Water Recycling and Energy Management in Virolan Puutarha

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GLOSSARY

LED	Light-emitting-diode
HPS	High pressure sodium
Lux	is a definition for the light intensity
Lumen	The definition for light flow
Hydroponic	Water work growing system
NFT	Nutrient film technique
ml	digital definition of lumen

ABSTRACT

The importance of Eco-Agriculture is getting more and more serious nowadays because of rapid world population growth. People need food to live. Energy and water are two essential inputs needed for every plant to grow and develop. Without energy and water no food can be produced. Energy and water resources are not evenly distributed on this planet. In some areas, like the Middle East and African countries, water is the limiting factor for producing food. At the same time, these countries have lots of energy resources in the form of sunshine. On the other side of the world the situation is totally different. In European countries, for example, water is not a problem. They have enough water resources but energy from sunlight is not always enough for plants to grow and produce food.

Producing food in a closed water system could be a good solution for Eastern countries with limited water resources. In a closed water recycling system, the water could be mechanically treated or filtered and reused. This system does no harm to the environment or ground water resources. In this thesis, one of the most efficient water recycling systems, namely the Hydroponic method of growing plants, is introduced. This closed system does have some problems however, such as algal growth. Prevention of algal growth is one of the main topics of this work.

CONTETS

1 INTRODUCTION

The importance of Eco-Agriculture is getting more and more serious nowadays because of rapid world population growth. People need food to live. Energy and water are two important facts for every plant to grow and develop. Without energy and water no food can be produced. Energy and water resources are not fairly distributed in this planet. In some areas like the Middle East and African countries water if the limiting fact for producing food. This is in a way that these countries have lots of energy resources and sunshine. In other side of the world the situation is totally different. In European countries for example, water is not a problem. They have enough water resources but energy and sunlight is not enough for plants to grow and produce food.

Producing food in closed water system could be a good solution for Eastern countries with less water resources. In a closed water recycling system, the water could be mechanically treated or filtered and reused. This system has no harm for environment and ground water resources. In this thesis one of the most efficient water recycling systems in form of Hydroponic method of growing plants will be introduced. This closed system however has some problems like algal growth prevention which is one of the main topics of this work.

Energy management is another part of this thesis. In Finland and most of European countries most of the year, the amount of light and heat in a day is not enough for plants to grow. Different lights are in use in different areas according to plants need. In this thesis, two different lightening systems will be compared with each other. High pressure sodium bulbs or HPS bulbs and light emitting diode or LED lights will be compared with each other according to their efficiency, heat production, color of the lights, quality and quantity of vegetables produced with these two different lights.

Aim of doing this thesis, materials and methods which are used to reach the aim will be introduced in details. At the end of thesis the best solutions and discussions will be also introduced. This final thesis tries to bring some big part of writers learning during 4 years of studying Environmental engineering in Tampere University of Applied Sciences and mix it with the daily working life of the writer in Virolan puutarha.

Most of the qualitative information is form writer’s personal 4 years work experiences in Virolan puutarha about the water recycling and energy management. The information about lights and problems with algae are the things that writer has seen and tried to help and solve the problem.

Picture 1 – Virolan puutarha

2 Virolan puutarha

2.1 History of Virolan puutarha

In the area of Tiihala part of Kangasala city, in the heart of the beautiful nature, Oksanen family bought an agricultural land in the year 1918. The hard working Oksanen family started their business first by apple trees and strawberries and next, by vegetables.

In 1930 first greenhouses of the family were built on the Kyläjärvi beach. At that time the greenhouses was specified for growing tomato. The irrigating water was pumped directly from the Kyläjärvi by windmill and the heating during winter was possible by burning wood in the old fire furnace.

In 1962, new greenhouses were built on the other side of the Tiihalantie and on top of the small hill. In these new rooms cucumber was planted. With the help of electricity and water pumps, water could be pumped in to the greenhouses for irrigation and other uses. Greenhouses were warmed by burning oil. The old greenhouses on the beach were still in use to crop dill in them for several years.

In 1970s, Virolan puutarha was several times the best cucumber producer in whole Finland.

In 1977, the place was transferred in to Timo Oksanens name. Timo was already in this business since his childhood. He always had a dream to improve the Hydroponic way of cucumber cultivations and at last he was successful to do so. From the first steps cucumbers were grown in to the closed watering system with no bed soil presents to keep them, where the water was circulated and nutrients did not lose from the irrigating system. Cucumber plants needed nutrients and in this hydroponic system the nutrients were given to the plants as soluble fertilizers mixed with the irrigating water. Virolan puutarha was the first place to bring up this technology in Finland.

In 1986, mesh pot salad cultivation started in Virolan puutarha. Very soon salad took place of cucumber in Virolan puutarha. The system of salad cultivation was nutrient film technique hydroponic and it was much easier than cucumber. At the same time because of the successful business in salad production, Virolan puutarha started to cultivate lettuce during whole year long from summer to winter and from spring to fall.

Bside different varieties of lettuce many different vegetables were also planted at the same time.
In 1994, Diesel electricity generator built in Virolan puutarha. The diesel electricity could produce the electricity was needed for lightening the greenhouse and also it could produce 90 % of the heat too. Diesel generators are still in use to cover the extra heat needed in the greenhouse during the cold winter.
In 1997, last greenhouses were built. The area of greenhouses all together are 10 000 squared meter.
In 2001, Siuronkoski and Arrakoski power plants where bought by Timo Oksanen. The idea was to insure the future of Virolan puutarha and to use renewable energy for vegetable production.
In future Virolan puutarha still tries to utilize other renewable sources of energy. Sami Oksanen is now the owner of the company and he tries to get permission to build the biggest wind survey of the area with 150 meters height to produce clean electricity for Virolan puutarha. (1)

2.2 Hydroponic system

The word Hydroponic is a combined Greek word. Hydro in Greek means water and ponics means labor, so the word Hydro-ponos means`` water working`` (2), which can give a quick view of soilless gardening. The Hydroponic systems are nowadays important because of their efficiency and speed. In hydroponic system, there is no soil and plants are growing mostly in water which can be feed with nutrients every now and then.
Virolan puutarha is one of the first inventors of Hydroponic vegetable growing system in Finland. The seeds are planting by automatic machine in small pots. The planted seeds are replaced to the warmer and more humid nurseries to germinate. When the young plants are about four leaves approximately, they will be transferred to the long spouts on the big tables. The table sizes in Virolan puutarha are varied from 60-500 squared meters. Spouts have holes same size as the standard pots for all kind of vegetables in the greenhouse. Each pot contains a young growing plant will be transferred to one of these holes on the spouts for final growth.
The spouts are moving forwards by hydraulic motors under each table. It only works by pressing the button when workers are packing vegetables. The Hydroponic technique in

Virolan puutarha is NFT technique which refers to Nutrient Film Technique Hydroponic Vegetable Growth System. In NFT system, vegetables which are already planted in small mesh pots and have four leaves will be transferred on the plastic spots. The spouts are placed on metal a table which automatically moves forwards. Irrigating water contains almost all the nutrition that vegetables need to grow. Nutrients are solved in water and they enter from one head of the spouts, pass through the spouts and flow out of the spouts on the other head. (2)

2.2.1 Advantages of hydroponic growing system in compare with the traditional soil growing system:

In hydroponic system the vegetables are not in contact with the soil and dirt, so the hydroponic system is more hygienic than normal soil growing system.
In hydroponic system, cultivation is happening in more suitable place for the workers, normally on the tables and the workers do not need to bend over and pack the vegetables or take care of them so the hydroponic cultivation system is easier for workers to do.
Weed control is much easier in hydroponic system and practically there is no weed which had a chance to grow because the place is limited and specified only for target plant to grow, there is no extra space for any kind of weed to grow in the pot.
Hydroponic system gives a chance to cultivate vegetables quite close to each other, but in soil cultivation the distance between plants is much bigger. For example in traditional soil cultivation the distance between two salads should be between 30-45 cm.
In hydroponic system because the growing condition is under control, the distance between two salad is only about 8 cm .The cultivation is independent of the soil structure of the area.
It is possible to do better fertilization in hydroponic system if fertilization is needed. Usually nutrients will dissolve in irrigating water.
Better use of recycled water, the system is actually based on recycled water and it works even for dry countries where the water is a limiting factor.
Overall quantity yields and better quality products are obtained by utilizing hydroponic system. (2)

2.3 Water Recycling in Virolan puutarha

Water is the limiting factor for agriculture in dry countries like Iran. This is in a way that, most of the dry developing countries have more water run-off after irrigation because they do not have proper irrigation or recycling system. In Iran 60 percent of the irrigation water is running out of the system and penetrates in to the land. Depend on its contents, it can contaminate the ground water resources and soil structure.

Energy is the limiting factor for cold climates like Finland. Ground water is protected in Finland and according to the groundwater protection law, any act which can contaminate or change the ground water quality is prohibited. The reason for having this act in Finish legislation is to protect the proper quality of the natural ground water, try to improve the quality of the water and to restore the ground water. (10)

In Virolan puutarha, closed irrigation system has already established in 1970s. The irrigating wastewater is recycled, so that it does not leave the system, but it is reused again and again.In Virolan greenhouse, hydroponic cultivation is happening on the big metal tables. Tables have some kind of slope to let the irrigating water flow from one side to another side of the spout. This will also prevent the wastewater to stand in the spout and around the roots which can cause diseases like root rot for the plants. In the back side of the table young plants with about 4 leaves are planting in the front side of the table. Already grown vegetables are ready to be packed every day. Lettuce and different kinds of vegetables are the main products of the company. Plants are cropping in mesh pots and later on they will get placed in to the holes on the plastic spouts. From one side of the spout irrigating water enters through the spout and from other side of the spout, where the big waste pipes are installed to collect the wastewater and pass it through metal mesh to be filtered. The metal mesh takes only the large objects like leaves and pots off from the waste water and makes it ready for the sand filtration.

2.3.1 Sand Filtration

There is a big container about 20 meter long, 5 meters wide and 2-3 meters high, full of sand in the back of the greenhouse, where all wastewater after irrigation needs to pass through. The sand filtration is a common mechanical way of treating wastewater. Sand filtration, depending on size of the sand, can mechanically clean the wastewater from small solid objects in the wastewater like soil, sand or even small piece of trash or leaves.

After sand filtration the mechanically treated water will be collected and saved in big tanks located underground in each room. Tanks capacity, depending on room size can be up to 3000 liters or even more. The water will be automatically pumped and reused for irrigation again.

Picture 2- Sand filtration area

Picture 3- water pump

Irrigation is done automatically. There are some sorts of computers beside the entrance of each room that can be set to irrigate the room between certain times when it's needed. Irrigation is important in producing all kinds of plants, but for sensitive plants with wide leaves like lettuce it is extra important. In summer time irrigation is even more important because of evaporation and the high temperature of the greenhouse rooms.

Picture 4 -Automatic Irrigating system

In Virolan puutarha no water goes out of the system. It means that all irrigation and washing water is going through a closed system. The irrigating water and the water which is used for washing spouts after packaging, they will be all recycled and reused and no water will be running out of the system or penetrating in to the ground. The ground is isolated with polystyrene to keep the temperature and covered by concrete. The concrete covered land prevents the floor from the water penetration and also prevents the greenhouse from rats, foxes and other rodent animals to enter the greenhouse.

Picture 5 - Underground Water tanks

2.4 Lightening system in Virolan puutarha

2.4.1 HPS or high pressure sodium lights:

In Finland most of the year, days are quite short and there is not enough light for plants to grow. HPS lights used for plant growing have been always one of the best alternatives for sunlight. HPS refers to high pressure sodium. The mechanism of this generation of lights is based on producing light from high pressure excited sodium. There is some mercury also in the bulb to start warming sodium gas. These lights can produce high temperature. Xenon is also used as starter in HPS lamps.

A life time expectancy of the HPS lights are between 12-18 months. The power of this generation of lamps could vary between 70-1000 watts. The bigger power of the lamp, the more light will be emitted from HPS grow lamp.

There are two different kinds of sodium lights, low pressure sodium lights and high pressure sodium lights. Because sodium vapor lamps cause less light pollutions than mercury-vapor lamps, they are more common and most of the companies prefer to use them instead of mercury-vapor lamps. Light pollution simply means having the light in unwanted place. High pressure sodium light can produce red/orange color light which is the best supply for the sunshine. Red/orange color light is ideal for encouraging the rapid growth, fruiting flowering and budding in general. (15)

2.4.2 Lumen & Lux

Light flow could be measured by lumen. In digital lux meters lumen is showed by ml. One lumen is equal to flow of light emitted from very small wax candle. Lux is a definition for the light intensity. The lumen output measures the light intensity. One lux is equal to one lumen per square meter. The higher intensity brings brighter lightening. Lights with higher lumen have higher intensity and they are brighter. Each HPS grow light can produce more than 140 ml/W or lumen per watt.

In hot summer day, the average amount of light received to the square meter land is about 50000 lux. In greenhouse conditions, minimum light needed for growth is between 1000-15000 lux or lumen per square meter. 400 watts HPS grow lights are producing the light flow of 50000 lumen per square meter which is the same amount of the light plants can get from sun shine. (15)

The height of HPS lamps is very important facts which must be keep in mind when the lights are installing. If lights are close to plants, the plants will die or leaves will be burned because of too much light. When the lights are so far from plants, the plants cannot get enough light and again they will die or deformed, so the optimal height for installing HPS grow lights should be measured before the cultivation process starts. Measuring the suitable height in Virolan puutarha happens normally by test. The testing plants should be checked every now and then to see if their leaves start to burn and brownish spots are observed on the edge of lettuce leaves, the distance between plants and lights should increase and if leaves are looking lighter than normal or lettuce is tall but there is not enough leaves on each plant, lights need to be closer to growing plants.

Picture 6- HPS bulbs

2.4.3 HPS grow lights in Virolan puutarha

High pressure sodium grow lights have been the only alternative lights for long dark cold winters in Virolan puutarha since cucumber was the main production of the company. 400 watt HPS lamps are set 1.5-2 meters higher than growing tables in each room and the scarcity of the lamps are between 2-4 squared meters. Average energy consumption HPS lightening rooms is 100 watts for each squared meter In Virolan puutarha.

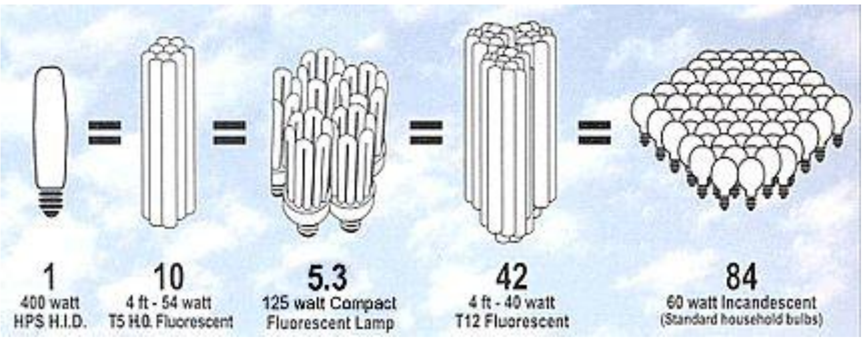
Metal sheets are used as reflectors around the horizontally installed HPS lights. These reflectors can increase the efficiency of the HPS grow lights up to 30 percent.

2.4.4 Advantages of HPS grow lights

HPS lights are good source of heat in greenhouse. The temperature of the HPS lights is sometimes bout 300˚.
Light spectrum color is quite the same as sun light and it looks so natural. (7)

2.4.5 Disadvantages of HPS grow lights

HPS lamps are consuming lots of electricity. They need high voltage and 400 watts of energy.



Picture 7- HPS bulb compared with other lamps (6)

HPS lights can burn sensitive leaves of vegetables. In Virolan puutarha HPS lights are installed 1.5-2 meters higher than vegetables.
Short life expectancy in compare with LED energy saving lamps.(7)

2.5 Energy management

The process of monitoring, controlling and conserving energy in a business means energy management. Saving energy can bring more benefit for the company. Using energy in a proper way, using renewable energy resources, proper use of available space in greenhouse and utilizing cheaper energy sources, equipments and devices are forming energy management system in Virolan puutarha. (13)

In the volatile energy market of nowadays, managing and controlling the use of energy is not be easy. For managing the energy use, we need to understand the energy usage in the company. We need to optimize the energy supply and improve our energy use efficiency. Oksanen family could nicely control and manage the energy consumptions in Virolan puutarha. They do the energy benchmarking and determine energy consumption of the company. They try to reduce consuming other sources of energy and focus on environmentally friendly electricity production as a main source of energy for Virolan puutarhas energy consumption.

Picture 8 - LED lamp

Picture 9- Cultivating in 4 floors by using LED lamps

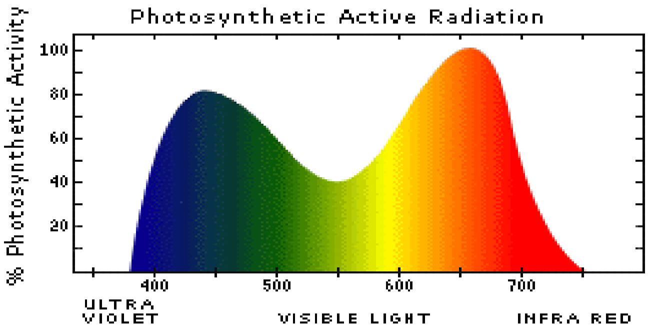
2.5.1 Efficient lights for growth

Utilizing solar energy in efficient way is important for plants to grow, especially in environments with low light intensity. Human eyes could only see seven different colors which are between 400-700 nm wavelengths. Visible colors in complete range of the wavelength (400-700 nm) are: red, orange, yellow, green, blue, indigo and violet. Phototropins and Cryptochromes are blue light photoreceptors in plants. Cryptochromes

The most efficient light for growth is red and blue. In LED lamps we have the possibility to mix these two lights together and get the best combined lights for growing plants.
The worst color for growth is green.
In Virolan puutaraha, the focus is mostly on red and blue color LED lamps.

are playing roll in UV-A or blue color reception. Blue lights are coordinately regulated to photomorphogenic processes, including de-etiolation or loosing color, vegetative growth, flowering induction and circadian or daily rhythms. Phytochromes are red or far red color receptors in plants. Phytochromes are also playing significant role in seed germination and shade avoidance. When the red light is mixed with small amount of blue light, leaf growth increases significantly. (22)& (23)
Three principal characters of lights can affect the growth:

Quantity: quantity of the lights refers to intensity or concentration of the light. In nature the quantity of sunlight in summer is at highest and in winter is at the lowest range. But in green house the aim is to keep the quantity always in highest as it could be. (7)
Quality: refers to the color or wavelength of the light. The most efficient colors for growth are red and blue. Blue color is responsible for leaf growth. Red color mixed with blue can encourage flowering. (7)
Duration: refers to length of the day of hours that lights are in used for plants to continue growing. (7)



Picture 10- Sun effects on photosynthesis (6)

200 - 280 nm	UVC ultraviolet range which is extremely harmful to plants because it is highly toxic.
280 - 315 nm	Includes harmful UVB ultraviolet light which causes plants colors to fade.
315 - 380 nm	Range of UVA ultraviolet light which is neither harmful nor beneficial to plant growth.
380 - 400 nm	Start of visible light spectrum. Process of chlorophyll absorption begins. UV protected plastics ideally block out any light below this range.
400 - 520 nm	This range includes violet, blue, and green bands. Peak absorption by chlorophyll occurs, and a strong influence on photosynthesis. (promotes vegetative growth)
520 - 610 nm	This range includes the green, yellow, and orange bands and has less absorption by pigments.
610 - 720 nm	This is the red band. Large amount of absorption by chlorophyll occurs, and most significant influence on photosynthesis. (promotes flowering and budding)
720 - 1000 nm	There is little absorption by chlorophyll here. Flowering and germination is influenced. At the high end of the band is infrared, which is heat.
1000+ nm	Totally infrared range. All energy absorbed at this point is converted to heat.

Table 1- Different lights wavelength and their effects on plants (6)

2.5.2 Basics of LED lamps

In the year 1907, The British scientist Henry J. Round discovered that the junction of semi-conductors can produce light. First generation of LED lamps were made of Silicon Carbide (Sic) and the light was really dim. Russian researcher Oleg Vladimirovich Losev, made the first LED light in 1920s, after long time that LED light was forgotten, but his research was not reflected by his country until 1936 that George Destriau produced the first official LED light by passing an electric current through Zinc Sulfide powders.The first visible and infrared red LEDs were developed in 1962 by Nick Holonyak in General Electric Company. Nick Holonyak is called the father of light emitting diode. (8)

LED or light-emitting-diode, is a semiconductor diode that produces narrow spectrum light with no filament. The diode has two terminals in the lams body and the light will produce when electricity passes unidirectional through the LED recruit. (3) In the mid 1990s, LED lamps were only used as traffic lights or automotive rear lights. The seedlings usually need blue LED light to grow, but adult plants need more red LED lights for growth and thrive. (5)

There are two different lights using for vegetable growth in Virolan puutarha. First and the still the most common one is the normal yellow color, 400 watt lamps and the new and more efficient ones with red-blue color, LED energy saving lamps with 25-90 watts energy consumptions.

The lamps are normally placed on top of the plants, but the suitable height and density of them is varied a lot. In Virolan puutarha, the Yellow 400 watt lamps are normally 1.5-2 meters higher than plants because they produce heat and they can burn the sensitive lettuce leafs. LED (Light-emitting-diode) lamps are possible to be placed closer to the plants because they do not produce much heat and in Virolan puutarha LED lamps are mostly 40- 60 cm higher that plants.

Density of the lights is also very important for growing vegetables. In Virolan puutarha, 400 watt lamps are 1-4 meters far from each other. LED lamps are closer, about 60 cm far from next LED lamp. The density of the lamps has a direct effect on the light needed for plants to live. If the lamps are very close to each other again there is a danger of leaf burning or water will be vaporized a lot so the water consumption will be raised and by that humidity of the vaporized water can raise the temperature inside greenhouse and some unreasonable costs for the company. If lights are more scarce, Plant will not get enough light and it can affect the growth.

In Virolan puutarha finding suitable height, density and the duration of using lights in the greenhouse are three important factors in greenhouse lightening.

2.5.3 Advantages of LED lamps as compared with normal 400 watts HPS greenhouse lamps

1. The higher efficiency of the LED lamps for growth. This higher efficiency could shorten the harvesting time. In Virolan puutarha, LED lights are most-

ly a mixture of red and blue color which is probably one of the best and most efficient colors for plant’s growth and development.

2. High energy efficiency of the LED lamps, LED lamps are turning almost 80 % of the input electrical energy to the light and only 20 % energy loss as heat in compare with other lamps with only 20 % light and 80 % electrical energy loss.(11)
3. The lamps do not become over heated. They do not burn plants.
4. LED lamps have longer life time than Yellow 400 watt lamps. Sometimes up to 50 000-100,000 hours for mounted LED lamps, which is extremely rugged life expectancy for a lamps. It means each LED lamp can be used continually 24 hours a day for about 11 years or half day use for 22 years which is not comparable with HPS lamps which is something about 5000 hours.(5)
5. Big amount of energy saving. Especially in countries where energy supply is a hard constraint. By utilizing LED lights, the amount of energy consumption will be almost half.(26)
6. The availability for making homogeneous lights distribution in the beam.(26)
7. Using the space, with utilizing LED lamps it is possible to cultivate in many different floors. This is what Virolan puutarha is doing. Cropping in 3-4 different floors by LED lightening.
8. These lamps never burn leafs because the amount of the heat they emit is nothing in compare with HPS bulbs.
9. They emit less UV radiation than any other types of light. In HPS light structure, different kind of chemicals like sodium gas is used, but LED lights are free of chemicals in their structures and they seems to be more healthier for human.

2.5.4 Disadvantages of LED lamps in compare with normal 400 watt greenhouse lamps

There are also some disadvantages about utilizing LED lamps in Virolan puutarha:

1. Price of LED lamps is still so high and this is a limiting fact for LED lamps to penetrating in to the markets.(25)

2. Sometimes and especially during the winter time when the lamps are producing heat in the greenhouse, it could be counted as a positive fact for the system. LED lights do not produce almost any heat during winter in greenhouse when the heat is needed.
3. LED lamps heat production is almost negligible in compare with 400 watt normal yellow greenhouse lamps. The heat produced by LED lamps is negligible in compare with 400 watts, HID lamps that produces about 230-290°C heat, so In Virolan puutarha which is quite a big area under greenhouse it is impossible to use only LED lamps because the greenhouse needs the heat arising out of HPS lamps. The price of energy is getting higher day by day but because the Oksanen family is using the same amount of electricity that they produce in Arra ja Siuronkoski, so electricity and the heat of HPS lamps is still the best solution for the family to warm Virolan puutarha.
4. Red and blue color of LED lights could make eyes tired. Especially for workers who are watching these lights for whole working day.

2.6 Algal growth

The term algae contains 20 000-30 000 different species. First algae were found in about 1,200 million years ago. Algae are a microscopic single celled form of the plant. Algae could grow in wet lands only. Where ever water and enough light are available green algae (Chlorophyceae) can grow and develop. Chlorophyceae name is because of their ability to do photosynthesis and produce food for themselves. The green color represents chlorophyll contents in green algae’s structure. When the amount of Phosphorous component in water is more than normal, the condition is ideal for algae growth. In most of hydroponic irrigating systems, the wastewater after irrigation contains high amount of Phosphorous. Green algae are the fastest algae to grow and develop in short time. If needed, it could do its growing cycle from germination to producing seeds in 24 hours. The desired PH condition for algae growth is between 7-9 and the best temperature for algae growth is 20-24 degree.

Picture 11- Green algae on pass ways

In Virolan puutarha, after each irrigation turn some water drops will continually fall in to the floor and Then they could be gathered and stay on the floor to produce a mass of slippery dark green algae on the floor. This mass of algae is making lots of problem for Workers who are walking on top of them. There is a danger of falling down during the Plant transportation from one room to another or replacing the Spouts after work. Some Algae could also have toxic effect in its living environment like blue – green algae or Cyanobacteria.

Algae needs water and light to live. Water and light limitation could work as limiting facts for algae growth.

Picture 12 - Green algae microscopic observation

3 Scope of the work

There are two important aims for doing this thesis:

3.1 To prevent algal growth in greenhouse

Where ever wastewater contains high amount of phosphorous elements stays on the floor for a long time it forms an ideal place for algae to grow. After a short time the color of water will turn to greenish and the floor will be slippery. This can cause problems in work place and specially transportation problems inside greenhouse. In this work, some practical and chemical solutions will be proposed to prevent the algal growth in pass ways of the greenhouse.

3.2 Comparing HPS lights with LED lights

HPS lights or high pressure sodium bulbs are the most common lights in horticultural businesses which are located in the areas where sunshine does not fulfill the plants need for food production. In this thesis HPS lights are compared with LED grow or light emit diode lights. This experiment could help to find better source of lightening in greenhouse which is cheaper and more efficient for vegetable production. Some experiments are done in Virolan puutarha to find the most efficient light color for vegetable growth. This thesis will reflect some of the results after doing these experiments to find the most efficient light color for growing vegetables and consuming less energy in the greenhouse.

3.2.1 Reduce energy consumption

Every successful business needs to think about reducing costs of its production processes. In Finland, energy is the most important cost for vegetable production. It’s a dream for every producer and greenhouse owner to decrease the cost of energy consumptions and produce more vegetables in the same area and gain more benefits.

4 Materials and Methods

The most important sources of information in this final thesis are the owners of Virolan puutarha especially Mr. Timo Oksanen and his good environmentally friendly sense of producing food and vegetables. Workers in Virolan puutarha are also one of the best sources of information. They are the one who does the work and they face the problems in workplace before anybody else.

LED light experience has been started in Virolan puutarha in 1993 and the writer had chance to be involved in the most important part of the experiment. This final thesis tries to bring up some big part of writers learning during four years of studying Environmental Engineering in Tampere University of Applied Sciences and mix this information with normal daily working life of the writer in Virolan Puutarha. The experiment will continue in future to find the best color ratio between Red & Blue lights in one meter LED grow light stick. (26)

Lux meter was one of the materials used to measure the amount of light in three different places in each greenhouse room. We compared plants, grown by two different light systems which are LED lights and HPS lights, when all other growing conditions like irrigation and heat kept the same. This could help to compare only the efficiency of two lamps or two different light colors or other factors. For each propose one separate testing table was specified and for each vegetable the test was done separately. This document will focus only on the main results and it does not go through the details for all different experiments done for each vegetable because the same test gave almost same results. For example the lightening test was done for dill, four different lettuce varieties, mint, and parsley but in this final thesis parsley and ice salad are the ones which are done by the writer and mentioned in here. This thesis is mostly based on long term practical experiments which are done in Virolan puutarha.

The HPS or high pressure sodium lights used in these experiments were:
OSRAM, 400 watts made in Slovakia
And LED lights were:
Philips 20-45 watts made by green power LED production. Module; red/blue 150 C4.

5 Results and discussions

5.1 Solutions to algal growth

1. Algae growth is happening when there is not enough oxygen dissolved in irrigating wastewater. The best way for solving the algae problem could be mixing the wastewater with some air. To inject some oxygen to the irrigating water, this can happen by inserting some sort of air pumps in to the tanks where the irrigating water is reserved. Injecting oxygen in to irrigating water can help organisms to decompose phosphorous which is necessary for algal growth. (24)
2. To install some more aerating systems or fans which can dry out the water drops faster, before algae could grow and also this could avoid the stagnant water to stay on the floor. The fans could be installed under the growing tables that they do not disturb transportations in the greenhouse. The direction of fans should be towards pass ways. This can evaporate water drops before they prepare a good basin for algae growth.
3. To install some sort of metal nets on the floor in a way that Workers could safely work and walk on the metal net but the algae growth is not stopped in this case. Algae need light for living because it has chlorophylls and this kind of green algae produces its own food by photosynthesis. In this solution if metal nests are hard enough to handle workers weight. They could be installing about 10 cm higher than floor and if they have smaller meshed which passes the air but less light could pass through the nets. In this case algae could not get enough light needed for its growth and it will die.
4. Using metal sheets around the irrigating pipes to prevent water drops. The metal sheets could be installing in two places to isolate water drops. Metal sheets with half meter width could be installed under growing tables and they could be shaped easily to direct all drops in to the water let pips. Metal sheets could be installed like wall with about maximum 30 cm height. This could bring all flying drops of irrigating water back to the watering system.
5. Each spout has two sides, from one side irrigating water enters and from other side of the spot it leaves after irrigation is done. If one side of the spout, the side which water leaves after irrigation is shaped like U form it

could prevent the water drops to go out of the system and water does not turn around the spouts and it will drop down much easier in to the watering system. The U forming for each spout could be done with heating the spout and pressing some metal stick on the inner side of the spout down wards.

6. Using salt could kill the algae and prevent the slippery effects of them. This idea has been tested but as mentioned before in water recycling part, the water system in Virolan puutarha is a closed system which means all the water will be collected and reused. Using salt on algae could stop algae growth but it will dissolve in wastewater and can change the PH of whole irrigating system.
7. One of the best options which have been tested in Virolan puutarha against algae growth is to put some kind of compressed plastics on the floor. (Appendix.1) they are car tires, recycled rubber floorings which are quite cheap and could be used as flooring material on the algae contaminated floor. The floor will be safe for workers to walk without falling down and algae's under rubbers could not use light to photosynthesis and they will die. In virolan puutarha using rubber flooring has been started since 6 month ago and the result is shown in picture bellow:

Picture 13 - Rubber Floor

Picture 14 - Algae disappeared after short time

8. Using chemicals to control algal growth. Potassium permanganate, Fungicides and algaecides could be used to control the algae growth. Using chemicals always has its own risk. When the idea is using chemical in greenhouse pass ways which are very close to the vegetables, chemicals could contaminate vegetables. Special care is needed to spray in a greenhouse like Virolan puutarha and sometimes it seems impossible.
9. Using ultra sound devices in storing tanks where water is stored. There are some kinds of devices which can send ultra sounds through the stored water and prevent bio-film formation of the algae. This device could control algal growth in water treatment plants and water tanks and it should be installed inside water source. (16)

After testing all options in Virolan puutarha, the best and the chosen idea which practically gave the best result permanently was option seven. The rubber floors which are made from recycled car tires. Under the rubber floor there is no light for algae to grow and photosynthesis. Algae die in few days and after about one week the floor is totally clean of algae. This system is now in use for whole greenhouse. The price of rubber floor is quite high and it’s not possible to cover the floor totally with rubbers, but important places like the place that workers need to stand and pack salad is covered by rubber floors and they wok pretty well. Picture 10 and 11 shows the difference before and after using rubber floors in Virolan puutarha.

5.2 LED grow lights in Virolan puutarha:

The history of utilizing LED lamps in Virolan puutarha is back to the year 1993, when Timo Oksanen started to test the first LED Lamps for growing vegetables in the green-house. Saving energy has been always important for every successful business as its important for Virolan puutarha. In 2010 virolan puutarha started to put more effort in utilizing LED lamps for vegetable production. Price of LED lamps is quite high so the company was not sure about the result. That was the reason for testing LED lamps only on one table and small scale.

In 15th June 2010 the experiment in small scale started. 6, 9 square meter space were used for LED grows parsley. On top of the parsley seedlings, seven 45 watt LED grow lamps were installed. The light per square meter was about 46 watts. The same space was specified to HPS bulb parsley growth. The amount of light per square meter was 116 watts.

The result of HPS parsley test per grams	The result of LED parsley test per grams
45 gram	33.6 gram

Table 2- The results of parsley grown by HPS and LED lights

The results are net weight of the parsley without mesh pots and compost. Even the re-sults were good but the weight of each plant was not enough for sale.

In November 2010, four different intensities of Red& Blue LED lights were utilized in test to find the best intensity of LED lamps on ice- lettuce growth.
Here are the results:

HPS light 94 watts per square meter	115 grams net ice-salad produced
LED with 52 watts per square meter	122 grams net ice-salad produced
LED with 55.8 watts per square meter	123 grams net ice-salad produced
LED with 74 watts per square meter	127 grams net ice-salad produced

Table 3- Ice- salad grown by HPS bulbs and three different light intensity of LED

The LED results were surprisingly good when intensity of the lights were higher. By half amount of energy consumption same weight high standard quality salads were produced and sold. This was a great success for LED experiment.

When the intensity of the lights is not enough, plants don't have enough leaves or they are thin and light. By adding more LED lamps in each square meter the quality of lettuce raised. Plants had more leaves and leaves were more greenish.

In HPS lamps room the amount of lights per square meter is 100 watts and in LED lamp rooms the amount of light is 50 watts per square meter which is exactly half of energy consumption in HPS rooms.

The amount of emitted light from lamp is not exactly the same as the amount of light that plants can gain. There are some light loss between the source of energy which is lamps and plants. Another experiment was done to compare the amount of receiving light in growing level in HPS, LED and normal sunny day light. Light in growing level was measured by Lux-meter device. The experiment was repeated five times in five different places in each greenhouse room and average of the results was compared to each other.

In a sunny day without any lightening/lux	HPS lights/lux	LED lights first testing room/lux	LED lights second testing room/lux
26300	6600	3700	1600
9600	3650	3050	2500
12000	4900	1270	1600
56000	5650	7110	3720
14000	12400	5170	2000
AVERAGE	AVERAGE	AVERAGE	AVERAGE
23580 lux/square meter	6640 lux/square meter	4060 lux/square meter	2284 lux/square meter

Table4- The amount of receiving light in growing level

Once again the experiment showed higher efficiency of LED lights. Even the amount of receiving light in LED lightening rooms were less than HPS or even much less than sunshine, but the character of the red and blue LED receiving light is enough for plants to grow and produce same quality lettuce in LED lightening greenhouse rooms.

5.2.1 Using greenhouse space in Virolan puutarha

One of the most important advantages of utilizing LED lamps is that, they do not produce much heat and they can be placed close to plants. This ability could give a chance to the gardeners to crop in many different layers or floors. The aim in Virolan puutarha is to maximum use of available space under greenhouse. Some tables have 3-4 floors full of salads and vegetables.

By cropping in many floors, energy and space will be saved with high production increase. In other word, the heat which is used to warm greenhouse is the same as before, also the area under the greenhouse is the same, but producing vegetables is happening in 4 floors instead of only one floor which means four times more production with the same cost for the company and this can bring a good benefit for the owner of the company. Also by Utilizing LED lamps the energy consumption was half and this is incredible energy saving.

After finding the optimal LED light intensity for growing vegetables which was 50 Watts per square meter, another problem is the best light color combination for vegetable growth. In Virolan puutarha Red- Blue color LED lamps are still in use and the ratio of red- blue color in each lamp is 5:2, which means 5 times red and 2 times blue color used in each LED lamp.

The question is:

Is Red- Blue LED lamps with this ratio, the best and the most efficient light colors for growth?

In Virolan puutarha, leaf growth is the main goal, because the vegetable which is already flowered is stuck and it will be thrown out to the garbage. No one buys salad which is flowered. Red – blue LED lights with ratio which is in use at the moment in the greenhouse are encouraging plants to flower when red light concentration is higher than blue color. The combination of Blue-red LED light could bring more leaf growth and it could be more beneficial for the company.

The writer had a discussion with Timo Oksanen and asked if it is possible to change the ratio of red blue LED lights from 5:2 in to more blue and less red color. For example 4:4 or even blue – red LED lamps like 5 times blue and 2 times red. Timo Oksanen says that is possible to do and the experiment will continue still to find the best color combination for LED grow lamps in vegetable production.

6 Conclusions

In horticulture and plant production according to each need, suitable color of light could be the best choice. When it's about germination white fluorescents could be the best. When flowering is important for business like rose production, red or red blue LED lamps could be a good choice. When leaves are important part of the growing process like salad and mostly vegetable productions, blue-red LED lights are the best and when heat is needed, HPS lamps are the best choice in the greenhouse.(Appendices 2,3,4and 5).

The best solution for Virolan puutarha is to use both LED and HPS lamps together, because the greenhouse needs also heat coming out of the HPS. Virolan puutarha is using a high technology shell & tube heat exchanging system but still in cold winter of Finland greenhouse needs the heat coming out of HPS lamps to keep the desirable temperature for growing vegetables.

By utilizing LED lights the energy consumption will be half and the company could save up to 50 percent of the energy costs for producing vegetables. Thich is quite a big money for every producer.
Best algae solution for Virolan puutarha at the moment is rubber floors. By using rubber floors algae could not gain enough light needed for photosynthesis and the algae growth will stop.

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8 APPENDICES

Appendix 1. Algal grows on the floor.

Appendix 2. Basilica grows under LED lights.

Appendix 3. Lettuce grows under LED lights.

Appendix 4. Parsley grows under LED lights.

Appendix 5. Parsley grows under LED lights.