl deoxynivalenol and fumonisin B_3. The same applies to nivalenol for which to a certain degree co-occurrence with deoxynivalenol can be observed. Furthermore, human exposure to nivalenol is estimated to be significantly below the t-TDI. As regards other trichothecenes considered in the abovementioned SCOOP-task, such as 3-acetyldeoxynivalenol, 15-acetyldeoxynivalenol, fusarenon-X, T2-triol, diacetoxyscirpenol, neosolaniol, monoacetoxyscirpenol and verrucol, the limited information available indicates that they do not occur widely and the levels found are generally low.

(1) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 4: Nivalenol (expressed on 19 October 2000) http://ec.europa.eu/food/fs/sc/scf/out74_en.pdf

(2) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 5: T-2 toxin and HT-2 toxin (adopted on 30 May 2001) http://ec.europa.eu/food/fs/sc/scf/out88_en.pdf

(3) Opinion of the Scientific Committee on Food on Fusarium-toxins Part 6: Group evaluation of T-2 toxin, HT-2toxin, nivalenol and deoxynivalenol. (adopted on 26 February 2002) http://ec.europa.eu/food/fs/sc/scf/out123_en.pdf

(4) Reports on tasks for scientific cooperation, Task 3.2.10 'Collection of occurrence data of Fusarium toxins in food and assessment of dietary intake by the population of EU Member States'. http://ec.europa.eu/food/fs/scoop/task3210.pdf

▼B

(33) Climatic conditions during the growth, in particular at flowering, have a major influence on the Fusarium toxin content. However, good agricultural practices, whereby the risk factors are reduced to a minimum, can prevent to a certain degree the contamination by *Fusarium* fungi. Commission Recommendation 2006/583/EC of 17 August 2006 on the prevention and reduction of Fusarium toxins in cereals and cereal products (¹) contains general principles for the prevention and reduction of Fusarium toxin contamination (zearalenone, fumonisins and trichothecenes) in cereals to be implemented by the development of national codes of practice based on these principles.

(34) Maximum levels of Fusarium toxins should be set for unprocessed cereals placed on the market for first-stage processing. Cleaning, sorting and drying procedures are not considered as first-stage processing insofar as no physical action is exerted on the grain kernel itself. Scouring is to be considered as first-stage processing.

(35) Since the degree to which Fusarium toxins in unprocessed cereals are removed by cleaning and processing may vary, it is appropriate to set maximum levels for final consumer cereal products as well as for major food ingredients derived from cereals to have enforceable legislation in the interest of ensuring public health protection.

(36) For maize, not all factors involved in the formation of Fusarium toxins, in particular zearalenone and fumonisins B_1 and B_2, are yet precisely known. Therefore, a time period is granted to enable food business operators in the cereal chain to perform investigations on the sources of the formation of these mycotoxins and on the identification of the management measures to be taken to prevent their presence as far as reasonably possible. Maximum levels based on currently available occurrence data are proposed to apply from 2007 in case no specific maximum levels based on new information on occurrence and formation are set before that time.

(37) Given the low contamination levels of Fusarium toxins found in rice, no maximum levels are proposed for rice or rice products.

(38) A review of the maximum levels for deoxynivalenol, zearalenone, fumonisin B_1 and B_2 as well as the appropriateness of setting a maximum level for T-2 and HT-2 toxin in cereals and cereal products should be considered by 1 July 2008, taking into account the progress in scientific and technological knowledge on these toxins in food.

(¹) OJ L 234, 29.8.2006, p. 35.

▼B

(39) As regards lead, the SCF adopted an opinion on 19 June 1992 (1) endorsing the provisional tolerable weekly intake (PTWI) of 25 µg/kg bw proposed by the WHO in 1986. The SCF concluded in its opinion that the mean level in foodstuffs does not seem to be a cause of immediate concern.

(40) In the framework of Directive 93/5/EEC 2004 the SCOOP-task 3.2.11 'Assessment of the dietary exposure to arsenic, cadmium, lead and mercury of the population of the EU Member States' was performed in 2004 (2). In view of this assessment and the opinion delivered by the SCF, it is appropriate to take measures to reduce the presence of lead in food as much as possible

(41) As regards cadmium, the SCF endorsed in its opinion of 2 June 1995 (3) the PTWI of 7 µg/kg bw and recommended greater efforts to reduce dietary exposure to cadmium since foodstuffs are the main source of human intake of cadmium. A dietary exposure assessment was performed in the SCOOP-task 3.2.11. In view of this assessment and the opinion delivered by the SCF, it is appropriate to take measures to reduce the presence of cadmium in food as much as possible.

(42) As regards mercury EFSA adopted on 24 February 2004 an opinion related to mercury and methylmercury in food (4) and endorsed the provisional tolerable weekly intake of 1,6 µg/kg bw. Methylmercury is the chemical form of most concern and can make up more than 90 % of the total mercury in fish and seafood. Taking into account the outcome of the SCOOP-task 3.2.11, EFSA concluded that the levels of mercury found in foods, other than fish and seafood, were of lower concern. The forms of mercury present in these other foods are mainly not methylmercury and they are therefore considered to be of lower risk.

(43) In addition to the setting of maximum levels, targeted consumer advice is an appropriate approach in the case of methylmercury for protecting vulnerable groups of the population. An information note on methylmercury in fish and fishery products responding to this need has therefore been made available on the website of the Health and Consumer Protection Directorate-General of the European Commission (5). Several Member States have also issued advice on this issue that is relevant to their population.

(1) Reports of the Scientific Committee for Food, 32nd series, Opinion of the Scientific Committee for Food on 'The potential risk to health presented by lead in food and drink', p. 7, http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_32.pdf

(2) Reports on tasks for scientific co-operation, Task 3.2.11 'Assessment of dietary exposure to arsenic, cadmium, lead and mercury of the population of the EU Member States'. http://ec.europa.eu/food/food/chemicalsafety/contaminants/scoop_3-2-11_heavy_metals_report_en.pdf

(3) Reports of the Scientific Committee for Food, 36th series, Opinion of the Scientific Committee for Food on cadmium, p. 67, http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_36.pdf

(4) Opinion of the Scientific Panel on contaminants in the Food Chain of the European Food Safety Authority (EFSA) on a request from the Commission related to mercury and methylmercury in food (adopted on 24 February 2004) http://www.efsa.eu.int/science/contam/contam_opinions/259/opinion_contam_01_en1.pdf

(5) http://ec.europa.eu/food/food/chemicalsafety/contaminants/information_note_mercury-fish_12-05-04.pdf

▼B

(44) As regards inorganic tin, the SCF concluded in its opinion of 12 December 2001 (1) that levels of inorganic tin of 150 mg/kg in canned beverages and 250 mg/kg in other canned foods may cause gastric irritation in some individuals.

(45) To protect public health from this health risk it is necessary to set maximum levels for inorganic tin in canned foods and canned beverages. Until data becomes available on the sensitivity of infants and young children to inorganic tin in foods, it is necessary on a precautionary basis to protect the health of this vulnerable population group and to establish lower maximum levels.

(46) As regards 3-monochloropropane-1,2-diol (3-MCPD) the SCF adopted on 30 May 2001 a scientific opinion as regards 3-MCPD in food (2), updating its opinion of 16 December 1994 (3) on the basis of new scientific information and established a tolerable daily intake (TDI) of 2 µg/kg bw for 3-MCPD.

(47) In the framework of Directive 93/5/EEC the SCOOP-task 'Collection and collation of data on levels of 3-MCPD and related substances in foodstuffs' was performed and finalised in June 2004 (4). The main contributors of 3-MCPD to dietary intake were soy sauce and soy-sauce based products. Some other foods eaten in large quantities, such as bread and noodles, also contributed significantly to intake in some countries because of high consumption rather than high levels of 3-MCPD present in these foods.

(48) Accordingly maximum levels should be set for 3-MCPD in hydrolysed vegetable protein (HVP) and soy sauce taking into account the risk related to the consumption of these foods. Member States are requested to examine other foodstuffs for the occurrence of 3-MCPD in order to consider the need to set maximum levels for additional foodstuffs.

(49) As regards dioxins and PCBs, the SCF adopted on 30 May 2001 an opinion on dioxins and dioxin-like PCBs in food (5), updating

(1) Opinion of the Scientific Committee on Food on acute risks posed by tin in canned foods (adopted on 12 December 2001) http://ec.europa.eu/food/fs/sc/scf/out110_en.pdf

(2) Opinion of the Scientific Committee on Food on 3-monochloro-propane-1,2-diol (3-MCPD) updating the SCF opinion of 1994 (adopted on 30 May 2001) http://ec.europa.eu/food/fs/sc/scf/out91_en.pdf

(3) Reports of the Scientific Committee for Food, 36th series, Opinion of the Scientific Committee for Food on 3-monochloro-propane-1,2-diol 3-MCPD), p. 31, http://ec.europa.eu/food/fs/sc/scf/reports/scf_reports_36.pdf

(4) Reports on tasks for scientific cooperation, Task 3.2.9 'Collection and collation of data on levels of 3-monochloropropanediol (3-MCPD) and related substances in foodstuffs'. http://ec.europa.eu/food/food/chemicalsafety/contaminants/scoop_3-2-9_final_report_chloropropanols_en.pdf

(5) Opinion of the Scientific Committee on Food on the risk assessment of dioxins and dioxin-like PCBs in food. Update based on new scientific information available since the adoption of the SCF opinion of 22nd November 2000 (adopted on 30 May 2001) http://ec.europa.eu/food/fs/sc/scf/out90_en.pdf

▼B

its opinion of 22 November 2000 ([1]) fixing a tolerable weekly intake (TWI) of 14 pg World Health Organisation toxic equivalent (WHO-TEQ)/kg bw for dioxins and dioxin-like PCBs.

(50) Dioxins as referred to in this Regulation cover a group of 75 polychlorinated dibenzo-p-dioxin (PCDD) congeners and 135 polychlorinated dibenzofuran (PCDF) congeners, of which 17 are of toxicological concern. Polychlorinated biphenyls (PCBs) are a group of 209 different congeners which can be divided into two groups according to their toxicological properties: 12 congeners exhibit toxicological properties similar to dioxins and are therefore often termed dioxin-like PCBs. The other PCBs do not exhibit dioxin-like toxicity but have a different toxicological profile.

(51) Each congener of dioxins or dioxin-like PCBs exhibits a different level of toxicity. In order to be able to sum up the toxicity of these different congeners, the concept of toxic equivalency factors (TEFs) has been introduced to facilitate risk assessment and regulatory control. This means that the analytical results relating to all the individual dioxin and dioxin-like PCB congeners of toxicological concern are expressed in terms of a quantifiable unit, namely the TCDD toxic equivalent (TEQ).

(52) Exposure estimates taking into account the SCOOP-task 'Assessment of dietary intake of dioxins and related PCBs by the population of EU Member States' finalised in June 2000 ([2]) indicate that a considerable proportion of the Community population has a dietary intake in excess of the TWI.

(53) From a toxicological point of view, any level set should apply to both dioxins and dioxin-like PCBs, but in 2001 maximum levels were set on Community level only for dioxins and not for dioxin-like PCBs, given the very limited data available at that time on the prevalence of dioxin-like PCBs. Since 2001, however, more data on the presence of dioxin-like PCBs have become available, therefore, maximum levels for the sum of dioxins and dioxin-like PCBs have been set in 2006 as this is the most appropriate approach from a toxicological point of view. In order to ensure a smooth transition, the levels for dioxins should continue to apply for a transitional period in addition to the levels for the sum of dioxins and dioxin-like PCBs. Foodstuffs must comply during that transitional period with the maximum levels for dioxins and with the maximum levels for the sum of dioxins and dioxin-like PCBs. Consideration will be given by 31 December 2008 to dispensing with the separate maximum levels for dioxins.

([1]) Opinion of the Scientific Committee on Food on the risk assessment of dioxins and dioxin-like PCBs in food. (adopted on 22 November 2000) http://ec.europa.eu/food/fs/sc/scf/out78_en.pdf

([2]) Reports on tasks for scientific cooperation, Task 3.2.5 'Assessment of dietary intake of dioxins and related PCBs by the population of EU Member States'. http://ec.europa.eu/dgs/health_consumer/library/pub/pub08_en.pdf

▼B

(54) In order to encourage a proactive approach to reducing the dioxins and dioxin-like PCBs present in food and feed, action levels were set by Commission Recommendation 2006/88/EC of 6 February 2006 on the reduction of the presence of dioxins, furans and PCBs in feedingstuffs and foodstuffs (1). These action levels are a tool for competent authorities and operators to highlight those cases where it is appropriate to identify a source of contamination and to take measures to reduce or eliminate it. Since the sources of dioxins and dioxin-like PCBs are different, separate action levels are determined for dioxins on the one hand and for dioxin-like PCBs on the other hand. This proactive approach to actively reduce the dioxins and dioxin-like PCBs in feed and food and consequently, the maximum levels applicable should be reviewed within a defined period of time with the objective to set lower levels. Therefore, consideration will be given by 31 December 2008 to significantly reducing the maximum levels for the sum of dioxins and dioxin-like PCBs.

(55) Operators need to make efforts to step up their capacity to remove dioxins, furans and dioxin-like PCBs from marine oil. The significant lower level, to which consideration shall be given by 31 December 2008, shall be based on the technical possibilities of the most effective decontamination procedure.

(56) As regards the establishment of maximum levels for other foodstuffs by 31 December 2008, particular attention shall be paid to the need to set specific lower maximum levels for dioxins and dioxin-like PCBs in foods for infants and young children in the light of the monitoring data obtained through the 2005, 2006 and 2007 programmes for monitoring dioxins and dioxin-like PCBs in foods for infants and young children.

(57) As regards polycyclic aromatic hydrocarbons, the SCF concluded in its opinion of 4 December 2002 (2) that a number of polycyclic aromatic hydrocarbons (PAH) are genotoxic carcinogens. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) performed in 2005 a risk assessment on PAHs and estimated margins of exposure (MOE) for PAH as a basis for advice on compounds that are both genotoxic and carcinogenic (3).

(58) According to the SCF, benzo(a)pyrene can be used as a marker for the occurrence and effect of carcinogenic PAH in food, including also benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, cyclopenta(c,d)pyrene, dibenz(a,h)anthracene, dibenzo(a,e)pyrene, dibenzo(a,h)pyrene, dibenzo(a,i)pyrene, dibenzo(a,l)pyrene, indeno(1,2,3-cd)pyrene and 5-methylchrysene.

(1) OJ L 42, 14.2.2006, p. 26.
(2) Opinion of the Scientific Committee on Food on the risks to human health of Polycyclic Aromatic Hydrocarbons in food (expressed on 4 December 2002) http://ec.europa.eu/food/fs/sc/scf/out153_en.pdf
(3) Evaluation of certain food contaminants — Report of the Joint FAO/WHO Expert Committee on Food Additives). 64th meeting, Rome, 8 to 17 February 2005, p. 1 and p. 61.
WHO Technical Report Series, No. 930, 2006 — http://whqlibdoc.who.int/trs/WHO_TRS_930_eng.pdf

▼B

Further analyses of the relative proportions of these PAH in foods would be necessary to inform a future review of the suitability of maintaining benzo(a)pyrene as a marker. In addition benzo(c)fluorene should be analysed, following a recommendation of JECFA.

(59) PAH can contaminate foods during smoking processes and heating and drying processes that allow combustion products to come into direct contact with food. In addition, environmental pollution may cause contamination with PAH, in particular in fish and fishery products.

(60) In the framework of Directive 93/5/EEC, a specific SCOOP-task 'Collection of occurrence data on PAH in food' has been performed in 2004 [1]. High levels were found in dried fruits, olive pomace oil, smoked fish, grape seed oil, smoked meat products, fresh molluscs, spices/sauces and condiments.

(61) In order to protect public health, maximum levels are necessary for benzo(a)pyrene in certain foods containing fats and oils and in foods where smoking or drying processes might cause high levels of contamination. Maximum levels are also necessary in foods where environmental pollution may cause high levels of contamination, in particular in fish and fishery products, for example resulting from oil spills caused by shipping.

(62) In some foods, such as dried fruit and food supplements, benzo(a)pyrene has been found, but available data are inconclusive on what levels are reasonably achievable. Further investigation is needed to clarify the levels that are reasonably achievable in these foods. In the meantime, maximum levels for benzo(a)pyrene in relevant ingredients should apply, such as in oils and fats used in food supplements.

(63) The maximum levels for PAH and the appropriateness of setting a maximum level for PAH in cocoa butter should be reviewed by 1 April 2007, taking into account the progress in scientific and technological knowledge on the occurrence of benzo(a)pyrene and other carcinogenic PAH in food.

(64) The measures provided for in this Regulation are in accordance with the opinion of the Standing Committee on the Food Chain and Animal Health,

(1) Reports on tasks for scientific co-operation, Task 3.2.12 'Collection of occurrence data on polycyclic aromatic hydrocarbons in food'. http://ec.europa.eu/food/food/chemicalsafety/contaminants/scoop_3-2-12_final_report_pah_en.pdf

▼B

HAS ADOPTED THIS REGULATION:

Article 1

General rules

1. The foodstuffs listed in the Annex shall not be placed on the market where they contain a contaminant listed in the Annex at a level exceeding the maximum level set out in the Annex.

2. The maximum levels specified in the Annex shall apply to the edible part of the foodstuffs concerned, unless otherwise specified in the Annex.

Article 2

Dried, diluted, processed and compound foodstuffs

1. When applying the maximum levels set out in the Annex to foodstuffs which are dried, diluted, processed or composed of more than one ingredient, the following shall be taken into account:

(a) changes of the concentration of the contaminant caused by drying or dilution processes;

(b) changes of the concentration of the contaminant caused by processing;

(c) the relative proportions of the ingredients in the product;

(d) the analytical limit of quantification.

2. The specific concentration or dilution factors for the drying, dilution, processing and/or mixing operations concerned or for the dried, diluted, processed and/or compound foodstuffs concerned shall be provided and justified by the food business operator, when the competent authority carries out an official control.

If the food business operator does not provide the necessary concentration or dilution factor or if the competent authority deems that factor inappropriate in view of the justification given, the authority shall itself define that factor, based on the available information and with the objective of maximum protection of human health.

3. Paragraphs 1 and 2 shall apply in so far as no specific Community maximum levels are fixed for these dried, diluted, processed or compound foodstuffs.

4. As far as Community legislation does not provide for specific maximum levels for foods for infants and young children, Member States may provide for stricter levels.

Article 3

Prohibitions on use, mixing and detoxification

1. Foodstuffs not complying with the maximum levels set out in the Annex shall not be used as food ingredients.

2. Foodstuffs complying with the maximum levels set out in the Annex shall not be mixed with foodstuffs which exceed these maximum levels.

▼B

3. Foodstuffs to be subjected to sorting or other physical treatment to reduce contamination levels shall not be mixed with foodstuffs intended for direct human consumption or with foodstuffs intended for use as a food ingredient.

4. Foodstuffs containing contaminants listed in section 2 of the Annex (Mycotoxins) shall not be deliberately detoxified by chemical treatments.

▼M5

Article 4

Specific provisions for groundnut, other oilseeds, tree nuts, dried fruit, rice and maize

Groundnuts (peanuts), other oilseeds, tree nuts, dried fruit, rice and maize not complying with the appropriate maximum levels of aflatoxins laid down in points 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.1.10 and 2.1.11 of the Annex can be placed on the market provided that these foodstuffs:

(a) are not intended for direct human consumption or use as an ingredient in foodstuffs;

(b) comply with the appropriate maximum levels laid down in points 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.9 and 2.1.12 of the Annex;

(c) are subjected to a treatment involving sorting or other physical treatment and that after this treatment the maximum levels laid down in points 2.1.5, 2.1.6, 2.1.7, 2.1.8, 2.1.10 and 2.1.11 of the Annex are not exceeded, and this treatment does not result in other harmful residues;

(d) are labelled clearly showing their use, and bearing the indication 'product shall be subjected to sorting or other physical treatment to reduce aflatoxin contamination before human consumption or use as an ingredient in foodstuffs'. The indication shall be included on the label of each individual bag, box etc. and on the original accompanying document. The consignment/batch identification code shall be indelibly marked on each individual bag, box etc. of the consignment and on the original accompanying document.

Article 5

Specific provisions for groundnuts (peanuts), other oilseeds, derived products thereof and cereals

A clear indication of the intended use must appear on the label of each individual bag, box, etc. and on the original accompanying document. This accompanying document must have a clear link with the consignment by means of mentioning the consignment identification code, which is on each individual bag, box, etc. of the consignment. In addition the business activity of the consignee of the consignment given on the accompanying document must be compatible with the intended use.

▼M5

In the absence of a clear indication that their intended use is not for human consumption, the maximum levels laid down in points 2.1.5 and 2.1.11 of the Annex shall apply to all groundnuts (peanuts), other oilseeds and derived products thereof and cereals placed on the market.

As regards the exception of groundnuts (peanuts) and other oilseeds for crushing and the application of the maximum levels laid down in point 2.1.1 of the Annex, the exception only applies to consignments which are clearly labelled showing their use and bearing the indication 'product to be subject to crushing for the production of refined vegetable oil'. The indication shall be included on the label of each individual bag, box etc. and on the accompanying document(s). The final destination must be a crushing plant.

▼B

Article 6

Specific provisions for lettuce

Unless lettuce grown under cover (protected lettuce) is labelled as such, maximum levels set in the Annex for lettuce grown in the open air (open-grown lettuce) shall apply.

Article 7

▼M9

Derogations

▼M8

————

▼M9

4. By way of derogation from Article 1, Finland, Sweden and Latvia may authorise the placing on their market of wild caught salmon (*Salmo salar*) and products thereof originating in the Baltic region and intended for consumption in their territory with levels of dioxins and/or dioxin-like PCBs and/or non-dioxin-like PCBs higher than those set out in point 5.3 of the Annex, provided that a system is in place to ensure that consumers are fully informed of the dietary recommendations with regard to the restrictions on the consumption of wild caught salmon from the Baltic region and products thereof by identified vulnerable sections of the population in order to avoid potential health risks.

Finland, Sweden and Latvia shall continue to apply the necessary measures to ensure that wild caught salmon and products thereof not complying with point 5.3 of the Annex are not marketed in other Member States.

Finland, Sweden and Latvia will report yearly to the Commission the measures they have taken to effectively inform the identified vulnerable sections of the population of the dietary recommendations and to ensure that wild caught salmon and products thereof not compliant with the maximum levels is not marketed in other Member States. They shall furthermore provide evidence of the effectiveness of these measures.

▼M9

5. By way of derogation from Article 1, Finland and Sweden may authorise the placing on their market of wild caught herring larger than 17 cm (*Clupea harengus*), wild caught char (*Salvelinus* spp.), wild caught river lamprey (*Lampetra fluviatilis*) and wild caught trout (*Salmo trutta*) and products thereof originating in the Baltic region and intended for consumption in their territory with levels of dioxins and/or dioxin-like PCBs and/or non dioxin-like PCBs higher than those set out in point 5.3 of the Annex, provided that a system is in place to ensure that consumers are fully informed of the dietary recommendations with regard to the restrictions on the consumption of wild caught herring larger than 17 cm, wild caught char, wild caught river lamprey and wild caught trout from the Baltic region and products thereof by identified vulnerable sections of the population in order to avoid potential health risks.

Finland and Sweden shall continue to apply the necessary measures to ensure that wild caught herring larger than 17 cm, wild caught char, wild caught river lamprey and wild caught trout and products thereof not complying with point 5.3 of the Annex are not marketed in other Member States.

Finland and Sweden will report yearly to the Commission the measures they have taken to effectively inform the identified vulnerable sections of the population of the dietary recommendations and to ensure that fish and products thereof not compliant with the maximum levels is not marketed in other Member States. They shall furthermore provide evidence of the effectiveness of these measures.

▼B

Article 8

Sampling and analysis

The sampling and the analysis for the official control of the maximum levels specified in the Annex shall be performed in accordance with Commission Regulations (EC) No 1882/2006 (1), No 401/2006 (2), No 1883/2006 (3) and Commission Directives 2001/22/EC (4), 2004/16/EC (5) and 2005/10/EC (6).

Article 9

Monitoring and reporting

▼M8

1. Member States shall monitor nitrate levels in vegetables which may contain significant levels, in particular green leaf vegetables, and communicate the result to EFSA on a regular basis.

▼M6

2. Member States and interested parties shall communicate each year to the Commission the results of investigations undertaken and the progress with regard to the application of prevention measures to avoid contamination by ochratoxin A, deoxynivalenol, zearalenone, fumonisin B_1 and B_2, T-2 and HT-2 toxin. The Commission shall make the results available to the Member States. The related occurrence data shall be reported to EFSA.

(1) See page 25 of this Official Journal.
(2) OJ L 70, 9.3.2006, p. 12.
(3) See page 32 of this Official Journal.
(4) OJ L 77, 16.3.2001, p. 14. Directive as amended by Directive 2005/4/EC (OJ L 19, 21.1.2005, p. 50).
(5) OJ L 42, 13.2.2004, p. 16.
(6) OJ L 34, 8.2.2005, p. 15.

▼M6

3. Member States shall report to the Commission findings on aflatoxins obtained in accordance with Commission Regulation (EC) No 1152/2009 (1). Member States should report to EFSA findings on furan, ethylcarbamate, perfluoroalkylated substances and acrylamide obtained in accordance with Commission Recommendations 2007/196/EC (2), 2010/133/EU (3), 2010/161/EU (4) and 2010/307/EU (5).

4. Occurrence data on contaminants collected by Member States should, if appropriate, also be reported to EFSA.

▼B

Article 10

Repeal

Regulation (EC) No 466/2001 is repealed.

References to the repealed Regulation shall be construed as references to this Regulation.

Article 11

Transitional measures

▼M11

This Regulation shall not apply to products that were placed on the market before the dates referred to in points (a) to (f) in conformity with the provisions applicable at the respective date:

▼B

(a) 1 July 2006 as regards the maximum levels for deoxynivalenol and zearalenone laid down in points 2.4.1, 2.4.2, 2.4.4, 2.4.5, 2.4.6, 2.4.7, 2.5.1, 2.5.3, 2.5.5 and 2.5.7 of the Annex;

▼M1

(b) 1 October 2007 as regards the maximum levels for deoxynivalenol and zearalenone laid down in points 2.4.3, 2.4.8, 2.4.9, 2.5.2, 2.5.4, 2.5.6, 2.5.8, 2.5.9 and 2.5.10 of the Annex;

▼B

(c) 1 October 2007 as regards the maximum levels for fumonisins B_1 and B_2 laid down in point 2.6 of the Annex;

(d) 4 November 2006 as regards the maximum levels for the sum of dioxins and dioxin-like PCBs laid down in section 5 of the Annex;

▼M11

(e) 01 January 2012 as regards the maximum levels for non dioxin-like PCBs laid down in section 5 of the Annex;

(f) 01 January 2015 as regards the maximum level for Ochratoxin A in *Capsicum* spp. laid down in point 2.2.11. of the Annex.

(1) OJ L 313, 28.11.2009, p. 40.
(2) OJ L 88, 29.3.2007, p. 56.
(3) OJ L 52, 3.3.2010, p. 53.
(4) OJ L 68, 18.3.2010, p. 22.
(5) OJ L 137, 3.6.2010, p. 4.

▼B

The burden of proving when the products were placed on the market shall be borne by the food business operator.

Article 12

Entry into force and application

This Regulation shall enter into force on the 20th day following its publication in the *Official Journal of the European Union*.

It shall apply from 1 March 2007.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

▼B

ANNEX

Maximum levels for certain contaminants in foodstuffs (1)

▼M8

Section 1: Nitrate

Foodstuffs (1)		Maximum levels (mg NO_3/kg)	
1.1	Fresh spinach (*Spinacia oleracea*) (2)		3 500
1.2	Preserved, deep-frozen or frozen spinach		2 000
1.3	Fresh Lettuce (*Lactuca sativa* L.) (protected and open-grown lettuce) excluding lettuce listed in point 1.4	Harvested 1 October to 31 March: lettuce grown under cover lettuce grown in the open air	 5 000 4 000
		Harvested 1 April to 30 September: lettuce grown under cover lettuce grown in the open air	 4 000 3 000
1.4	'Iceberg' type lettuce	Lettuce grown under cover	2 500
		Lettuce grown in the open air	2 000
1.5	Rucola (*Eruca sativa, Diplotaxis* sp., *Brassica tenuifolia, Sisymbrium tenuifolium*)	Harvested 1 October to 31 March:	7 000
		Harvested 1 April to 30 September:	6 000
1.6	Processed cereal-based foods and baby foods for infants and young children (3) (4)		200

▼B

Section 2: Mycotoxins

▼M5

Foodstuffs (1)		Maximum levels (μg/kg)		
2.1.	**Aflatoxins**	B_1	Sum of B_1, B_2, G_1 and G_2	M_1
2.1.1.	Groundnuts (peanuts) and other oilseeds (40), to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs, with the exception of: — groundnuts (peanuts) and other oilseeds for crushing for refined vegetable oil production	8,0 (7)	15,0 (7)	—
2.1.2.	Almonds, pistachios and apricot kernels to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs	12,0 (7)	15,0 (7)	—

▼M5

Foodstuffs (1)		Maximum levels (μg/kg)		
2.1.3.	Hazelnuts and Brazil nuts, to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs	8,0 (7)	15,0 (7)	
2.1.4.	Tree nuts, other than the tree nuts listed in 2.1.2 and 2.1.3, to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs	5,0 (7)	10,0 (7)	—
2.1.5.	Groundnuts (peanuts) and other oilseeds (40) and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs, with the exception of: — crude vegetable oils destined for refining — refined vegetable oils	2,0 (7)	4,0 (7)	—
2.1.6.	Almonds, pistachios and apricot kernels, intended for direct human consumption or use as an ingredient in foodstuffs (41)	8,0 (7)	10,0 (7)	—
2.1.7.	Hazelnuts and Brazil nuts, intended for direct human consumption or use as an ingredient in foodstuffs (41)	5,0 (7)	10,0 (7)	
2.1.8.	Tree nuts, other than the tree nuts listed in 2.1.6 and 2.1.7, and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	2,0 (7)	4,0 (7)	—
▼M12				
2.1.9.	Dried fruit, other than dried figs, to be subjected to sorting, or other physical treatment, before human consumption or use as an ingredient in foodstuffs	5,0	10,0	—
2.1.10.	Dried fruit, other than dried figs, and processed products thereof, intended for direct human consumption or use as an ingredient in foodstuffs	2,0	4,0	—
▼M5				
2.1.11.	All cereals and all products derived from cereals, including processed cereal products, with the exception of foodstuffs listed in 2.1.12, 2.1.15 and 2.1.17	2,0	4,0	—
2.1.12.	Maize and rice to be subjected to sorting or other physical treatment before human consumption or use as an ingredient in foodstuffs	5,0	10,0	—
2.1.13.	Raw milk (6), heat-treated milk and milk for the manufacture of milk-based products	—	—	0,050
2.1.14.	Following species of spices: *Capsicum* spp. (dried fruits thereof, whole or ground, including chillies, chilli powder, cayenne and paprika) *Piper* spp. (fruits thereof, including white and black pepper) *Myristica fragrans* (nutmeg) *Zingiber officinale* (ginger) *Curcuma longa* (turmeric) Mixtures of spices containing one or more of the above-mentioned spices	5,0	10,0	—

▼M5

	Foodstuffs (1)	Maximum levels (µg/kg)		
2.1.15.	Processed cereal-based foods and baby foods for infants and young children (3) (7)	0,10	—	—
2.1.16.	Infant formulae and follow-on formulae, including infant milk and follow-on milk (4) (8)	—	—	0,025
2.1.17.	Dietary foods for special medical purposes (9) (10) intended specifically for infants	0,10	—	0,025
▼M12				
2.1.18.	Dried figs	6,0	10,0	—
▼B				
2.2	**Ochratoxin A**			
2.2.1	Unprocessed cereals	5,0		
▼M11				
2.2.2	All products derived from unprocessed cereals, including processed cereal products and cereals intended for direct human consumption with the exception of foodstuffs listed in 2.2.9, 2.2.10 and 2.2.13	3,0		
▼B				
2.2.3	Dried vine fruit (currants, raisins and sultanas)	10,0		
2.2.4	Roasted coffee beans and ground roasted coffee, excluding soluble coffee	5,0		
2.2.5	Soluble coffee (instant coffee)	10,0		
2.2.6	Wine (including sparkling wine, excluding liqueur wine and wine with an alcoholic strength of not less than 15 % vol) and fruit wine (11)	2,0 (12)		
2.2.7	Aromatised wine, aromatised wine-based drinks and aromatised wine-product cocktails (13)	2,0 (12)		
2.2.8	Grape juice, concentrated grape juice as reconstituted, grape nectar, grape must and concentrated grape must as reconstituted, intended for direct human consumption (14)	2,0 (12)		
2.2.9	Processed cereal-based foods and baby foods for infants and young children (3) (7)	0,50		
2.2.10	Dietary foods for special medical purposes (9) (10) intended specifically for infants	0,50		
▼M11				
2.2.11.	Spices, including dried spices			
	Piper spp (fruits thereof, including white and black pepper) *Myristica fragrans* (nutmeg) *Zingiber officinale* (ginger) *Curcuma longa* (turmeric)	15 µg/kg		
	Capsicum spp. (dried fruits thereof, whole or ground, including chillies, chilli powder, cayenne and paprika)	30 µg/kg until 31.12.2014 15 µg/kg as from 1.1.2015		
	Mixtures of spices containing one of the abovementioned spices	15 µg/kg		

▼B

	Foodstuffs (1)	Maximum levels (μg/kg)
▼M4		
2.2.12.	Liquorice (*Glycyrrhiza glabra, Glycyrrhiza inflate* and other species)	
2.2.12.1.	Liquorice root, ingredient for herbal infusion	20 μg/kg
2.2.12.2.	Liquorice extract (12), for use in food in particular beverages and confectionary	80 μg/kg
▼M11		
2.2.13.	Wheat gluten not sold directly to the consumer	8,0
▼B		
2.3	**Patulin**	
2.3.1	Fruit juices, concentrated fruit juices as reconstituted and fruit nectars (14)	50
2.3.2	Spirit drinks (15), cider and other fermented drinks derived from apples or containing apple juice	50
2.3.3	Solid apple products, including apple compote, apple puree intended for direct consumption with the exception of foodstuffs listed in 2.3.4 and 2.3.5	25
2.3.4	Apple juice and solid apple products, including apple compote and apple puree, for infants and young children (16) and labelled and sold as such (4)	10,0
2.3.5	Baby foods other than processed cereal-based foods for infants and young children (3) (4)	10,0
▼M1		
2.4	**Deoxynivalenol** (17)	
2.4.1	Unprocessed cereals (18) (19) other than durum wheat, oats and maize	1 250
2.4.2	Unprocessed durum wheat and oats (18) (19)	1 750
2.4.3	Unprocessed maize (18), with the exception of unprocessed maize intended to be processed by wet milling (17)	1 750 (20)
2.4.4	Cereals intended for direct human consumption, cereal flour, bran and germ as end product marketed for direct human consumption, with the exception of foodstuffs listed in 2.4.7, 2.4.8 and 2.4.9	750
2.4.5	Pasta (dry) (22)	750
2.4.6	Bread (including small bakery wares), pastries, biscuits, cereal snacks and breakfast cereals	500
2.4.7	Processed cereal-based foods and baby foods for infants and young children (3) (7)	200
2.4.8	Milling fractions of maize with particle size > 500 micron falling within CN code 1103 13 or 1103 20 40 and other maize milling products with particle size > 500 micron not used for direct human consumption falling within CN code 1904 10 10	750 (20)

▼M1

Foodstuffs (1)		Maximum levels (μg/kg)
2.4.9	Milling fractions of maize with particle size ≤ 500 micron falling within CN code 1102 20 and other maize milling products with particle size ≤ 500 micron not used for direct human consumption falling within CN code 1904 10 10	1 250 (23)
2.5	**Zearalenone** (17)	
2.5.1	Unprocessed cereals (18) (19) other than maize	100
2.5.2	Unprocessed maize (18) with the exception of unprocessed maize intended to be processed by wet milling (37)	350 (23)
2.5.3	Cereals intended for direct human consumption, cereal flour, bran and germ as end product marketed for direct human consumption, with the exception of foodstuffs listed in 2.5.6, 2.5.7, 2.5.8, 2.5.9 and 2.5.10	75
2.5.4	Refined maize oil	400 (23)
2.5.5	Bread (including small bakery wares), pastries, biscuits, cereal snacks and breakfast cereals, excluding maize-snacks and maize-based breakfast cereals	50
2.5.6	Maize intended for direct human consumption, maize-based snacks and maize-based breakfast cereals	100 (23)
2.5.7	Processed cereal-based foods (excluding processed maize-based foods) and baby foods for infants and young children (3) (7)	20
2.5.8	Processed maize-based foods for infants and young children (3) (7)	20 (23)
2.5.9	Milling fractions of maize with particle size > 500 micron falling within CN code 1103 13 or 1103 20 40 and other maize milling products with particle size > 500 micron not used for direct human consumption falling within CN code 1904 10 10	200 (23)
2.5.10	Milling fractions of maize with particle size ≤ 500 micron falling within CN code 1102 20 and other maize milling products with particle size ≤ 500 micron not used for direct human consumption falling within CN code 1904 10 10	300 (23)
2.6	**Fumonisins**	Sum of B_1 and B_2
2.6.1	Unprocessed maize (18), with the exception of unprocessed maize intended to be processed by wet milling (37)	4 000 (23)
2.6.2	Maize intended for direct human consumption, maize-based foods for direct human consumption, with the exception of foodstuffs listed in 2.6.3 and 2.6.4	1 000 (23)

▼M1

Foodstuffs [1]		Maximum levels (µg/kg)
2.6.3	Maize-based breakfast cereals and maize-based snacks	800 [23]
2.6.4	Processed maize-based foods and baby foods for infants and young children [3] [7]	200 [23]
2.6.5	Milling fractions of maize with particle size > 500 micron falling within CN code 1103 13 or 1103 20 40 and other maize milling products with particle size > 500 micron not used for direct human consumption falling within CN code 1904 10 10	1 400 [23]
2.6.6	Milling fractions of maize with particle size ≤ 500 micron falling within CN code 1102 20 and other maize milling products with particle size ≤ 500 micron not used for direct human consumption falling within CN code 1904 10 10	2 000 [23]
▼B		
2.7	**T-2 and HT-2 toxin** [17]	Sum of T-2 and HT-2 toxin
2.7.1	Unprocessed cereals [18] and cereal products	

Section 3: Metals

Foodstuffs [1]		Maximum levels (mg/kg wet weight)
3.1	**Lead**	
3.1.1	Raw milk [6], heat-treated milk and milk for the manufacture of milk-based products	0,020
3.1.2	Infant formulae and follow-on formulae [8] ►M3 [9] ◄	0,020
3.1.3	Meat (excluding offal) of bovine animals, sheep, pig and poultry [6]	0,10
3.1.4	Offal of bovine animals, sheep, pig and poultry [6]	0,50
3.1.5	Muscle meat of fish [24] [25]	0,30
▼M6		
3.1.6	Crustaceans [26]: muscle meat from appendages and abdomen [44]. In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) muscle meat from appendages.	0,50
▼B		
3.1.7	Bivalve molluscs [26]	1,5
3.1.8	Cephalopods (without viscera) [26]	1,0
▼M6		
3.1.9	Legume vegetables [27], cereals and pulses	0,20

▼M6

	Foodstuffs (1)	Maximum levels (mg/kg wet weight)
3.1.10	Vegetables, excluding brassica vegetables, leaf vegetables, fresh herbs, fungi and seaweed (27). For potatoes the maximum level applies to peeled potatoes.	0,10
3.1.11	Brassica vegetables, leaf vegetables (43) and the following fungi (27): *Agaricus bisporus* (common mushroom), *Pleurotus ostreatus* (Oyster mushroom), *Lentinula edodes* (Shiitake mushroom)	0,30
▼B		
3.1.12	Fruit, excluding berries and small fruit (27)	0,10
3.1.13	Berries and small fruit (27)	0,20
3.1.14	Fats and oils, including milk fat	0,10
3.1.15	Fruit juices, concentrated fruit juices as reconstituted and fruit nectars (14)	0,050
3.1.16	Wine (including sparkling wine, excluding liqueur wine), cider, perry and fruit wine (11)	0,20 (28)
3.1.17	Aromatized wine, aromatized wine-based drinks and aromatized wine-product cocktails (11)	0,20 (28)
▼M3		
3.1.18	Food supplements (39)	3,0
3.2	**Cadmium**	
3.2.1	Meat (excluding offal) of bovine animals, sheep, pig and poultry (6)	0,050
3.2.2	Horsemeat, excluding offal (6)	0,20
3.2.3	Liver of bovine animals, sheep, pig, poultry and horse (6)	0,50
3.2.4	Kidney of bovine animals, sheep, pig, poultry and horse (6)	1,0
3.2.5	Muscle meat of fish (24) (25), excluding species listed in points 3.2.6, 3.2.7 and 3.2.8	0,050
3.2.6	Muscle meat of the following fish (24) (25): bonito (*Sarda sarda*) common two-banded seabream (*Diplodus vulgaris*) eel (*Anguilla anguilla*) grey mullet (*Mugil labrosus labrosus*) horse mackerel or scad (*Trachurus species*) louvar or luvar (*Luvarus imperialis*) mackerel (*Scomber species*) sardine (*Sardina pilchardus*) sardinops (*Sardinops species*) tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*) wedge sole (*Dicologoglossa cuneata*)	0,10

▼M3

Foodstuffs (1)		Maximum levels (mg/kg wet weight)
3.2.7	Muscle meat of the following fish (24) (25): bullet tuna (*Auxis species*)	0,20
3.2.8	Muscle meat of the following fish (24) (25): anchovy (*Engraulis species*) swordfish (*Xiphias gladius*)	0,30
▼M6		
3.2.9	Crustaceans (26): muscle meat from appendages and abdomen (44). In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) muscle meat from appendages.	0,50
▼M3		
3.2.10	Bivalve molluscs (26)	1,0
3.2.11	Cephalopods (without viscera) (26)	1,0
3.2.12	Cereals excluding bran, germ, wheat and rice	0,10
3.2.13	Bran, germ, wheat and rice	0,20
3.2.14	Soybeans	0,20
▼M6		
3.2.15	Vegetables and fruit, excluding leaf vegetables, fresh herbs, leafy brassica, fungi, stem vegetables, root and tuber vegetables and seaweed (27)	0,050
3.2.16	Stem vegetables, root and tuber vegetables excluding celeriac (27). For potatoes the maximum level applies to peeled potatoes.	0,10
3.2.17	Leaf vegetables, fresh herbs, leafy brassica, celeriac and the following fungi (27): *Agaricus bisporus* (common mushroom), *Pleurotus ostreatus* (Oyster mushroom), *Lentinula edodes* (Shiitake mushroom)	0,20
▼M3		
3.2.18	Fungi, excluding those listed in point 3.2.17 (27)	1,0
3.2.19	Food supplements (39) excl. food supplements listed in point 3.2.20	1,0
▼M6		
3.2.20	Food supplements (39) consisting exclusively or mainly of dried seaweed, products derived from seaweed, or of dried bivalve molluscs	3,0
▼B		
3.3	**Mercury**	
▼M6		
3.3.1	Fishery products (26) and muscle meat of fish (24) (25), excluding species listed in 3.3.2. The maximum level for crustaceans applies to muscle meat from appendages and abdomen (44). In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) it applies to muscle meat from appendages.	0,50

▼B

Foodstuffs (1)		Maximum levels (mg/kg wet weight)
▼M3		
3.3.2	Muscle meat of the following fish (24) (25): anglerfish (*Lophius species*) Atlantic catfish (*Anarhichas lupus*) bonito (*Sarda sarda*) eel (*Anguilla species*) emperor, orange roughy, rosy soldierfish (*Hoplostethus species*) grenadier (*Coryphaenoides rupestris*) halibut (*Hippoglossus hippoglossus*) kingklip (*Genypterus capensis*) marlin (*Makaira species*) megrim (*Lepidorhombus species*) mullet (*Mullus species*) pink cusk eel (*Genypterus blacodes*) pike (*Esox lucius*) plain bonito (*Orcynopsis unicolor*) poor cod (*Tricopterus minutes*) Portuguese dogfish (*Centroscymnus coelolepis*) rays (*Raja species*) redfish (*Sebastes marinus, S. mentella, S. viviparus*) sail fish (*Istiophorus platypterus*) scabbard fish (*Lepidopus caudatus, Aphanopus carbo*) seabream, pandora (*Pagellus species*) shark (all species) snake mackerel or butterfish (*Lepidocybium flavobrunneum, Ruvettus pretiosus, Gempylus serpens*) sturgeon (*Acipenser species*) swordfish (*Xiphias gladius*) tuna (*Thunnus species, Euthynnus species, Katsuwonus pelamis*)	1,0
3.3.3	Food supplements (39)	0,10
▼B		
3.4	**Tin (inorganic)**	
3.4.1	Canned foods other than beverages	200
3.4.2	Canned beverages, including fruit juices and vegetable juices	100
3.4.3	Canned baby foods and processed cereal-based foods for infants and young children, excluding dried and powdered products (3) (29)	50
3.4.4	Canned infant formulae and follow-on formulae (including infant milk and follow-on milk), excluding dried and powdered products ►M3 (8) ◄ (29)	50
3.4.5	Canned dietary foods for special medical purposes (8) (29) intended specifically for infants, excluding dried and powdered products	50

▼B

Section 4: 3-monochloropropane-1,2-diol (3-MCPD)

Foodstuffs (1)		Maximum levels (μg/kg)
4.1	Hydrolysed vegetable protein (30)	20
4.2	Soy sauce (30)	20

▼M9

Section 5: Dioxins and PCBs (31)

Foodstuffs		Maximum levels		
		Sum of dioxins (WHO-PCDD/F-TEQ) (32)	Sum of dioxins and dioxin-like PCBS (WHO-PCDD/F-PCB-TEQ) (32)	Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES – 6) (32)
5.1	Meat and meat products (excluding edible offal) of the following animals (6):			
	— bovine animals and sheep	2,5 pg/g fat (33)	4,0 pg/g fat (33)	40 ng/g fat (33)
	— poultry	1,75 pg/g fat (33)	3,0 pg/g fat (33)	40 ng/g fat (33)
	— pigs	1,0 pg/g fat (33)	1,25 pg/g fat (33)	40 ng/g fat (33)
5.2	Liver of terrestrial animals referred to in 5.1 (6), and derived products thereof,	4,5 pg/g fat (33)	10,0 pg/g fat (33)	40 ng/g fat (33)
5.3	Muscle meat of fish and fishery products and products thereof (25) (34), with the exemption of: — wild caught eel — wild caught fresh water fish, with the exception of diadromous fish species caught in fresh water — fish liver and derived products — marine oils The maximum level for crustaceans applies to muscle meat from appendages and abdomen (44). In case of crabs and crab-like crustaceans (*Brachyura and Anomura*) it applies to muscle meat from appendages.	3,5 pg/g wet weight	6,5 pg/g wet weight	75 ng/g wet weight
5.4	Muscle meat of wild caught fresh water fish, with the exception of diadromous fish species caught in fresh water, and products thereof (25)	3,5 pg/g wet weight	6,5 pg/g wet weight	125 ng/g wet weight
5.5	Muscle meat of wild caught eel (*Anguilla anguilla*) and products thereof	3,5 pg/g wet weight	10,0 pg/g wet weight	300 ng/g wet weight

▼M9

	Foodstuffs	Maximum levels		
		Sum of dioxins (WHO-PCDD/F-TEQ) ([32])	Sum of dioxins and dioxin-like PCBS (WHO-PCDD/F-PCB-TEQ) ([32])	Sum of PCB28, PCB52, PCB101, PCB138, PCB153 and PCB180 (ICES – 6) ([32])
5.6	Fish liver and derived products thereof with the exception of marine oils referred to in point 5.7	—	20,0 pg/g wet weight ([38])	200 ng/g wet weight ([38])
5.7	Marine oils (fish body oil, fish liver oil and oils of other marine organisms intended for human consumption)	1,75 pg/g fat	6,0 pg/g fat	200 ng/g fat
5.8	Raw milk ([6]) and dairy products ([6]), including butter fat	2,5 pg/g fat ([33])	5,5 pg/g fat ([33])	40 ng/g fat ([33])
5.9	Hen eggs and egg products ([6])	2,5 pg/g fat ([33])	5,0 pg/g fat ([33])	40 ng/g fat ([33])
5.10	Fat of the following animals:			
	— bovine animals and sheep	2,5 pg/g fat	4,0 pg/g fat	40 ng/g fat
	— poultry	1,75 pg/g fat	3,0 pg/g fat	40 ng/g fat
	— pigs	1,0 pg/g fat	1,25 pg/g fat	40 ng/g fat
5.11	Mixed animal fats	1,5 pg/g fat	2,50 pg/g fat	40 ng/g fat
5.12	Vegetable oils and fats	0,75 pg/g fat	1,25 pg/g fat	40 ng/g fat
5.13	Foods for infants and young children ([4])	0,1 pg/g wet weight	0,2 pg/g wet weight	1,0 ng/g wet weight

▼M7

Section 6: Polycyclic aromatic hydrocarbons

	Foodstuffs	Maximum levels (μg/kg)	
6.1	Benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene	Benzo(a)pyrene	Sum of benzo(a)pyrene, benz(a)anthracene, benzo(b)fluoranthene and chrysene ([45])
6.1.1	Oils and fats (excluding cocoa butter and coconut oil) intended for direct human consumption or use as an ingredient in food	2,0	10,0

▼M7

Foodstuffs		Maximum levels (μg/kg)	
6.1.2	Cocoa beans and derived products	5,0 μg/kg fat as from 1.4.2013	35,0 μg/kg fat as from 1.4.2013 until 31.3.2015 30,0 μg/kg fat as from 1.4.2015
6.1.3	Coconut oil intended for direct human consumption or use as an ingredient in food	2,0	20,0
6.1.4	Smoked meat and smoked meat products	5,0 until 31.8.2014 2,0 as from 1.9.2014	30,0 as from 1.9.2012 until 31.8.2014 12,0 as from 1.9.2014
6.1.5	Muscle meat of smoked fish and smoked fishery products (25) (36), excluding fishery products listed in points 6.1.6 and 6.1.7. The maximum level for smoked crustaceans applies to muscle meat from appendages and abdomen (44). In case of smoked crabs and crab-like crustaceans (*Brachyura* and *Anomura*) it applies to muscle meat from appendages.	5,0 until 31.8.2014 2,0 as from 1.9.2014	30,0 as from 1.9.2012 until 31.8.2014 12,0 as from 1.9.2014
6.1.6	Smoked sprats and canned smoked sprats (25) (47) (*sprattus sprattus*); bivalve molluscs (fresh, chilled or frozen) (26); heat treated meat and heat treated meat products (48) sold to the final consumer	5,0	30,0
6.1.7	Bivalve molluscs (26) (smoked)	6,0	35,0
6.1.8	Processed cereal-based foods and baby foods for infants and young children (3) (29)	1,0	1,0
6.1.9	Infant formulae and follow-on formulae, including infant milk and follow-on milk (8) (29)	1,0	1,0
6.1.10	Dietary foods for special medical purposes (9) (29) intended specifically for infants	1,0	1,0

▼M11

Section 7: Melamine and its structural analogues

Foodstuffs		Maximum levels (mg/kg)
7.1.	Melamine	
7.1.1.	Food with the exception of infant formulae and follow-on formulae (49)	2,5
7.1.2.	Powdered infant formulae and follow-on formulae	1

▼B

(1) As regards fruits, vegetables and cereals, reference is made to the foodstuffs listed in the relevant category as defined in Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC (OJ L 70, 16.3.2005, p. 1) as last amended by Regulation (EC) No 178/2006 (OJ L 29, 2.2.2006, p. 3). This means, *inter alia*, that buckwheat (*Fagopyrum* sp) is included in 'cereals' and buckwheat products are included in 'cereal products'. ►M3 Tree nuts are not covered by the maximum level for fruit. ◄

(2) The maximum levels do not apply for fresh spinach to be subjected to processing and which is directly transported in bulk from field to processing plant.

(3) ►M6 Foodstuffs listed in this category as defined in Commission Directive 2006/125/EC of 5 December 2006 on processed cereal-based foods and baby foods for infants and young children (OJ L 339, 6.12.2006, p. 16). ◄

(4) The maximum level refers to the products ready to use (marketed as such or after reconstitution as instructed by the manufacturer).

(5) ►M5 The maximum levels refer to the edible part of groundnuts (peanuts) and tree nuts. If groundnuts (peanuts) and tree nuts 'in shell' are analysed, it is assumed when calculating the aflatoxin content all the contamination is on the edible part, except in the case of Brazil nuts. ◄

(6) Foodstuffs listed in this category as defined in Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin (OJ L 226, 25.6.2004, p. 22).

(7) The maximum level refers to the dry matter. The dry matter is determined in accordance with Regulation (EC) No 401/2006.

►M3 (8) Foodstuffs listed in this category as defined in Commission Directive 2006/141/EC (OJ L 401, 30.12.2006, p. 1). ◄

(9) Foodstuffs listed in this category as defined in Commission Directive 1999/21/EC of 25 March 1999 on dietary foods for special medical purposes (OJ L 91, 7.4.1999, p. 29).

(10) The maximum level refers in the case of milk and milk products, to the products ready for use (marketed as such or reconstituted as instructed by the manufacturer) and in the case of products other than milk and milk products, to the dry matter. The dry matter is determined in accordance with Regulation (EC) No 401/2006.

(11) Foodstuffs listed in this category as defined in Council Regulation (EC) No 1493/1999 of 17 May 1999 on the common organisation of the market in wine (OJ L 179, 14.7.1999, p. 1) as last amended by the Protocol concerning the conditions and arrangements for admission of the Republic of Bulgaria and Romania to the European Union (OJ L 157, 21.6.2005, p. 29).

(12) The maximum level applies to products produced from the 2005 harvest onwards.

(13) Foodstuffs listed in this category as defined in Council Regulation (EEC) No 1601/91 of 10 June 1991 laying down general rules on the definition, description and presentation of aromatised wines, aromatised wine-based drinks and aromatised wine-product cocktails (OJ L 149, 14.6.1991, p. 1) as last amended by the Protocol concerning the conditions and arrangements for admission of the Republic of Bulgaria and Romania to the European Union. The maximum level for OTA applicable to these beverages is function of the proportion of wine and/or grape must present in the finished product.

(14) Foodstuffs listed in this category as defined in Council Directive 2001/112/EC of 20 December 2001 relating to fruit juices and certain similar products intended for human consumption (OJ L 10, 12.1.2002, p. 58).

(15) Foodstuffs listed in this category as defined in Council Regulation (EEC) No 1576/89 of 29 May 1989 laying down general rules on the definition, description and presentation of spirit drinks (OJ L 160, 12.6.1989, p. 1), as last amended by the Protocol concerning the conditions and arrangements for admission of the Republic of Bulgaria and Romania to the European Union.

(16) ►M6 Infants and young children as defined in Directive 2006/141/EC (OJ L 401, 30.12.2006, p. 1) and Directive 2006/125/EC. ◄

(17) For the purpose of the application of maximum levels for deoxynivalenol, zearalenone, T-2 and HT-2 toxin established in points 2.4, 2.5 and 2.7 rice is not included in 'cereals' and rice products are not included in 'cereal products'.

(18) The maximum level applies to unprocessed cereals placed on the market for first-stage processing. 'First-stage processing' shall mean any physical or thermal treatment, other than drying, of or on the grain. Cleaning, sorting and drying procedures are not considered to be 'first-stage processing' insofar no physical action is exerted on the grain kernel itself and the whole grain remains intact after cleaning and sorting. In integrated production and processing systems, the maximum level applies to the unprocessed cereals in case they are intended for first-stage processing.

(19) The maximum level applies to cereals harvested and taken over, as from the 2005/06 marketing year, in accordance with Commission Regulation (EC) No 824/2000 of 19 April 2000 establishing procedures for the taking-over of cereals by intervention agencies and laying down methods of analysis for determining the quality of cereals (OJ L 100, 20.4.2000, p. 31), as last amended by Regulation (EC) No 1068/2005 (OJ L 174, 7.7.2005, p. 65).

►M1 (20) Maximum level shall apply from 1 October 2007. ◄

►M1 ———— ◄

(22) Pasta (dry) means pasta with a water content of approximately 12 %.

(23) Maximum level shall apply from 1 October 2007.

▼B

(24) Fish listed in this category as defined in category (a), with the exclusion of fish liver falling under code CN 0302 70 00, of the list in Article 1 of Council Regulation (EC) No 104/2000 (OJ L 17, 21.1.2000, p. 22) as last amended by the Act concerning the conditions of accession of the Czech Republic, the Republic of Estonia, the Republic of Cyprus, the Republic of Latvia, the Republic of Lithuania, the Republic of Hungary, the Republic of Malta, the Republic of Poland, the Republic of Slovenia and the Slovak Republic and the adjustments to the Treaties on which the European Union is founded (OJ L 236, 23.9.2003, p. 33). In case of dried, diluted, processed and/or compound foodstuffs Article 2(1) and 2(2) apply.

(25) Where fish are intended to be eaten whole, the maximum level shall apply to the whole fish.

(26) Foodstuffs falling within category (c) and (f) of the list in Article 1 of Regulation (EC) No 104/2000, as appropriate (species as listed in the relevant entry). In case of dried, diluted, processed and/or compound foodstuffs Article 2(1) and 2(2) apply.

(27) The maximum level applies after washing of the fruit or vegetables and separating the edible part.

(28) The maximum level applies to products produced from the 2001 fruit harvest onwards.

(29) The maximum level refers to the product as sold.

(30) The maximum level is given for the liquid product containing 40 % dry matter, corresponding to a maximum level of 50 μg/kg in the dry matter. The level needs to be adjusted proportionally according to the dry matter content of the products.

(31) ►M9 Dioxins (sum of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), expressed as World Health Organisation (WHO) toxic equivalent using the WHO-toxic equivalency factors (WHO-TEFs)) and sum of dioxins and dioxin-like PCBs (sum of PCDDs, PCDFs and polychlorinated biphenyls (PCBs), expressed as WHO toxic equivalent using the WHO-TEFs). WHO-TEFs for human risk assessment based on the conclusions of the World Health Organization (WHO) – International Programme on Chemical Safety (IPCS) expert meeting which was held in Geneva in June 2005 (Martin van den Berg et al., The 2005 World Health Organization Re-evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Toxicological Sciences 93(2), 223-241 (2006))

Congener	TEF value	Congener	TEF value
Dibenzo-p-dioxins ('PCDDs')		**'Dioxin-like' PCBs Non-ortho PCBs + Mono-ortho PCBs**	
2,3,7,8-TCDD	1		
1,2,3,7,8-PeCDD	1	*Non-ortho PCBs*	
1,2,3,4,7,8-HxCDD	0,1	PCB 77	0,0001
1,2,3,6,7,8-HxCDD	0,1	PCB 81	0,0003
1,2,3,7,8,9-HxCDD	0,1	PCB 126	0,1
1,2,3,4,6,7,8-HpCDD	0,01	PCB 169	0,03
OCDD	0,0003		
Dibenzofurans ('PCDFs')		*Mono-ortho PCBs*	
2,3,7,8-TCDF	0,1	PCB 105	0,00003
1,2,3,7,8-PeCDF	0,03	PCB 114	0,00003
2,3,4,7,8-PeCDF	0,3	PCB 118	0,00003
1,2,3,4,7,8-HxCDF	0,1	PCB 123	0,00003
1,2,3,6,7,8-HxCDF	0,1	PCB 156	0,00003
1,2,3,7,8,9-HxCDF	0,1	PCB 157	0,00003
2,3,4,6,7,8-HxCDF	0,1	PCB 167	0,00003
1,2,3,4,6,7,8-HpCDF	0,01	PCB 189	0,00003
1,2,3,4,7,8,9-HpCDF	0,01		
OCDF	0,0003		

Abbreviations used: 'T' = tetra; 'Pe' = penta; 'Hx' = hexa; 'Hp' = hepta; 'O' = octa; 'CDD' = chlorodibenzodioxin; 'CDF' = chlorodibenzofuran; 'CB' = chlorobiphenyl. ◄

(32) Upperbound concentrations: Upperbound concentrations are calculated on the assumption that all the values of the different congeners below the limit of quantification are equal to the limit of quantification.

(33) ►M9 The maximum level expressed on fat is not applicable for foods containing < 2 % fat. For foods containing less than 2 % fat, the maximum level applicable is the level on product basis corresponding to the level on product basis for the food containing 2 % fat, calculated from the maximum level established on fat basis, making use of following formula:

▼B

Maximum level expressed on product basis for foods containing less than 2 % fat = maximum level expressed on fat for that food x 0,02. ◄

►M2 ([34]) Foodstuffs listed in this category as defined in categories (a), (b), (c), (e) and (f) of the list in Article 1 of Regulation (EC) No 104/2000, with the exclusion of fish liver referred to in point 5.11. ◄

►M7 ———————— ◄

([36]) Foodstuffs listed in this category as defined in categories (b), (c), and (f) of the list in Article 1 of Regulation (EC) No 104/2000.

►M1 ([37]) The exemption applies only for maize for which it is evident e.g. through labelling, destination, that it is intended for use in a wet milling process only (starch production). ◄

►M2 ([38]) In the case of canned fish liver, the maximum level applies to the whole edible content of the can. ◄

►M3 ([39]) The maximum level applies to the food supplements as sold. ◄

►M5 ([40]) Oilseeds falling under codes CN 1201, 1202, 1203, 1204, 1205, 1206, 1207 and derived products CN 1208; melon seeds fall under code ex 1207 99.

([41]) In case derived/processed products thereof are derived/processed solely or almost solely from the tree nuts concerned, the maximum levels as established for the corresponding tree nuts apply also to the derived/processed products. In other cases, Article 2(1) and 2(2) apply for the derived/processed products. ◄

►M4 ([42]) The maximum level applies to the pure and undiluted extract, obtained whereby 1 kg of extract is obtained from 3 to 4 kg liquorice root. ◄

►M6 ([43]) The maximum level for leaf vegetables does not apply to fresh herbs (falling under Code number 0256000 in Annex I to Regulation (EC) No 396/2005).

([44]) This definition excludes the cephalothorax of crustaceans. ◄

►M7 ([45]) Lower bound concentrations are calculated on the assumption that all the values of the four substances below the limit of quantification are zero.

([46]) Meat and meat products that have undergone a heat treatment potentially resulting in formation of PAH, i.e. only grilling and barbecuing.

([47]) For the canned product the analysis shall be carried out on the whole content of the can. As regards the maximum level for the whole composite product Art. 2(1)(c) and 2(2) shall apply. ◄

►M11 ([48]) The maximum level does not apply to food for which it can be proven that the level of melamine higher than 2,5 mg/kg is the consequence of authorized use of cyromazine as insecticide. The melamine level shall not exceed the level of cyromazine. ◄