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Beyond the case of Northern Power Plant and oil waste contamination in Chunnakam, Sri Lanka: Social, Economic and Environmental Implications

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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Groundwater contamination is one of the major concern in Sri Lanka where Chunnakam Aquifer pollution occurred since 2008 due to oil wastage contamination from Northern Power plant. It created a huge impact on local people who depend mainly on Groundwater sources to meet their domestic and agricultural needs. This study aims to understand the social, economic and environmental impacts on the livelihoods of local people caused by Chunnakam Aquifer Pollution. A community-based retrospective cross-sectional study was done among 60 participants in the Chunnakam South region. All the participants in this study live closer to the Chunnakam Power Station. It was found out that, 60% of them are aware of the safety level of their water source. Further, 85% of the participants started purchasing water from the shops after the contamination was identified. Among them, 58% of them changed the water source after the recommendation from Public health inspectors. The participants on average spend 1942 LKR on purchasing water on a monthly basis. These results and responses indicates the economic loss, economic burden on families, health hazards, property loss, and severe pollution that are caused by Chunnakam Aquifer pollution. Government with the help of local councillors provided a limited amount of water to affected people on a daily basis as a temporary solution. Thus, the Government and other responsible authorities including the Northern provincial council should take proper action to solve the impacts caused by groundwater pollution and ensure the basic needs are met by local people in a sustainable way.

Keywords: Environment, Groundwater, Contamination, Sri Lanka, Water crisis, Aquifer

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Table of Contents **Page**

List of Tables (Page Number)

List of Figures (Page number)

List of Abbreviations

CEA	Central Environment Authority
CEB	Ceylon Electricity Board
CENS	Centre for environmental and Natural studies
CPS	Chunnakam Power Station
NWSDB	National Water Supply and Drainage Board
NPC	Northern Power Company
NPP	Northern Power Plant
WHO	World Health Organization
UNDP	United Nations Development Program
UNEP	United National Environment Program
LKR	Sri Lankan Rupee

1.0 Introduction

Exploitation and contamination of groundwater sources have been two emerging issues around the world, especially among Asian countries where the majority of the people depend on groundwater resources on a daily basis for drinking, washing, for agricultural activities and to support their livelihood. With the population growth, urbanization and industrialization demand for water has increased everywhere and quantity and quality of water require to meet that demand changes rapidly with different sectors in a country (IWMI 2018). Around 40% of global water consumption for irrigation comes from purely groundwater sources (Hertig and Gleeson 2012). Especially, the South Asian region depends on irrigation from more than 25 million ground water wells owned by individuals (Shah 2010).

Thus, impacting the quality and the quantity of groundwater can immensely disturb people's livelihood on a larger scale. Groundwater sources can be polluted by many factors. It can happen due to anthropogenic activities such as dumping industrial and domestic wastages in the water sources, exploiting ground water aquifers, increasing deforestation, using ineffective water-based transport services, contaminating with fertilizers and other chemicals. Groundwater can also be polluted due to natural factors such as flood, volcano eruption and existing natural levels of contamination. One of the main reasons, water sources are polluted in Sri Lanka is due to the disposal of factory wastages to the water sources directly or indirectly. This activity pollutes both ground and surface water sources in many instances.

Further, severe exploitation and pollution of land and water resources by energy production companies is one of the main concerns in Asia where, in general, land acquisition and exploitation of natural resources for businesses and development has been possible for multi-national companies, privately owned companies, and government authorities. Environmental damages and social impacts caused by such electricity production plants are highly significant among tribal communities and disempowered minorities since their

livelihood mostly depends on Agriculture. Often, the impact is largely on the livelihood of local people by loss of agricultural land, contamination of both underground water resources and surface water resources, and further social marginalization (Nair *et al*. 2008).

Furthermore, energy production can be a problematic process even it is the most beneficial things for human beings on this earth. Different nations use different energy sources such as coal (non-renewable), fossil fuel, water, and biogas, thermal, solar and wind (renewables) to produce electricity in order to meet their energy demand. Like every other anthropogenic activity, electricity production also produces wastages in the forms of carbon dioxide, poisonous gas, heat, ash, particulate matters, oil, grease, steam, and hot water. Most of It can affect the surrounding nature during the production phase and during waste management phase. Sri Lanka, a country with a larger number of people depend on groundwater sources for their daily water usage, is no exception in facing such environmental pollution and resource exploitation by electricity producing companies.

Groundwater contamination in Chunnakam is one such a case faced by many local people since their major water sources such as open dug wells, agro wells, and deep tube wells have been polluted perhaps had to be abandoned since 2008. Although the contamination was observed by local farmers in 2008, this case did not get much attention from the government until 2013. After that, many types of researches were undertaken by both government and non-governmental organizations during last six years (2013 – 2019) in order to understand the real impact on groundwater quality created by the oil and grease wastage from Chunnakam Power station, mainly Northern Power Plant. Researches that have been undertaken previously have focused mainly on the source of pollution, the scale of pollution, types of contaminants, water quality parameters, and spatial distribution of polluted wells. Majority of these studies have not shed a light on the social, economic and environmental impacts of Chunnakam Aquifer pollution in the last six years and beyond.

2.0 Literature review

2.1 Water resources in Sri Lanka

Sri Lanka, an Island, is located along the equatorial line of earth surface surrounded by the Indian Ocean. It has the area of 65610 square kilometres, accommodating approximately 21million people. People receive rain during south-western monsoon (May to August) and Northeast monsoon (November to February) during two seasons of the years. They are not able to receive water during the dry season and other prolonged drought seasons (Jeyalal *et al*. 2005).

Sri Lanka has both natural and man-made water resources available for people. There are a vast variety of natural water resources such as sea, lakes, larger rivers, streams and waterfalls and man-made resources such as reservoirs, deep wells, dug wells, ponds, and tanks. Many of these resources benefitted Sri Lankans for many years in agriculture, irrigation, electricity production, domestic usage, industrial purpose, fisheries, transportation, and leisure activities.

According to the Food and Agriculture Organization (FAO) report on renewable water sources, total renewable water sources in Sri Lanka are estimated to be 52.8 km^3 /year (2011). Further, there are above 100 river basins around the country which covers water supply for 90% of the Island. Among that, Jaffna district has three non-perennial rivers such as Thondaiman Aaru, Uppu Aaru, and Valuki Aaru. These rivers hold and supply water only during the rainy season.

2.1.1 Groundwater resources and management in Sri Lanka

Groundwater sources are one of the major sources benefitted local people for many years as it is a renewable source. There are mainly six types of aquifers such as karstic aquifers in the Jaffna peninsula, shallow regolith aquifers which are mostly found in hard rock region, deep confined aquifers, sand aquifers around the coastal region, the alluvial aquifers and the lateritic aquifers in the southwestern regions of Sri Lanka (FAO 2011). In Sri Lanka, groundwater sources are estimated to be 7.8 km^3 /year and most of this ended up water mix

with river systems and serve as surface water sources. Above 1500 water supply schemes based on Groundwater produces approximately 6 million cubic meters per year water (FAO 2011). Further, there are around 23000 tube wells are available in the country for the domestic purpose (Jeyalal *et al.* 2005).

Deep-water streams and water wells that are being used for both agriculture and domestic purpose. Groundwater is the major substituted in many regions of Sri Lanka for surface water as they are severely polluted or dried out in the summer season. Thus, most of the places under the dry zone of Sri Lanka depend on groundwater source throughout the year. For instance, the Jaffna region which falls under the dry zone of Sri Lanka, depend on water supply from around 20000 agro wells 2433 man-made ditches for agriculture and domestic needs (Appathurai 2016).

Water scarcity and pollution are the major issues associated with Groundwater management in Sri Lanka. Water scarcity is Sri Lanka mainly happens due to spatial variability in rainfall, lack of rainfall, groundwater depletion, salinity intrusion, and surface and groundwater pollution. Sri Lanka has been listed mostly under country with little to no water scarcity or country with moderate water conditions when water scarcity assessments are made by any authority (FAO 2011). However, they do not acknowledge the scarcity which happens due to water pollution and contamination. There are many social, economic and environmental challenges associated with managing groundwater sources in Sri Lanka. As mentioned above ground water table and aquifers can be severely polluted due to industrial activities, and agricultural activities. Most of the time, it takes a longer duration to identify the pollution that happened in certain aquifers since the aquifers are found to be in the deeper part of the earth. It is hard to control, monitor or navigate any sort of pollution associated with groundwater table until the condition worsens in most of the cases in Sri Lanka such as that of

Chunnakam Aquifer issue. Moreover, inefficient wastewater management facilities have caused water pollution in Sri Lanka for long many years.

2.2 Wastewater management system in Sri Lanka

Controlling and monitoring of waste management in Sri Lanka has been an environmental issue with the increasing population and infrastructure development. Especially the disposal of wastages becomes a major issue which is also a time consuming, demanding and expensive procedure. On the other hand, dumping of garbage on domestic areas and sensitive areas such as marine ecosystems, agricultural lands, wetlands, marshy lands, and reservation areas is a common practice adopted by the public and some local authorities. This is due to the attitude of people towards the disposal of waste and the difficulties faced by the relevant institutions due to their inability to handle proper methods to solve the problem. The main issue is that inappropriate way of discharging waste in the environment can be more hazardous to all humans, other living beings and to the environment as a whole (UNEP 2013).

Integrated waste management in Sri Lanka has been under development in order to reduce the hazardous impact that's been happening all around the country both with Solid and liquid wastes. Sri Lankan government developed a National Policy on Solid Waste Management in 2007 to maintain the solid waste management system effective and useful to citizens of Sri Lanka and it addresses two kinds of waste management such as municipal solid waste and biomedical waste (CEA 2003). However, Sri Lanka is still lacking in developing strict protocols for wastewater management. There are several stakeholders participating in maintaining the waste management system in Sri Lanka including the Ministry of Environment, Ministry of Local Government and Provincial Councils, Central Environmental Authority, Provincial Council, Municipal Councils, Experts from Universities, Private Sector Company (involved in waste management), Non-Governmental Organizations and Freelance experts (Bandara 2011).

There are several problems associated with wastewater management in Sri Lanka starting from lack of awareness to lack of technology. According to NWSDB, the government allocates around 5 billion Sri Lankan rupees per year to wastewater disposal management. In Sri Lanka, the Central Environment Authority (CEA) has created standards for industrial effluent discharge and function as a regulatory body. Further, Ministry of water supply and drainage board has the largest responsibility to look after wastewater management around the country. Under this Ministry, National Water Supply and Drainage Board (NWSDB) has its branches all over the country to share the responsibilities within each district of Sri Lanka. However, for a country with increasing development and population, the responsibilities of wastewater management should be shared among other stake holders. As the Ministry of Forestry and environment work on a national strategy for solid waste management in Sri Lanka, the responsibilities for Liquid waste management should also be shared with the other national government bodies, local authorities, private sectors and the public as well to manage a network of multiple sectors which will be more productive to find the challenges and needs in each level (Karunasena *et al*. 2012).

Roughly 10% of waste water produced by industries are led to the environment without any sort of treatment although the Central Environment Authority has strict regulations for this. It happens mainly due to lack of awareness among small businesses about the consequences of untreated wastewater disposal. Small businesses and manufacturers who run the factory or industry without any proper license have disposed of wastewater to the nearby open water source or dump it to underground without treating it many times (Jeyalal *et al*. 2005). Like many other countries around the world, discharging wastewater directly into the environment without proper treatment is prohibited in Sri Lanka. Although the regulations are in Place there are groundwater contamination issues happening around the country. Further, blocked drainage systems, streams, rivers, lagoons, reservoirs, tanks become a major

threat to pure water consumption around the country. The mixture of solid waste with water leads to water contamination and water-borne diseases. Further, contaminated and abandoned water body due to the poor solid waste management near to water bodies provides space to mosquitoes and houseflies to inhibit and spread diseases. Further destruction of flora and fauna for the purpose of landfill leads to a mass loss of natural habitat and biodiversity loss. Also, the chemicals which are used in the process contaminate the underground water which is a threat for potable water.

2.3 Energy/Electricity production and development in Sri Lanka

Electricity in Sri Lanka is produced using different energy sources such as fossil fuels, thermal power, biogas, hydropower, solar and wind. As a part of electricity production, larger amount of wastage is produced by the power plants. Power plants receive license every year after going through several assessments including environmental risk assessments. In Sri Lanka, electricity production has been done with the mix of both non-renewable energy sources and renewable energy sources. They are of two types such as grid-connected and off-grid systems. The electricity is produced by both government (Ceylon Electricity Board) and private power producers such as Northern Power Company and Agrico Power Company. Although the Ceylon Electricity Board (CEB) and Private Power Producers (PPP) are involved in electricity production, grid-connected electricity production is dominated by CEB in general (UNDP 2017).

2.3.1 Electricity production in Northern Province

Northern Province had been provided electricity from the main grid (Laxabana) until 1973. During the 30 years of civil war, many parts of the country didn't receive electricity especially the Northern Province as it was not connected in the main grid. During this time, privately own company such as Northern Power Company brought all the raw materials to build Chunnakam power station by air and sea to the Northern Province as the landmark to it was closed by the government. Northern Power plant is a fossil fuel based thermal power

plant which was built in early 2008 around the end period of the civil war. During that time, since the government was struggling with war and casualties, it could not focus much on environmental regulations before agreeing on building power plants back in those time. Whereas the local residents of Northern Province were more than happy to receive a limited supply of electricity instead of questioning the consequences of the power plant. It led to many problems later in the country including groundwater pollution. Further, the government inaugurated Uththuru Janani Power plant in 2013 in Chunnakam Power station. Northern Province, especially the Jaffna district was connected to the main grid again in 2012. However, Northern Power Plant and Uththuru Janani Power plants continued to function to meet peak hour electricity demand in Jaffna district.

2.4 Case Summary

Northern Power Plant is one of the thermal Power plants built in Valikamam zonal division, Chunnakam, Jaffna, Sri Lanka. It is formerly called New Chunnakam Power station as it was connected to Northern power station. Northern Province including Jaffna received electricity from the main grid until 1973. After that due to the civil war situation, the government stopped providing electricity to Jaffna from the main grid until 2009. After this, the Ceylon Electricity Board refused to start their operation in Northern Province due to the war situation. At that time, Northern Power Company was given the contract to run a fossil fuel based thermal power plant until 2012 when the government started providing electricity from the main grid again. Thus, Northern Power Plant (NPP) started it function in 2009 (Rupatheesan 2015). During this time, Northern Power Company (NPC) disposed of around 100,000 to 200,000 liters of lubrication oil into the surrounding land by pumping into drilling holes under pressure. Moreover, the power station at Chunnakam was always under the surveillance of military thus, the public was not aware of what was happening inside the 20 acres of land (Somasundaram 2016). The war situation not only caused many casualties but

also limited people from access to electricity. At that time, people were happier that they at least received electricity. So, they did not interfere with the regulations of power plant.

Further, Uththuru Janani is also a thermal Power plant built in Valikamam zonal division very close distance to the Northern Power Plant. It is formerly called New Chunnakam Power station as it was connected to Northern Power station. This power plant has three diesel engines with the capacity of producing 8 megawatts each. The total capacity of the power plant is 24 megawatt. It can produce up to 176 Gigawatt hour of electricity annually to add to the northern power grid (MPEBD 2013). It also has its own oil refinery system, a fuel storage site, and a waste disposal site. A lump sum amount of 3.5 billion Sri Lankan Rupees (LKR) was invested by the government in building this power plant from the energy and power sector development budget. It was ready to be used from January 2013. It was then inaugurated by the former president of Sri Lanka, Mahinda Rajapaksa on 12th February 2013 (Perera 2013). The power plant was mainly built to meet the electricity demand in Northern Province, especially for Jaffna district and to provide the local people with uninterrupted power supply in order to support their livelihood. The electricity produced by the power plant costs 17.89 LKR per unit of electricity.

Local people of Valikamam region observed oil and grease contamination in their water sources at the beginning of 2010. Later with the end of the war and increasing awareness about groundwater contamination, local people started questioning the local authorities such as village council and divisional secretariat about the contamination happening around. The whole protest and fights started with farmer's association of Chunnakam South sending a request letter to the Government Agent (GA) after they observed oil contamination in their agro wells. Later many communities from the Valikamam region complained as they observed oil stain in their water sources in 2012 (CENS 2016). However, at that time when the complaints went to the reach of higher officials, both Northern Power

Plant and Uththuru Janani was in function. It created a huge issue as to who was responsible for this contamination.

According to Yatawara (2015), many areas including Chunnakam, Thellipalay, Mallakam, Uduvil, Inuvil, Thavaddy, and Kattuvan were severely impacted by this contamination. Local people who live around the 6 km radius to the power plant and many other neighboring village locals noticed changes in the drinking water with oil stain and grease in next two years since the opening of the new power plant. They complained to the local authorities to take proper action against that issue. This issue had started since the beginning of January 2015. Medical officer of Health (MOH) and the Public Health Inspectors (PHI) blamed Northern Power Company for the oil waste contamination in the water wells (Selvanayagam 2017). Nearly 10000 families including 20000 individuals in Valikamam region have been affected by this contamination directly and local people decided to invade the plant in order to fight against the responsible authorities (Rupatheesan 2015).

Further, local people organized a hunger strike on 20th January 2015 with the help of around 60 local doctors, university officials, village groups, community leaders, students and political parties. Protestors demanded three requests: closure of the power station to stop the oil leakage, immediate visit of the minister who is responsible for energy and power sector, and initiate permanent solutions to effectively eliminate oil contaminants and to supply drinking water (Tamil Guardian, 2015). Northern provincial council appointed a group including university academics to check on the water quality around the affected area to understand the emerging problem. After the protest, the chairman of the center for Environment and Natural Study (CENS), Dr. Ravindra Kariyawasam initiated a petition among the local people and filed against Northern Power Company (NPC) for violating people's fundamental rights to clean water and clean environment. Further, he filed the case

explaining the fact that improper disposal of wastage containing fuel oil was done by Northern Power Company in the vicinity of the power plant (Tamil Guardian 2019).

In April 2015, Mallakam Magistrate court ordered to reopen the Chunnakam Thermal Power plant in favor of Northern Power Company as they submitted an appeal against the previous court decision to temporarily closing the power plant. In Early 2016, Supreme Court of Sri Lanka took the petition and issued an interim injunction to suspend all activities associated with Northern power station until it meets the requirements for environmental standards. Meantime, the government with the support of Northern Provincial council arranged a group of scientists and local researchers to carry out a study to check the water quality parameters. In April 2019, after so much of struggle and protests, Supreme Court of Sri Lanka ordered the Northern Power Company who is the owner of both Northern Power Plant and Uththuru Janani power plant to provide the affected families with compensations worth 20million Sri Lankan Rupees (LKR) for the social and environmental damage caused by the oil waste contamination. Further, this compensation will be divided among approximately 500 families each receiving 40000 LKR. These 500 families who live around 1.5km radius to the power plant and own severely impacted water wells will be given the compensation through the National Water Supply and Drainage Board (NWSDB) (Tamil Guardian 2019). The compensation will be provided with the aim of cleaning up the wells that were contaminated with oil and grease wastage.

2.5 Groundwater pollution in Chunnakam Aquifer

Groundwater pollution due to oil and grease waste contamination has happened in Chunnakam aquifer since 2008. However, people started protesting in the streets since 2013. At the beginning of the protest around 2013, everyone including the Central Environment Authority (CEA) and provincial council were not sure about the source contamination. Authorities were trying to find the sources as it could have happened due to one of the many

sources such as Northern Power Plant, an older power plant run by Agrico in the early years and Uththuru Janani Power plant. Thus, many studies were done on Chunnakam Aquifer pollution to understand the source of pollution, to narrow down the polluted area, to locate the contaminated wells, to identify the scale of pollutants, and to understand the severity of the pollution. There was an allegation against Northern Power plant brought from local doctors at the beginning of 2013. However, Northern Power Plant owners denied the allegation and said it was not their responsibility and they always saved waste oil in tanks and did not dump it into the ground. Further, owners of the Northern Power Plant confirms that they go through quarterly checkup by Central Environment Authority and requested for an expert committee to run an independent study to confirm their allegations (Rupatheesan 2015). However, it was very necessary to identify the source of contamination in order to control it from further expanding to other neighboring villages.

A pilot study was done by Saravanan Suntharalingam with the support of National Water Supply and Drainage Board (NWSDB) between 2013 and 2014 figures out the major source of contamination to be located in Chunnakam area (Wijesekara *et al*. 2015). This was one of the first rounds of study done in Chunnakam Aquifer issue where the water quality parameters were taken into consideration. The study also found 109 (73%) wells out of 150 wells were contaminated with higher amount of oil compared to the Sri Lankan standard of 1.0 mg/l and 23% of the wells were not contaminated with oil waste. Moreover, the higher concentrations of oil and grease in the wells were found within the 1.5Km radius to the Chunnakam Power station. When the Ministry of Health (MOH) collected samples from the Chunnakam Power station and all those samples were found containing Oil and grease above the Sri Lankan Standard (Suntharalingam 2018).

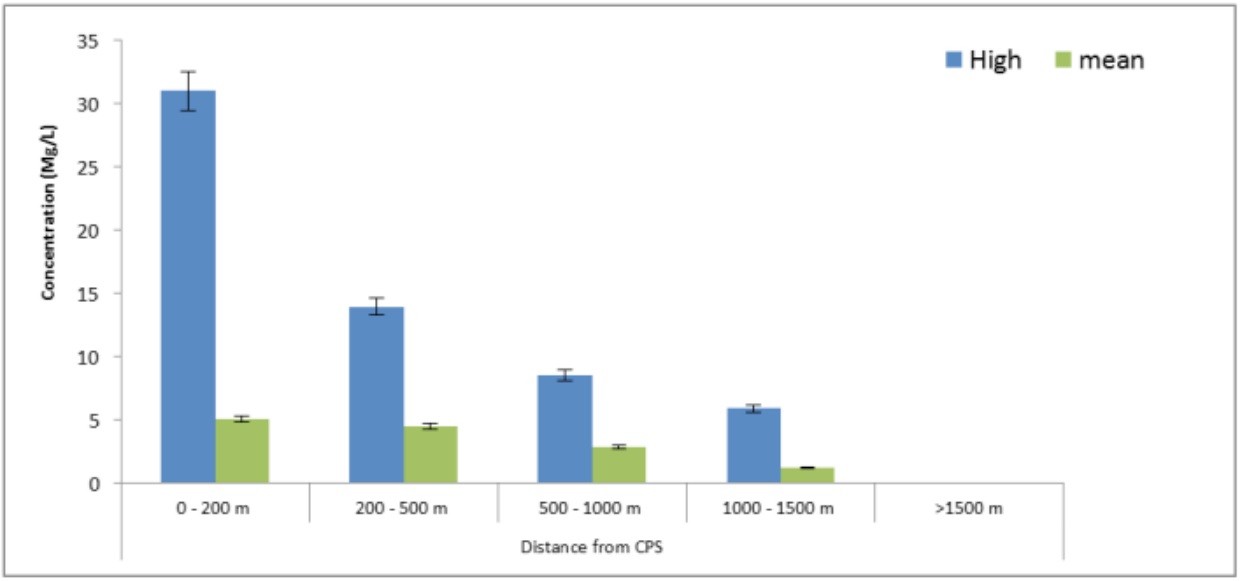

Figure 1: Change in Oil contamination level with the distance from Chunnakam Power Station (Source: Suntharalingam 2018)

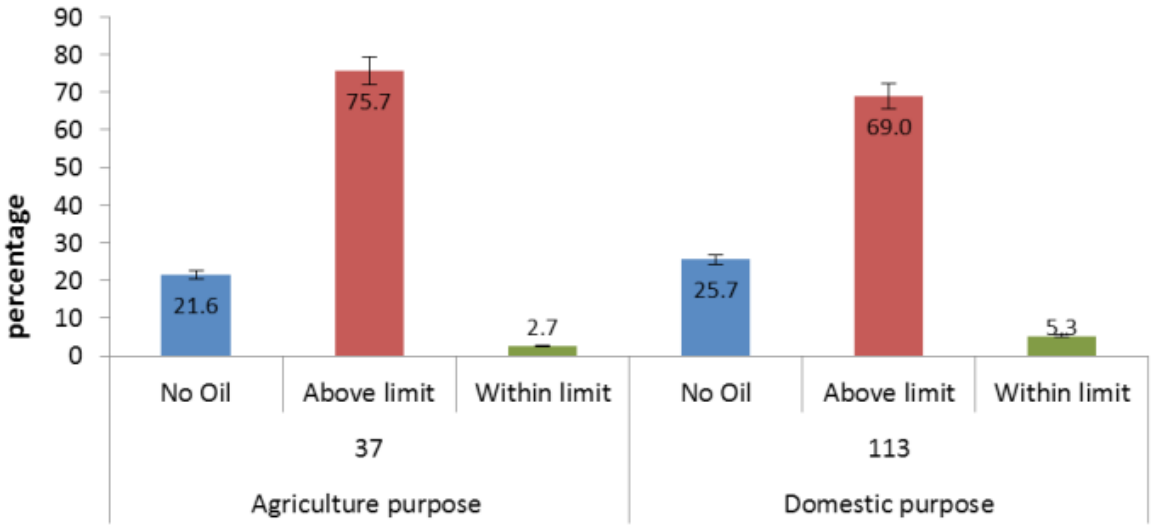

Figure 2: Oil concentration level in Agro wells and domestic wells within 1500m distance of Chunnakam Power Station (Source: Suntharalingam 2018)

During the study, well water in different distances were collected by NWSDB and water quality parameter checkup was done. The Results from this study shows (Figure 1), the concentration of oil in the water sources decreases with the distance from the power station. This indicates the Chunnakam Power station to be the potential point source of pollution. This

study concludes that the contamination has spread out surely up to 1500m distance from the power station. Within this 1500m distance majority of the agro wells (75.7%) and domestic wells (69%) were found to be severely contaminated with oil waste.

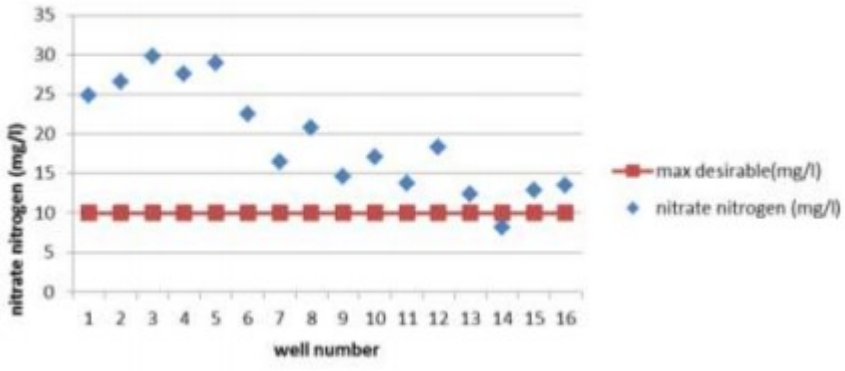

Figure 3: Nitrate concentration of water samples (Source: Jeevaratnam *et al*. 2017)

Another study was done to check the quality of groundwater near the area of Chunnakam power station by Jeevaratnam *et al*. (2017). It also proved the drinking water samples are not suitable for domestic purpose. In this study, Physical, chemical and microbiological parameters of the 16 water samples were tested in the laboratory-based experiments. This study found out that 15 out of 16 wells contain E-coli form above the permissible level. Figure 3 depicts the nitrate concentration found in those 13 well water samples in this study. Further, Average nitrogen concentration the samples were found to range between 8.2 to 29.8 mg/l (Mean Value = 19.25 mg/l). However, according to Sri Lankan standard, water containing Nitrate above 10mg/l is not suitable for drinking purpose (Jeevaratnam *et al*. 2017).

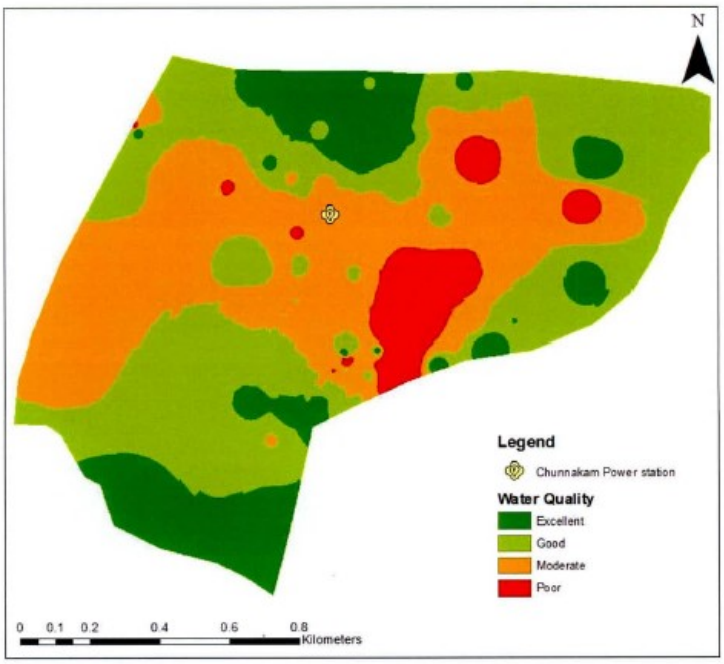

Figure 4: Geospatial distribution of water wells based on quality in Chunnakam South (Source: Appathurai 2016)

Moreover, another study was done by Senthuran Appathurai (2016) to analyze the groundwater quality in the Chunnakam Area in 2016. This study was contacted using the data from the National Water Supply and Drainage Board (NWSDB). In this study water quality analysis was done for 109 well water samples which were collected from Chunnakam region. Unlike other studies, this researcher used the data to map the spatial distribution of polluted wells in the Chunnakam region. GIS mapping was done for all the parameters including Nitrate concentration, Total dissolved Solids (TDS), pH level, and overall water quality by using the data given by NWSDB (Appathurai 2016). This study also did not analyze much on social and ecological impacts directly associated with Chunnakam Ground water contamination.

3.0 The Aim of the Study

The major aim of this study is to understand the overall social, economic and environmental impacts caused by the ground water contamination on the livelihood of local people of Chunnakam, Sri Lanka. Further, this study also discusses the possible solutions to overcome this issue, and to stop the reoccurrence of this incident in Sri Lanka due to improper waste management systems.

4.0 Specific Study Objectives

4.1 Objective 1:To study the overall socioeconomic conditions of local people from Chunnakam region where the northern power plant is located since 2009

This is to understand the demographic characteristics of the sampled area using the quantitative part of the questionnaire. Prior to analyzing the social and economic impacts associated with the groundwater contamination, it is necessary to understand the current conditions among the local people. In order to understand the basic socioeconomic conditions of the population in the defined study area, data on demographic characteristics such as age, gender, educational level, occupational status, number family members, income level and availability of water sources are obtained from the participants through a survey done in April 2019. The variables about income level, amount of money spent for buying water on a monthly basis, owning water wells in their homes, using different types of purification methods were used in analyzing the economic conditions of the local people who live within an approximately 4km radius from the northern power plant in Chunnakam region.

4.2 Objective 2: To qualitatively and quantitatively assess the environmental problems created by the Chunnakam groundwater contamination

Environmental damages are the major impact caused by this groundwater contamination in Chunnakam region. Assessing the environmental damages caused by the contamination can help us to scale or measure the seriousness of such water contamination issue Sri Lanka. Further, it also gives us a clear picture of what should be done in order to overcome this issue. To study this aspect, open-ended questions were asked to the local population on what changes have happened in the environment and what they have experienced as a consequence of this water contamination between 2009 and 2019. Further,

variables on water quality change, data on water quality parameters from previously done researches are included in this study to understand the scale of pollution further.

4.3 Objective3: To analyze the social and economic impacts associated with the groundwater contamination on the livelihood of local people

This is to identify the present socio-economic condition of local people that are affected by the power plant directly. This was done using a qualitative approach. Local people who have been living within the 4km radius to the power plant were asked questions regarding economic burden caused by this issue, how it has affected their day to day life, how many years they have been affected by this issue, what are the changes they made in their life to cope up with this situation. These questions were developed on the basis of previous researches carried out on Chunnakam Aquifer pollution and other such groundwater contamination issues that happened in Sri Lanka. It also includes the questions related to socio-economic status, livelihood opportunities and struggles, health problems, economic loss, economic problems associated with environmental hazards, water substitute, and compensation methods. This objective has been fulfilled by manually assessing the answers provided in the questionnaire. Answer with common concepts is categorized manually in order to picture the overall socio-economic impacts.

4.4 Objective 4**:** To understand local peoples' perceptions on groundwater pollution, environmental regulations, responsibilities of the citizens, and pollution control methods

As a part of an ecosystem, human beings are also affected by any sort of environmental hazard. Further, analyzing people's vulnerabilities and sensitiveness towards this water contamination issue may help the researchers further in predicting future consequences. Since it is a community-based study, understanding and including participant's

perception is very important as it can help us in finding potential solutions for this environmental hazard. Involvement of public in decision making process for environmental challenges can help both public and the decision makers. Effective involvement of public in decision making help responsible stakeholder to find high quality decision when the intended environmental risk is faced by public (Beierle 1998). It shows how important and effective it is to consider affected people's perceptions in order to find solutions for environmental hazards.

This issue in Chunnakam raised a huge problem between minorities, other local people, researchers, government authorities, and political parties. This happened mainly due to lack of understanding about what is happening around in the environment, blaming on each other to escape from the responsibilities, lack of political willingness to intervene in environmental hazards, not coming up with solutions to overcome the problems created and limited support from the government authorities to local people to meet their basic rights. Furthermore, there were even stakeholders whose main intention was to benefit from this water contamination by creating problems among local people. Thus, perceptions and ideas on awareness level of this groundwater contamination case, government and others actions to solve this issue, responsibilities for paying the damage, environmental regulations related to ground water management were collected using open-ended questions in the survey to analyze the situation.

4.5 Objective 5: To study potential solutions to overcome groundwater contamination issues in Chunnakam

As far as we study the overall socioeconomic and environmental impacts, it is also necessary to identify potential solutions to overcome Chunnakam groundwater contamination case and other such cases in Sri Lanka. This specific objective may help local people of

Chunnakam region to achieve their basic right to potable clean water and clean environment and to avoid future environmental hazards. As a part of this study, participants were asked about the potential solutions to overcome this issue. Further, the questions included ways to enforce environmental regulations in place by the common people. And, by asking these questions, people were given a chance to think critically about this water contamination issue and what can be done by common people in such a situation, instead of waiting for it to be solved by the government. People's perception of this issue was asked to support the idea that, we, as common people have to understand our responsibilities in saving the natural water sources and act responsibly in order to demand our rights. Furthermore, participants were made aware of their responsibilities and the ways to approach environmental hazards rather than complaining about it until the situation is worsen.

5.0 Methodology

5.1 Study setting and study area

This community-based, retrospective cross-sectional study was conducted among the local people of Chunnakam and around. Chunnakam area is located in the Valikamam South district secretariat division of Jaffna district, Northern Province of Sri Lanka. According to the preliminary report of the Department of Census and Statistics Valikamam South region accommodate around fifty-one thousand (51000) people (2008). This is where the Northern power plant and Uththuru Janani Power plant are located. Chunnakam Aquifer is one of the major low salinity, limestone based, aquifers which covers the total fresh water supply of Valikamam Region (Sutharsini *et al*. 2012). Although many areas under the Valikamam South region has been affected by groundwater contamination, Chunnakam is the place where the majority of the people have been affected. According to previously done study on water quality parameters, Chunnakam is found to be the place which has been severely impacted by the oil waste contamination which makes it a suitable study area to conduct this research (Appathurai 2016). All the participants in this study live in the Chunnakam and within the 4km radius of the power plant since the plant was inaugurated.

Figure 5: Northern Power Plant (Source: Selvanayagam 2019)

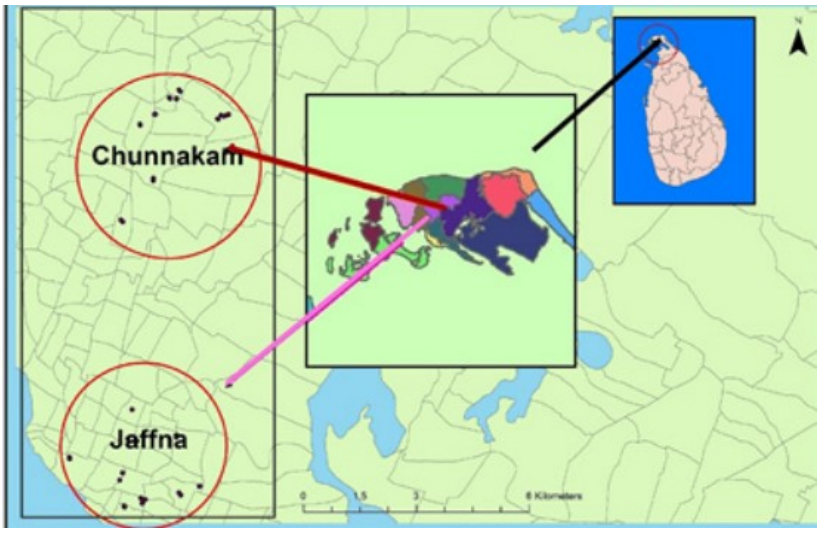

Figure 6: Geographical distribution of the affected area/Study location (Source: Harshan et.al 2016)

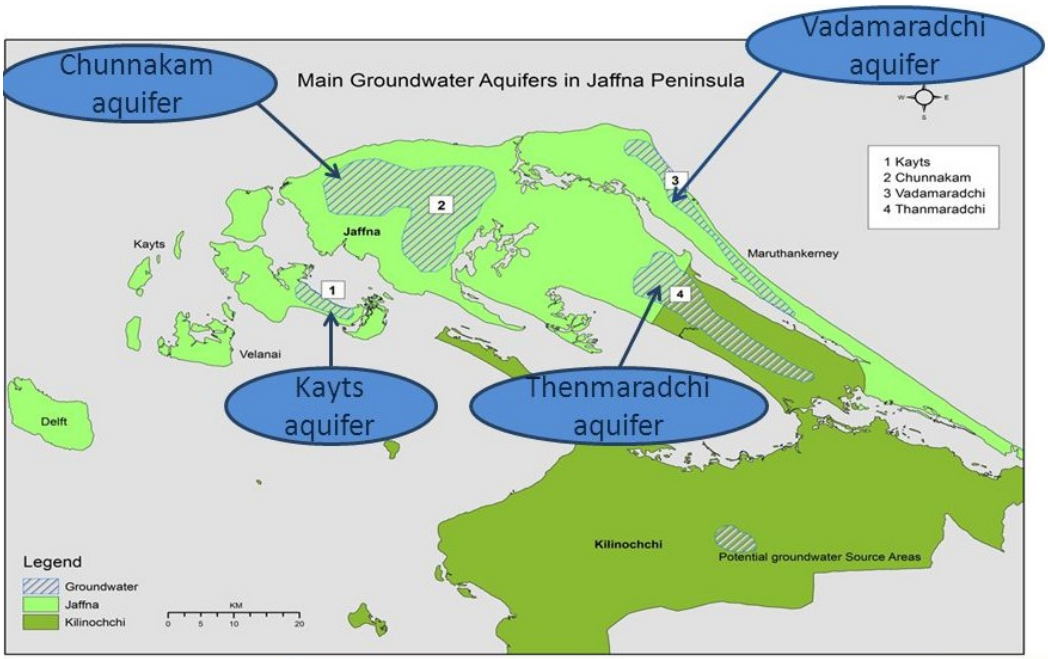

Figure 7: Chunnakam Aquifer (Source: International Water Management Institute, 2015)

5.2 Ethical Clearance and Access to Participants

The study was first approved by the Department of Environmental Sciences and Policy at the Central European University to conduct research among human participants in December 2018. Further, approval was gathered from the Chunnakam village councilor and relevant Community Health Officers in Valikamam Zonal division, Chunnakam, Jaffna

district of Sri Lanka to conduct the surveys in the different locations prior to start the field work. All the participants were met at their preferred locations during their preferred timing to make it easy for them to participate. To respect the rights of the respondents, informed consent was obtained after explaining the aims and procedures of the study. All the participants were provided with clearly defined participatory information forms to provide signature prior to start the surveys. Necessary contact details were provided to reach out if they have any queries related to this study in the future. The survey was done in the participant's local language (Tamil) in order to facilitate the open-ended questions.

5.3 Study Design and Participants

This study used a retrospective cross-sectional design and conducted from April 1st to May 1st 2019. Identified participants were those that live in the affected area around the Thermal Power plant in Chunnakam Sri Lanka. Prior to initiating the study, all the participants were chosen from the general population using both convenience and snowball sampling method. It was confirmed that all the participants have been living in the current location at least since the thermal power plant was inaugurated in 2013.

5.4 Sample Size determination and Sampling Method

Considering the availability of resources, funds, fieldwork facility, and time, the sample size was reasonably determined to be 80 participants in total. As mentioned above convenience sampling was made at the beginning of the study with the help of village counselors who helped in narrowing down the area suitable for data collection. Data collection was started from one family and moved to other houses randomly. Although around 80 participants participated in the study, around 20 of them did not fill up the survey questionnaires with adequate information and did not meet certain criteria such as living in the current location for last six years. It made it difficult to include all the data thus limiting the interviewed population to 60 data points.

5.5 Data Collection

Data collection was done in two parts using a designated questionnaire. Participants were met at their preferred places mostly home to conduct the survey. At first, face to face interviews was done using the questionnaire to collect quantitative data about each individual by the researcher and author of this thesis with the help of a trained research assistant from the local community. The study questionnaire was developed by modifying the validated questionnaires collected from different resources. Survey data related to participants' socioeconomic status, demographic characteristics, availability of water sources, drinking water habit and purification methods were obtained. Secondly, open-ended questions were asked about the awareness of the groundwater contamination problem, actions taken by the Sri Lankan government, responsible authorities, and their perceptions and solution for ground water pollution such as that happened in their area. Due to limited funding and time, quantitative data on water quality parameters from the affected water sources were taken from previously done researches to support this study. All the responses and questionnaires are kept confidentially after the field work. The responses are shared and discussed between the author of this thesis, research assistant and the thesis supervisor.

5.6 Data Analysis

Both quantitative and qualitative data have has been analyzed to identify the socio-economic and environmental impacts happened consequent to groundwater contamination in Chunnakam. Quantitative data entry was done right after finishing the field work using excel spreadsheet. All the questions with options and variables were coded for further analysis. Quantitative data were analyzed using SPSS version 24. Chi-square test, an independent sample t-test, crosstabs, logical regression, linear regression tests were done according to the independent variables and the outcome. Frequency distributions of socio-demographic variables were calculated. In addition to that, independent sample test was done between

continuous variables to compare the mean values. Linear regression was done to see the changes between two continuous depended variables. Further, outcome from SPSS analysis was presented using bar charts, pie charts, tables, graphs and figures according to the data type.

Qualitative data gathered from open-ended questions are analyzed manually by summarizing common answers under several categories. They are used in describing people's perceptions on groundwater contamination, what government has done to solve this problem and to analyze the overall environmental impacts caused by oil waste contamination. Analyzed qualitative data are presented using tables and diagrams. Participant's names and personal details are kept anonymous in order to keep confidentiality.

6.0 Results

6.1 Socio demographic characteristics of the participants

Table 1: Socio demographic characteristics of sample population (Total 60)

Characteristics	Categories	Frequency	Percentage
Gender	Male	37	61.7
	Female	23	38.3
Mean Age (Mean ± SD)		45.85 ± 15.7*	
Number of Family Members		4.03 ± 1.37 *	
Occupation	Government Service	15	25
	Business	16	26.7
	Day Laborers	1	1.7
	Farmer	7	11.7
	Others (Retired, Home makers, job seekers and etc)	21	35.0
Monthly Income	<10000	6	10
	10000-20000	11	18.3
	20000-30000	24	40
	>30000	19	31.7
Educational Level	Primary education	2	3.3
	Secondary education	21	35.0
	Higher education	28	46.7
	Graduate	9	15.0
Availability of water source	Yes	60	100
	No	0	

*Mean value ± Standard deviation (STD)

Table 1 gives the description and the overall characteristics of the sample population (Total 60). Throughout the study, 60 people from Chunnakam region who live closer to the Northern power plant were involved. Among the participants 61.7% were males and 38.3% were females. Mean age of participants were found to be 45.85 (STD 15.7) with the minimum age of 21 and Maximum age of 78 years old. All the participants were Tamil language speaking people as their first language. Mean amount of family members that each family consists of is 4.03 with 1.37 standard deviation. Participants who are involved in varieties of occupations were covered in this study. Among the participants, the majority of them (35%) has chosen the option "Others". Further, they mentioned 'retired from the job', 'homemakers', 'housekeepers', 'drivers', 'Carpentry', 'food processing', 'entrepreneurs' and 'job seekers'. Among them, 26.7% of them were involved in business activities, around 25% of them were government service holders and around 12% of them were farmers. The Majority of (40%) of the participants have a monthly income ranging between 20000-30000 Sri Lankan Rupees (LKR). And only 10% of them earn less than 10000LKR and 31.7% of them earn above 30000 LKR. All of the participants received some level of education throughout their life. Education level was categorized using a defined scale according to the Sri Lankan education system. People who received an education until grade 5 categorized as primary education receivers. Grade 6 to 10, grade 11 to 13 and College to university are categorized as secondary education, higher education and Graduate respectively. Further, people who studied above graduation such as Ph.D., and post-graduate degrees were also categorized under the option "Graduate". Among them, the majority (46.7%) of them received up until the higher education and 21% of them pursued secondary education. The study covered 9 graduated participants and 2 people with only primary education. All the 60 (100%) participants own running water sources at their home.

6.2 Availability of water sources

All the participants in this study have running water sources in their houses. There are many types of running water sources found in the village such as dug wells, hand pump (tube wells), public taps, community wells, household piped water supply, and tank water supply. They are all specifically groundwater sources. However, all the participants in this study have open dug wells, built with concrete walls as the lining between soil and water. They have been using these water sources for drinking, cooking, farming, home gardening, agricultural activities, and other domestic purposes since they were built. These wells were mostly old some of which were built thirty to forty years ago. These wells have been their only source of drinking ever since they start living in their respective houses.

6.3 Awareness, perceptions, and safety precaution

Table 2: Awareness about water sources and safety precautions taken by respondents (Frequency distribution)

Variable	Categories	Frequency	Percentage
Aware of the safety level of water	Yes	36	60
	No	24	40
Satisfaction with water source	Very Satisfied	6	10
	Somewhat Satisfied	19	31.7
	Neither Satisfied Nor Unsatisfied	18	30
	Somewhat dissatisfied	14	23.3
	Very Dissatisfied	3	5
Availability of purification methods	Yes	44	73.3
	No	16	26.7

Aware of oil contamination	Yes No	60 00	100 00
Aware of water borne diseases	Yes No	60 00	100 00

Table 2 contains the variables which give us a clear understanding of how much people are aware of the safety level of their drinking water sources, satisfaction level towards the water source, and availability of purification methods and how much they are aware of the oil contamination in their region. Among the participants, 60% of them said they are aware of whether their main water source is safe for drinking purpose or not and 40% of them are not aware of it yet. Majority of the participants 73.3% of them use some sort of purification method to purify their water before consuming it. Interestingly, all 60 participants (100%) responded saying they are well aware of the oil contamination issue happened in their region. This makes it a very good pool of sample to analyze the perception of social and environmental challenges they faced due to this contamination. Further, all 60 participants said they are aware of water-borne diseases which might occur if they consume contaminated/ polluted water for drinking purpose and agriculture.

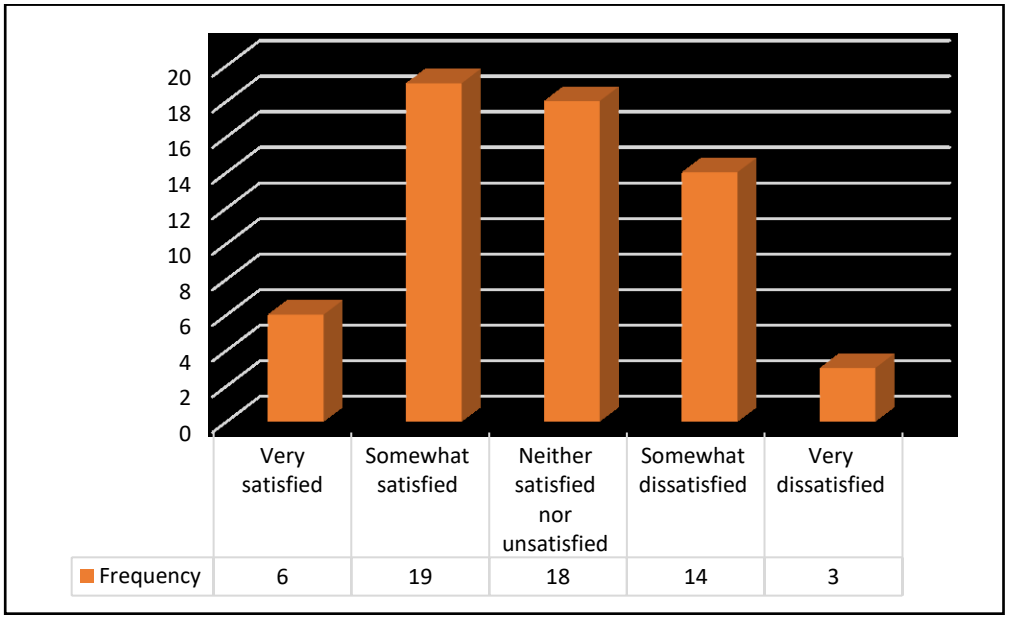

Figure 8: Satisfaction level towards drinking water source

The bar chart in figure 8 above shows the responses given by the participants when they were asked to scale their satisfaction level towards the water source they use for drinking purpose. Majority of them (19) are somewhat satisfied with their drinking water source whereas 14 of them are somewhat dissatisfied with their water source. 18 of them responded as "Neither satisfied nor dissatisfied". Only a few people are either very satisfied (6) or very dissatisfied (3) with their water source.

Table 3: Different purification methods used among participants (Frequency distribution)

Purification method	Category	Frequency	Percentage
Boiling	Yes	34	56.7
	No	26	43.3
Filter with cloth	Yes	5	8.3
	No	55	91.7
Use halogen tablet	Yes	20	33.3
	No	40	66.7
Chemicals	Yes	0	0
	No	60	100
Water dispenser	Yes	12	20
	No	48	48
Others	Yes	0	0
	No	60	100

Table 3 depicts the different purification methods used by the participants in this study. Boiling is one the basic method to purify water in case if we do not have other facilities

at home. Further adding chlorine tablets (Halogen) directly to the water source is found to be one common practice among Sri Lankans for a long time. Also with the developing technology and facilities available in the society, people nowadays use water dispensers in their households, offices and public places to filter the water at their convenience. In this study also, the majority of the people responded saying they use boiling (34), halogen tablet (20) and water dispensers (12) to purify the drinking water prior to consuming it. Filtering with the cloth used to be an old and least expensive method to filter the water although it does not necessarily save you from getting in contact with microbes or contaminants in the water. In this study also, filtering with cloth, using chemicals to purify water are found to be lease common options for purification method.

Table 4: Perceptions of participants about clean water (Frequency distribution)

Perceptions	Response	Frequency	Percentage
Will cause no	Yes	42	70
disease	No	18	30
Clean in appearance	Yes	38	63.3
	No	22	36.7
Odorless	Yes	47	78.3
	No	13	21.7
Colorless	Yes	46	76.7
	No	14	23.3
No Harmful taste	Yes	26	43.3
	No	34	56.7
No suspended	Yes	27	45
materials	No	33	55

Table 4 shows the responses given by the participants when they were asked about their idea on clean potable water. They were provided with the options such as clean water cause no disease, it looks clean in appearance, odorless, colorless, have no harmful taste and have no suspended materials in it. Majority of them chose it to be odorless (78.3%), colorless (76.7%), will cause no disease (70%) and clean in appearance (63.3%). Comparatively fewer people chose the clean water to have no harmful taste (43.3%) and no suspended materials (45%).

Table 5: Money spent on buying water from the shop, contamination impact on water source (Frequency distribution and descriptive statistics)

Variable	Category	Frequency	Percentage
Buy water from the shop	Yes	43	71.7
	No	17	28.3
Amount of money spend on purchasing water	1942.95 LKR ± 1027.05*		
Contaminated water source	Yes	53	88.3
	No	7	11.7
Duration of contamination	41.83 months ± 19.84 *		
Change of water sources	Yes	51	85
	No	9	15
Affected by ground water pollution	Yes	52	86.7
	No	8	13.3

*Mean value ± Standard deviation (STD)

Table 5 shows the frequency distribution of participants who buy water from the shop, who have contaminated water source at their home, who changed their water source after the contamination occurred and who are personally affected by groundwater pollution. Among the participants, 43 (71.7%) of them buy water from the shop for drinking purpose. These 43 of them were asked to respond to how much they usually spend on purchasing purified/ bottled water from the shop on a monthly basis. Mean amount of money spend is 1942.95 LKR with the standard deviation of 1027.05 LKR. When they were asked if their water source been affected by this contamination issue, 88.3% of them said yes. The mean duration of contamination is 42.83 months with the standard deviation of 19.84 months. Among the participants, 51 of them have already changed their drinking water source and move to bottled water, purified water and deciding to fetch water from other safe sources such as those temporary tanker water provided by the government. 52 of them (86.7%) said they were affected by this issue in general.

6.4 findings on association between education level, income status, usage of purification methods, owning contaminated water source, awareness on safety level of water, chances of changing water sources (Chi-square test)

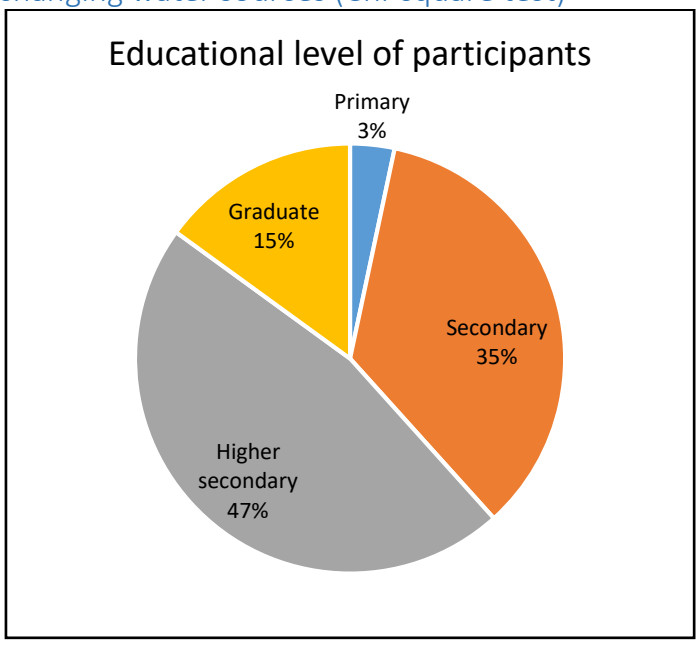

Figure 9: Educational level of participants

Table 6: Association between education level and usage of purification method (Chi-square test)

	Usage of drinking water purification method		Chi- Square	P-value
Education Level	Yes	No		
Primary education (2)	0	2		
Secondary Education (21)	17	4		
Higher Education (28)	20	8	6.266	0.099*
Graduate (9)	7	2		

(*p value < 0.1)

Independent variable: Educational level

Dependent Variable: Usage of purification method prior to drinking water

(Analysis at the 90% confidence level considering the smaller sample size)

Simple chi-square test was done to see if there is any significant association between the education level of the participants and the chances of them using any sort of purification method prior to consuming water. It suggests that there is a statistically significant association between educational level and usage of purification methods at a 90% confidence level (P value < 0.1). Further, it shows that more educated people (with higher education) 6.266 higher chance of using the purification method compare to other groups.

Table 7: Association between Educational level and Awareness about safety level of drinking water source (Chi-square test)

	Aware of water safety		Chi- Square	P-value
Educational level	Yes	No		

Primary education	0	2	4.263	0.234
Secondary Education	12	9		
Higher Education	17	11		
Graduate	7	2		

Independent variable: Educational level

Dependent variable: Aware of water safety

(Analysis at the 90% confidence level considering the smaller sample size)

There is no significant association found between educational level and the awareness of water safety level among the participants. It shows that the educational level of the participants did not affect their awareness about water safety in this study. (P value > 0.1)

Table 8: Association between income level and choosing to buy water from the shop (Chi-Square test)

	Choice of buying water		Chi- Square	P-value
Income level	Yes	No		
<10000	2	4	5.07	0.167
10000-20000	9	2		
20000-30000	18	6		
>30000	14	5		

Independent variable: Income level

Dependent variable: Choice of buying water

(Analysis at the 90% confidence level considering the smaller sample size)

There is no significant association found between income level and the chances of buying water from the shop (P value >0.1). This shows people buy water regardless of how

much they own on a monthly basis considering their health and necessity for clean drinking water.

Table 9: Association between contaminated water source and choosing to buy water from the shop (Chi-Square test)

		Choose to buy water		Chi- Square	P-value
	Categories	Yes	No		
Contaminated	Yes	51	2	44.90	0.001
water source	No	0	7		

Independent variable: Contamination of water source

Depend variable: Choice of buying water

(Analysis at the 90% confidence level considering the smaller sample size)

There is a statistically significant association found between owning contaminated water source and chances of buying water among the participants. People who own contaminated water sources are 44.9 times higher chance of buying water regardless of their income level or occupational status (P value < 0.1 and < 0.05). Participants of this study carefully decided to buy water in order to avoid health issues and other consequences.

Table 10: Association between owning contaminated water source, awareness level about safe water, usage of purification method and chances of changing water source

		Purify water (Dependent variable)		Chi- Square	P-value
Independent variable	Categories	Yes	No		

Contaminated water	Yes	40	13	1.062	0.303
source	No	4	3		
Awareness about	Yes	30	6	4.602	0.032*
Safety level of Water	No	14	10		
		Change water source (Dependent variable)			
water source is	Yes	51	2	44.90	0.001*
contaminated	No	0	7		

There is a statistically significant association found between having awareness about water safety and the chances of using any sort of purification method at 95% confidence level. There is 4.6 times higher chance of using the purification method if the participants are aware of the safety level of their water sources (P-value < 0.05). However, there is no significant association found between owning a contaminated water source and using the purification method. It clearly explains the fact that even if the participants own contaminated water sources, there will not be able to opt for purification method until and unless they are aware of the safety level of the water they are consuming on a daily basis. Further, there is a statistically significant association found between owning a contaminated water source and opting to change their water source at 95% confidence level (P-value < 0.05). It shows that participants who own contaminated water source definitely are 44 times higher chance of changing their water source after they become aware of the water safety level.

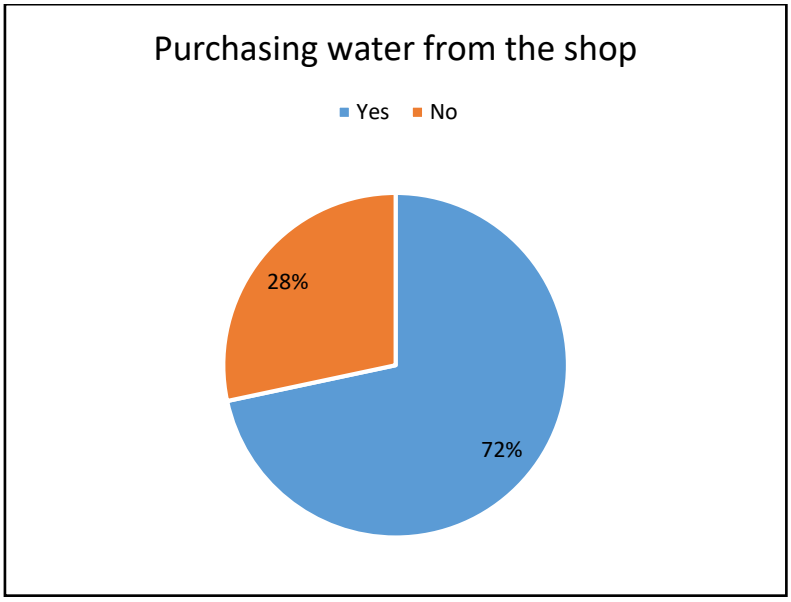

Figure 10: Option of buying water

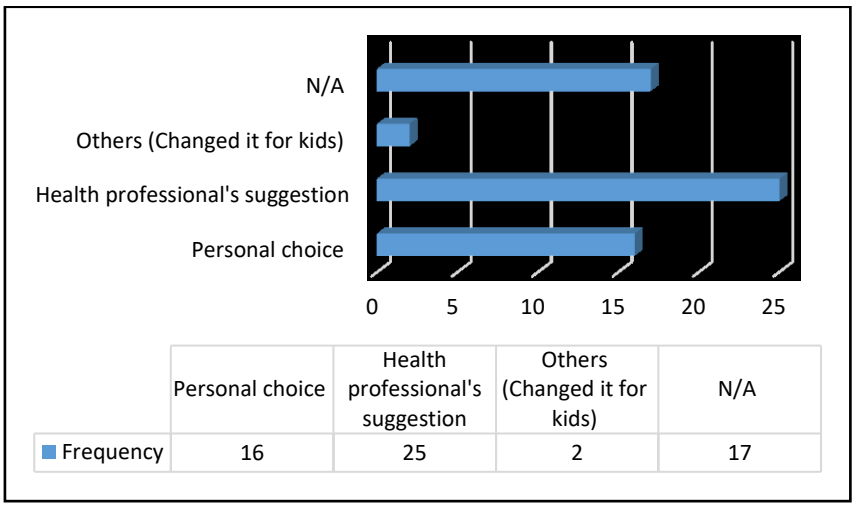

Figure 11: Reasons to buy water from the shop

Figure 3 and 4 show the percentage of participants who purchase purified or bottled water from the shop and what are the reasons for purchasing the water while owning a permanent water source at their houses respectively. Among the 60 participants, 43(72%) of them buy water on a monthly basis for drinking purpose. Among the 43 participants, the majority of them (25) decided to change the water source after the health professionals from their region such as medical doctors and Public health Inspectors (PHI) suggested them. 16 of them decided to change for their personal choice after the water contamination issue

happened. Among them, two families changed their water source only for their kids as they are very prone to water-borne diseases.

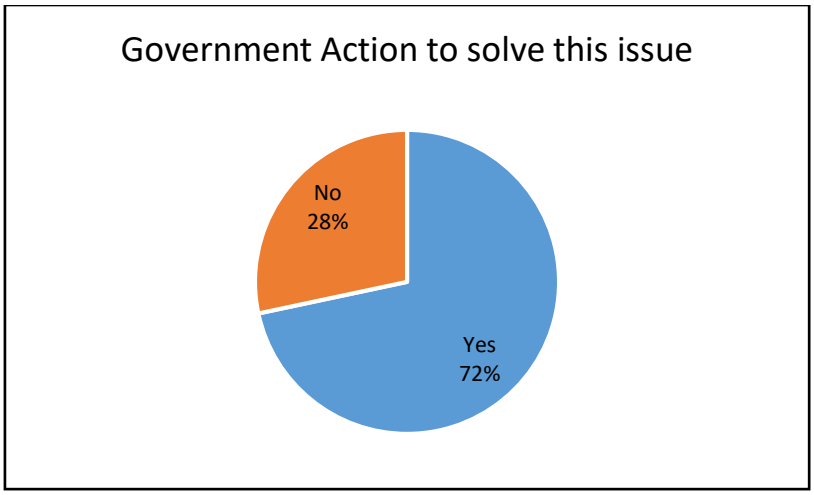

Figure 12: responses for the question on government action

Participants were finally asked if the government has done anything to solve this problem, to overcome the impacts caused by the contamination issue and to pay compensation for the environmental damage caused. 72% of them responded saying the government took some sort of action for this issue. 28% of them responded saying the government did not take any action for this. The reasons for this response will be discussed in the qualitative analysis of the results.

7.0 Discussion

7.1 Socio, economic and environmental impacts of Ground water contamination

There are many socio-economic problems occurred due to the groundwater contamination in Chunnakam aquifer including diseases, health hazards, economic loss, and increased financial burden. Chunnakam falls under the Valikamam region. Valikamam region fully depends on groundwater sources to fulfill their water demands for agriculture, industry, and households since the rainfall in this region is very limited by high surface run-off and evapotranspiration of the dry zone (Rajasooriyar *et al*. 2002). Above 18000 local people were affected by this contamination issue in Chunnakam Area since 2008 (Rupatheesan 2015).

When the people's total water supply depend on solely groundwater sources, it is crucial to control the groundwater pollution and contamination. There can be many impacts created by groundwater contamination such as social, economic, environmental and cultural impacts. These impacts vary on the basis of local people's socioeconomic status, age, sensitiveness to health problems, and exposure to contaminated drinking water, lifestyle and adaptability to changes in the environment.

7.2 Diseases and health hazards associated with oil contamination in Chunnakam Aquifer

Drinking water is the necessary things for human beings for their survival. There are many water-borne diseases which can affect people in the short and long span of their lifetime. Some of them are cholera, diarrhea, dysentery, typhoid, polio, chronic kidney disease, renal failure, and skin diseases (WHO 2018). 80% of all the diseases are associated with water among human beings (Jeevaratnam *et al*. 2017). Villholth *et al*. (2009) says that "Uncontrolled groundwater use and contamination or natural poor quality are leading to access limitations and health concerns".

People in this Chunnakam region also suffered many diseases due to this groundwater contamination since 2008. Few participants responded saying they experienced skin itchiness

and irritation while taking shower using water from their wells. Further, children and older people are very prone to water-borne diseases as their immune system is not yet fully developed or do not function well. It was identified in many families of Chunnakam region that, they changed their water source eventually as they want to avoid their children getting sick. Further, MOH and PHIs from Chunnakam region instructed people to stop consuming water from the polluted/ contaminated water sources. Further, they suggested, the diseases can be only identified if the people are exposed to this contaminants by ingesting water for a long period of time. A recent report from Water Resource Board of Sri Lanka says "Long term expose of the contamination may cause cancer, miscarriages and detriment to early childhood development, skin and mental health" (Yatawara 2015). Majority of the participants in this study (85%) changed their source of drinking water after they become aware of the contamination in their water source. Moreover, 58% of the people who purchase filtered water from the shop, changed their water source after the recommendation of PHIs in Chunnakam area. It shows that the severity of health impacts and awareness from PHIs motivated the people to change the water sources immediately. It shows that restraining the people from using the polluted water could save them from diseases occurrences in the future

Furthermore, few people in this study also mentioned that they experienced abdominal pain and illness after consuming water from the contaminated wells. Few participants suggested that, their village people are not aware of the consequences of the polluted water. They continue to consume and use this water for cooking and drinking as they get used to it for a long time and do not have the facility for another water source. It was also reported by Chunnakam residents that many people still continue to drink water from the same polluted source without realizing the harmful impacts. Further, when people from outside Chunnakam region visit this area and drink water from contaminated wells, they get severe infections (The

Sunday Times 2015). It shows that proper awareness program should be provided to local people to educate them about the future consequences of consuming water with contaminants.

7.3 Economic loss or increased economic burden

One of the negative consequences of this issue is a huge economic loss for local people in terms of money, property, wealth and health. As discussed above, dug wells are the major source of drinking water in the majority of the people's houses. However, after this contamination issue, participants had to change their major source of drinking water and perhaps abandon their older water source.

As explained in the results section, majority of the participants (85%) decided to change their water source and buy purified or bottled water from the shop after the recommendation from health professionals such as MOH, PHIs and medical doctors. This is one of the lifestyle changes they made after the Chunnakam aquifer contamination. Due to this, their economic burden has been increased. Because of this lifestyle change, they have to spend extra money from their monthly income. The mean income of the participants was found to be between 20000 to 30000 LKR. Participants on average spend 1942.95 LKR money for purchasing water from the shops. It shows that participants spend 6.5% to 19% of their monthly income on purchasing water. It is a larger portion of the salary for a middle income earning household. Further, participants have been experiencing this issue for around 42 months on average. This gives us a clear indication of how much money they have already spent and how much they will have to spend for the rest of their life to meet the demand for drinking water.

Water sources has been a major part of non-moving property among people of Sri Lanka. Participants in this study responded saying, having water well at their houses adds economic and cultural value to them. Further, it gives more value to the property if they want to sell or buy a house in Sri Lanka. If the well is contaminated or abandoned for a long period

of time, none will be willing to buy or sell it in the market. It gives a negative impact on the property's value. It explains how much of an economic loss it is to abandon a water source which they have been using for many years. Further, few participants mentioned that, with the odor and dirty appearance it creates due to oil and grease contaminants spreading in the wells, the water wells lose the aesthetic value along with property value.

Moreover, Agricultural loss is very huge on the scale. Local farmers are the ones who observed severe oil contamination in the agro wells since 2008. Due to this issue, some farmers had to abandon their agro wells they had been using for many years. Some farmers kept on using the same water sources even after they identified the grease formation on the surface since they do not have any other option. Due to this issue, crop production has been impacted severely which led to huge economic loss to the local farmers.

7.4 Environmental challenges associated with oil contamination of Chunnakam Aquifer

There are many environmental damage and challenges caused by oil contamination in Chunnakam Aquifer. At first, severe damage to the natural Chunnakam aquifers with contaminants such as heavy metals, oil and grease was caused by this oil waste dumping (Suntharalingam 2018). Around 88.3% of the participants in this study are affected by groundwater contamination in one way or another. Further, 86.7% of them reported saying, their major water source has been contaminated with oil and grease since 2013. One of the protest organizers, Dr. Senthuran, in Chunnakam against Northern Power Company reported to local newspapers that the company has been leaking above 400000 liters of oil waste since 2013 (Tamil Guardian 2015). It happened mainly due to improper waste disposal from Chunnakam Power station. Unfortunately, none of the open dumpsites in Sri Lanka are engineered and therefore the pollutants are released directly into the environment and often to the nearest water body (Wijesekara *et al*. 2017). In this power plant also the oil waste was

dumped directly under the land without any sort of treatment. It shows how much of an environmental hazard is caused by this continuous contamination of Oil waste.

Secondly, there are many ecosystem service association with natural water sources including agricultural activities, ecotourism, drinking water sources and industrial activities. Due to this Chunnakam Aquifer pollution, many of these ecosystem services are affected largely. Few participants also said that, people would not be willing to buy land from this area as the water sources are contaminated with oil and grease. Participants noted that, they see very less tourist around there are since the protests have started. Further, visitors and tourist will be hesitant to visit Chunnakam are due to petroleum odor and unwelcoming appearance of oil and grease on the surface of wells. This creates a huge problem for people who earn money from home-stay tourism. Moreover, the people worry, it gives a negative image to their community from the outsiders.

Further, in order to solve this issue temporarily, the Sri Lankan government with the help of regional council provided tank water to the local people. Only a limited amount of water per family was provided on a daily basis. Apparently, no solution was given to the farmers who have been using contaminated agro wells for their irrigation. This led to contamination of the agricultural land in Chunnakam Area.

Participants also talked about the impact of water contamination on birds, animals and plants in their surrounding environment. People who nurture pets and cattle at their homes struggled to meet water demand to feed them regularly. Further, people who own home gardens and small-scale farm were also affected by this issue. Most of them responded saying, they had to stop farming activities due to limitation for clean water. They could not afford to buy clean water for any activities except for drinking and cooking.

8.0 Limitations of the study and solutions

There are many limitations in this study which may have impacted the outcome of the study and the discussion. At first, the sample size was quite small compared to the total population of the study area. Especially for this type of retrospective cross-sectional studies where we look for overall social and environmental challenges faced by the local people as a consequence of an environmental hazard: Groundwater contamination, the larger sample size is necessary. Due to the time limit, lack of funding and resources, sample size had to be limited to 60- 80 participants. Analyzing this issue using a larger sample size and extending the study period to get more responses in the future studies would give a better outcome in this field of study.

Secondly, bias is one of the sampling associated issue in this study. As it was mentioned, participant selection for this study was done using convenience and snowball sampling method. In these methods, participants are selected for the researcher's convenience and most of the time it was on a voluntary basis. When participants voluntarily take part in a study, there is a huge possibility for bias in answering. Further, the selected samples may not be representative of the larger population that are covered in this study. In order to avoid the biases occurred due to sampling techniques, random sampling with larger sample size should be done in future studies.

Thirdly, few questionnaires from participants had to be omitted from the study due to two reasons such as participants not falling under certain criteria and not filling up the questionnaires with adequate answers. The water contamination issue in Chunnakam area started in 2009. Participants were chosen on the basis of region. After we chose the participants and started the survey only, we figured out that there are few families that moved to this region recently. We expected the participants to have lived in the region for at least since 2009 to understand the overall impact of contamination during the last 10 years (2009-2019). Further, few participants did not fill up the questionnaires with necessary responses.

They left the qualitative part of the questionnaire left unanswered. Considering both cases, we had to omit around 20 responses from the results. It would be better in the future studies to clearly define the criteria prior to the study and give incentives to participants in order to encourage them to participate effectively.

Next, not being able to obtain the first-hand data on water quality parameters for this study due to the lack of funding and laboratory resources. As this issue is related to government authorities, it was really difficult to obtain permission for laboratory-based experiments with water samples. Further, each sampling would cost approximately 50 USD to check for all the basic water quality parameter check up in the government authorized laboratories. Secondary data on water quality parameter from previously done research in used to support this study. Having first-hand data would benefit more in understanding and analyzing the data in one's own perspective.

Further, there is only a limited amount of researches and literature available on this study. This groundwater contamination issue has been happening since 2009. It has been already 10 years since the power plant was built. Although there have been many studies done in order to understand the water quality issues, social challenges, waste management challenges, water management issues, environmental hazards associated with Northern power plant, the data and articles are not publicly available for the researchers to use. It is mainly due to government restrictions and political influence. As this issue can create huge problems to government authorities, they intentionally shut down many local researchers from voicing against them and publishing research papers against them. It made it difficult to analyze this study in depth. It would be really effective if all kinds of studies done regarding Northern Power plant since 2009 to become available for other future researchers to use.

Thus, by omitting all these above-mentioned limitations effectively and doing the study with the more representative sample would be beneficial for both researchers and the

participants. It would help the researcher in analyzing the social, economic and environmental challenges of Chunnakam water contamination issue adequately and precisely.

9.0 Potential Solution to the Water contamination issue

There are few potential solutions to solve social, economic and environmental impacts caused by Chunnakam Aquifer contamination and to further stop the reoccurrence of this issue in the future. The solutions includes, Polluter paying option, enforcing new as well as already existing policies and regulation on wastewater management, monitoring and evaluating the regulations strictly with the help of local authorities, fastening the process of court hearing and law enforcement when common people file complaints and ensuring basic rights of the people are met in Chunnakam Region.

At first, there are few major institutions involved in the wastewater management in Sri Lanka such as Central Environmental Authority, Ministry of Environment, Ministry of Agriculture and Environmental and occupational health, National Water Supply and Drainage Board. Wastewater management is regulated by the National Environmental Act (NEA) no 47 of 1988 and 2000. It covers all the regulations and objective of wastewater management and protection of the environment associated with pollution control (Jeyalal *et al*. 2005). Although the regulations are explicitly informed to any authorities who provide the license to industries with harmful effluents, they most of the time failed to comply with the regulatory instructions. The Central Environment Authority should strictly look into this matter while providing license to any industrial activities. It was also identified that many small businesses actively discharge their effluents without any license in rural areas. Proper regulation should be made to include the small businesses into the category where they are required to comply with regulations. Moreover, the role of groundwater in achieving sustainable development and in the development of appropriate water management institutions needs to be highlighted and

specifically addressed in policy discussions and during decision-making processes (Villholth 2009).

Next, Groundwater quality can never be reversed once it is polluted just by restraining the pollutants from the source of pollution (Ramakrishnaiah *et al.* 2009). It can only be solved if the waste management system is further developed and the polluted sites are properly cleaned out. However, proper wastewater management system is one of the necessary systems that Sri Lanka lacks behind compared to other developing countries. Central Environmental authority basically requires industries to check on highest water levels, quality of ground and surface water sources, location of public and private water wells within one-kilometer radius before setting up a waste management system in their surroundings (CEA 2018). However, industries do not tend to follow the instructions to avoid the extra cost associated with the prior checkup. It ultimately leads to severe environmental hazards in the future. In order to control this from happening, CEA with the support of the ministry of environment should evaluate the industrial buildings before they start any process.

Further, in order to stop the reoccurrence of the groundwater contamination, industry or whoever is found responsible for the polluting activities should be given severe punishment. This punishment should create both awareness of the common people and teach the value of ecosystem services in the environment. The "*Polluter paying*" concept/regulation is most suitable in this case. Even Supreme Court of Sri Lanka ordered the Northern Power Plant which is the polluter in this Chunnakam case to pay the compensation to the affected people. Further, Rio declaration states that "*National authorities should endeavor to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment"*

(Ranawana 2019). This clears explains how polluter pay concept should be taken into consideration while solving environmental pollution related hazards.

It was observed in this study that, lack of awareness about environmental issues and ignorance towards the responsibilities to take part in pollution control are interconnected problems among Chunnakam local people. Many of them mentioned as they are aware of the contamination issue. However, most of them do not know the actual cause of this contamination. It leads to common people misunderstanding and accusing different authorities and sources for this pollution. Around 15% of the participants in this study were found to keep using the same polluted water source for their drinking purpose even after they become aware of the contamination. Moreover, the farmers, who do not have any substitute their major water sources continued to use the polluted water for their irrigation purpose. Many studies found poisonous contaminants in the Chunnakam polluted wells. Potential risks of heavy metals and other toxic contaminants cannot be ignored and taken into utmost consideration as they can cause severe health hazards in the long term (Wijesekara et al, 2014). But, due to lack of water and awareness people kept using the polluted water. These instances show how much these people are not aware of the severity of this pollution. Thus, CEA and other authorities who are responsible for wastewater management should create awareness among local people. Researchers and local scientists should come forward and educate people on these issues which might save many lives from getting water-borne diseases in society.

10.0 Conclusion

Water is a necessary thing for human beings to survive apart from food and shelter. An adequate supply of safe drinking water is a prerequisite for a healthy life and impurities while contamination in drinking water can cause many diseases (WHO, 2018). As much as the water is important for us to survive, it is important for us to get clean potable water for drinking purpose perhaps for cooking and bathing as well. Along with groundwater exploitation, groundwater contamination has become a very serious concern in Sri Lanka, where the majority of the people depend on ground water for drinking purpose. Chunnakam Aquifer pollution is one of the many incidents where ground water is polluted by industrial activity. Previous studies done in Chunnakam Aquifer issue found out the water wells around the area to be severely polluted with oil and grease. Further, this study found out the overall social, economic and environmental challenges associated with Chunnakam Water contamination. Along with the water pollution, lack of awareness, lack or regulation in groundwater management and irresponsible acts of industries who focus only on increasing profit cause many challenges in Chunnakam residents. Further studies should be undertaken in the Valikamam region covering many samples in order to understand the impact on a larger scale. This might give a clear idea to the Central Environment authority to start working on sustainable solutions to recover from the impacts caused in the long run. Thus, the Sri Lankan government should develop the waste management system and policy regulations associated with this field. Further, Local people should be made aware of the problems and the development needed for the issues in order to make them understand their responsibilities as citizens of Sri Lanka.

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12.0 Appendices

1:

Qualitative analysis of the responses on awareness, public perceptions, government action, responsibilities, and social, economic and environmental challenges.

1: What are the ways it affected your day to day life?

- Need to buy water
- Hard to manage everyday
- Extra cost from the income
- Had to change the water source for kids as they are very prone to diseases
- Disease and physical unwell ness
- Oil staining during shower and washing
- Experience itchiness in the skin while taking shower

2: How do you think the oil waste contamination in Chunnakam aquifer changed the environment around you?

- We could not use already made wells
- Effected/polluted many water sources around this area
- They built new water tanks for people and tanks for schools
- Wastage of already build wells for long time
- Polluted water problems among people
- Ground water pollution affected the trees and other plants around this area

3: Whom do you think should be responsible for paying for the damage, to clean up and to enforce environmental regulations for this issue?

- Factory authorities
- Factory issue
- Power station
- Electricity board
- Private company

4: What are the actions government took?

- Built few water tanks as substitutes, mobile water supply through regional council
- Provided clean water in the community schools
- Temporarily stop the functions in the factory
- Requested people to check on water issue (to check the quality)
- Tested water sample for few houses
- Government asked to pay 5000 to water parameter checking

5: What do you think can be done by common people to reduce the damage caused by the issue, to enforce environmental regulations?

- Public should be aware about what's happening around them
- We should voice against the issues. However, it is not safe for us to talk about this always as it is related to the Government.

- People should be made aware of this issue so that they don't keep drinking the polluted water.
- We need to protest against the people who are responsible for this issue as water is very important for us
- Our area people should meet together and protest against this problem
- Provide awareness through public gatherings and providing newsletters
- Government should intervene and stop this power plant

2: Questionnaire used in the study

Hi, I am going to ask you some questions related to your drinking water habit and Chunnakam aquifer contamination. This is to determine the social and environmental implications caused by the oil waste contamination of Chunnakam Aquifer. Please answer these questions even if you do not consider yourself to be a person directly affected by this issue. Take a while to recall and answer as much as you remember. Thank you so much for your time and your great help. *நான் உங்களிடம் குடி நீர் பாவனை மற்றும் சுன்னாகம் நிலத்தடி நீர் பிரச்சனை தொடர்பாக சில கேள்விகள் கேட்க உள்ளேன். சுன்னாகம் நிலத்தடி நீர் எண்ணெய் கழிவு அசுத்தத்தினால் ஏற்பட்ட சமூக மற்றும் சுற்று சூழல் பாதிப்பு எவ்வாறானது என்பதை அறிந்துகொள்ளும் நோக்குடன் இந்த கேள்விகள் வினாவப்பட்டுள்ளது. நீங்கள் இந்த பிரச்சினையினால் நேரடியாக பாதிக்கப்படவில்லையாயினும் பின்வரும் வினாக்களுக்கு உங்களால் முடிந்தவரை பதில் அளித்து உதவுமாறு தாழ்மையுடன் கேட்டுக்கொள்கிறேன். உங்களுடைய நேரத்திற்கும் உதவிக்கும் மனமார்ந்த நன்றிகள்.*

Title: Social and Environmental implications of oil waste contamination in Chunnakam Aquifer (*சுன்னாகம் நிலத்தடி நீர் எண்ணெய் கழிவு அசுத்தத்தினால் ஏற்பட்ட சமூக மற்றும் சுற்று சூழல் பாதிப்பு*)

1: Name /*பெயர்*: ……

2: Age /*வயது*: …… yrs (*வருடங்கள்*)

3: Gender/*பால்* :…. Male (*ஆண்*)…. Female (*பெண்*)

4: Location or address /*முகவரி*: ……..

5: Occupation /*தொழில்* :

….. Government Service (*அரசவேலை*)

….. Business (*வணிகம்*)

….. Day Laborer (*கூலி வேலை*)

…...Farmer (*விவசாயம்*)

…... Others, specify (*வேறு*)

6: Educational Level *கல்வி தகைமை*

… Primary (*ஆரம்பநிலை*)

--- Secondary (*இடைநிலை கல்வி*)

--- Higher Secondary (*மேல்நிலை கல்வி*)

--- Graduate (*பட்டதாரி*)

7: Number of family members / *குடும்ப உறுப்பினர்கள் எண்ணிக்கை*:

……

8: What is the monthly income of the household? *மாதாந்த வருமானம்*?

…….. <10000 Rs

……. 10000-20000 Rs

…….20000-30000 Rs

…….> 30000 Rs

9: Is there any source of drinking water in your home? (*உங்கள் வீட்டில் குடிநீர் வழங்கல் உள்ளதா*)? …….Yes (*ஆம்*) ……. No (*இல்லை*)

10: If yes, which of the following sources of drinking water are available in your home? (Check all that apply) *உங்கள் வீட்டில் உள்ள குடிநீர் பெறும் வழிமுறைகள்? (சரியான அனைத்தையும் தெரிவு செய்க)*
….Dug Well (*கிணறு*)
…hand pump (*குழாய்க்கிணறு*)
…Public tap (*பொதுக்குழாய்*)
…Community well (*பொதுக்கிணறு*)
…Household water supply/piped (*வீடு குடிநீர் வழங்கல்*)
…Other (*வேறு*)
11: What means safe drinking water for you? (Check all that apply) *பாதுகாப்பான குடிநீர் பற்றி உங்கள் எண்ணம் என்ன? (சரியான அனைத்தையும் தெரிவு செய்க)*
…Will cause no disease/ health problem / *நோய் அல்லது சுகாதார பிரச்சனையை விளைவிக்காது*
…Clean in appearance / *தெளிவான தோற்றம்*
…Odorless/ *மணமற்றது*
…Colorless / *நிறமற்றது*
…No harmful taste/ *பாதகமான சுவையற்றது*
…No suspended materials /*அசுத்தமான படிவுகள் அற்றவை*
…Don't know/ *அறிந்திருக்கவில்லை*
12: Do you know whether the water is safe for drinking purpose or not? *நீங்கள் உபயோகப்படுத்தும் குடிநீர், பாதுகாப்பானதா என அறிந்துள்ளீர்களா?*
…Yes (ஔ/*ஆம்*) …No (ஊ/*இல்லை*)
13: Overall how satisfied are you with quality of drinking water in home? *நீங்கள் உபயோகிக்கும் குடிநீர் பற்றி உங்களது கருத்து என்ன?*
…Very satisfied/*மிகவும் திருப்தி*,
…Somewhat satisfied/*ஓரளவு திருப்தி*,
…Neither satisfies nor unsatisfied/*நடுநிலை*
…Somewhat dissatisfied/*அதிருப்தி*
…Very dissatisfied/ *மிகவும் அதிருப்தி*
14: Generally, does the drinking water in your household smell? *நீங்கள் உபயோகிக்கும் குடிநீர் மணமுடையதா?* …….Yes /*ஆம்* ……. No /*இல்லை*
15: Does the drinking water in your household have a taste? *நீங்கள் உபயோகிக்கும் குடிநீர் சுவையுடையதா?* …….Yes /*ஆம்* ……. No /*இல்லை*
16: What does the drinking water in your household look like? *நீங்கள் உபயோகிக்கும் குடிநீரின் தோற்றம் என்ன?* …… Clear (*தெளிவானது*) …… Cloudy /Dirty (*அசுத்தமானது*)
17: In your home, is there any method for water purification? *வீட்டில் குடிநீர் சுத்திகரிப்பு முறை உள்ளதா?* …….Yes (*ஆம்*) ……. No (*இல்லை*)

18: If yes, which of the following water purification method is currently used in your household? *ஆம் எனில், எவ்வாறான முறை?*
…Boiling/*கொதிக்கவைத்தல்*
…Filter with cloth/*துணியால் வடிகட்டல்*
…Halogen tablet /*குளோரின் பயன்படுத்தல்*
…Chemicals/*இரசாயன வடிகட்டல்*

…water dispenser /நீர் சுத்தீகரிக்கும் இயந்திரம்
…Others, specify /வேறு
19: Do you buy water for drinking purpose? நீங்கள் குடிநீர் தேவைக்காக கடையில் கொள்வனவு செய்பவரா? …….Yes (ஆம்) ……. No (இல்லை)

20: If yes, how much do you spend a week in your household for drinking water? குடிநீரை கடையில் கொள்வனவு செய்வதற்கு வாரத்தில் செலவாகும் பணத்தின் பெறுமதி? .

..... Rs/ ரூபாய்

21: Reason for buying water from the shop? குடிநீரை கடையில் கொள்வனவு செய்வதற்கான காரணம்?
…Personal Choice/சுயவிருப்பம்
…health professional's suggestion /சுகாதார சேவையாளர் அல்லது மருத்துவரின் கோரிக்கை
…No water source/நீர் வழங்கல் பற்றாக்குறை
…others, Specify /வேறு

Questions on Social Implications (*சமூக பிரச்சனை*)

22: Have you heard about the oil waste contamination in Chunnakam Aquifer? சுன்னாகம் நிலத்தடி நீர் அசுத்தம் பற்றி நீங்கள் அறிந்துள்ளீர்களா?
…….Yes (ஆம்) ……. No (இல்லை)
23: Have you been affected by oil waste contamination in Chunnakam Aquifer? சுன்னாகம் நிலத்தடி நீர் அசுத்தத்தினால் நீங்கள் எந்த வகையிலும் பாதிப்படைந்துள்ளீர்களா?
…….Yes (ஆம்) ……. No (இல்லை)
24: If yes, How long have you been affected by this issue? ஆம் எனில், எவ்வளவு காலமாக பாதிப்படைந்துள்ளீர்கள்? ……Months/Years
25: Did it affect your major source of drinking water? இது உங்களுடைய முதன்மையான குடிநீர் மூலத்தை பாதித்துள்ளதா? …….Yes (ஆம்) ……. No (இல்லை)
26: What are the other ways it affected you day to day life? இந்த குடிநீர் பிரச்சனை, வேறு எந்த வகையில் உங்கள் நாளாந்த வாழ்க்கையை பாதித்துள்ளது?

Environmental Implication (*சுற்றுசூழல் பாதிப்பு*)

27: How do you think the oil waste contamination in Chunnakam Aquifer changed the environment around you? சுன்னாகம் நிலத்தடி நீர் பிரச்சனையை உங்கள் சுற்று சூழலை எவ்வாறு பாதித்துள்ளது?

Solutions: *தீர்வுகள்*

28: Did you change the source of drinking water after this incident? இந்த பிரச்சனையின் பின்னர் நீங்கள் உங்கள் குடிநீர் மூலத்தை மாற்றியுள்ளீர்களா?
…….Yes (ஆம்) ……. No (இல்லை)
29: Whom do you think should be responsible for paying for the damage, to clean up and to enforce environmental regulations for this issue? இந்த நிலத்தடி நீர் பிரச்சனைக்கு யார் பிரதான காரணம் என்று நினைக்கிண்றீர்கள்?

30: As far as you know, does government take any action to clean up the oil waste or to compensate for the damage caused by this issue? இந்த நிலத்தடி நீர் அசுத்தத்தை தடுப்பதற்கும்,

சுற்றுசூழல் பாதுகாப்புக்கான சட்டதிட்டங்களை அமுல்படுத்தவும் அரசாங்கம் இதுவரையில் எந்த விதமான நடவடிக்கைகளையும் எடுத்துள்ளதா?

…….Yes (ஆம்) ……. No (இல்லை)

31: If yes, what are the actions they took? ஆம் எனில், எவ்வாறான நடவடிக்கைகளை எடுத்துள்ளது?

32: What do you think can be done by common people to reduce the damage caused by the issue, to enforce environmental regulations? இந்த நிலத்தடி நீர் அசுத்தத்தை தடுப்பதற்கும், சுற்றுசூழல் பாதுகாப்புக்கான சட்டதிட்டங்களை அமுல்படுத்தவும் பொது மக்கள் எந்த விதமான நடவடிக்கைகளை எடுக்க வேண்டும்?
