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Impact of Climate Change on Groundwater Resources and Its Eco-System in Jaffna Peninsula, Sri Lanka

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ABSTRACT

Jaffna Peninsula is one of the 25 districts of Sri Lanka which has the unique geologic and physical patterns from other parts of the country. As it has the ironic source of groundwater influenced over other potential resources, the district derives more attention on groundwater contamination. The studies carried out in the region show that there is a huge impact on groundwater resource due to the dramatic variation in climate over the years whether it is anthropogenic or natural process.Basically, the climatic circumstances depend on the continuous weather patterns in a time frame. The overall climate pattern is decided by the observations of individual factors; temperature, rainfall and direct sunshine in a certain region. Meanwhile, groundwater contamination is identified with the factors of BOD, DO and other ion presence. These groundwater contamination indicators fluctuate greatly even in terms of a tiny change of climatic condition. Thus, the ecosystem and other livelihood which depend on the groundwater resource face difficulties in regards to the survival on earth. This paper would emphasize on how the climatic factors will influence the parameters in terms of groundwater contamination in Jaffna Peninsula and the chronic issues faced by the surrounded ecosystem and livelihood. Also, it may reveal number of suggestions and recommendations aimed at the mitigation of the climate change impact on groundwater contamination and its ecosystem.

1.0 INTRODUCTION

There is no life without water and it leads the human on Earthto stand on the edge of the life due to the challenges created by the water issues. Groundwater is the major source for freshwater owing to its capacity of natural purification. First of all, because of seasonal variation, groundwater has immensely become an important resource for human in both urban and rural areas to meet people's demandfor water supply. Approximately 1600 to 2000 million people worldwide depend on this groundwater resource as their primary water supply 63.

However, the insufficient understanding and knowledge lead to undervalued irrational exploitation and inadequate practice of protecting the groundwater overall. Especially, countries like Sri Lanka that had the rich resources of groundwater once upon a time, but currently it is being devastated in terms of its quality and potential 127. Groundwater contamination in Sri Lanka is an emerging problem with huge attention due to the WHO standard level for water quality 59. Most of the districts of Sri Lanka struggle on the basis of groundwater contamination. However, Jaffna district gets more attention, because it has no surface water and the only source of having water is the groundwater **Error! Reference source not found.**.

Despite of anthropogenic activities, groundwater primarily gets polluted as a result of Climate Change process. Hence, with respected evidence and interesting results, this paper will discuss on the topic of groundwater contamination due to Climate Change phenomenon over the years, in the region called Jaffna Peninsula Sri Lanka.

2.0 OBJECTIVES

The objectives of this study are

- Analyze the hypothesis in terms of climate change impact on water resource and its ecosystem in Jaffna Peninsula, Sri Lanka
- Conduct survey and determine the different perspective on the same concepts
- Compare our data with the past dataand evaluate the differences
- Study the trend of Climate pattern in different time period but same space
- Examine the effect of climatic factors in the water quality changes

3.0 HYPOTHESES

A positive relationship is found between the parameters of groundwater contamination and climatic condition factors in Jaffna Peninsula. Especially temperature, rainfall and the direct sunshine contribute to reflect the fluctuation in groundwater contamination indicators such as BOD, DO, Cl^-, NO^-_3, and other ions present in the water.

4.0 LITERATURE REVIEW

4.1 *General background*

From the ancient time up to this century, water beneath the earth surface or groundwater has been exploited for various purposes such as domestic use, livestock and irrigated agriculture. As a result, the successful methods of extracting water from the underground to the surfacehave been developed over the ageswith the advanced civilization.

As evidence, it is estimated that the 22% from the total volume of water distribution isoriginatedin the form of groundwater storage, under the earth surface 63. Among thefreshwater sources, other thanthe areas of polar ice caps and Polar Regions, where the water is being locked, the balanced 95% of all fresh water is potentially available for human activities 63. This groundwater source is stored in lakes, swamps, reservoirs and rivers that all account for only 3.5% of total freshwater body 127. At the same time, in comparison to the surface water usage, groundwater usage on a global scale is recognized as small portion. On the other hand, ground water usage has become significant in terms of safe drinking water. Moreover, based on WHO report, the quality of groundwater is considered to be standard enough 6. In other wordsdue to its purity which occurs soon afterthe au-

tomatic filtering by the effect of porous aquifer medium,thegroundwaterdoes not require further treatment for drinking purpose.

4.2 Occurrence of Groundwater and its Storage

Groundwater occurs in many different geological formations. Almost all the rocks in the upper part of the earth's crust possess openings called pores or voids6. The volume of water contained in the rock, depends on the percentage of the openings or pores or voids. The above is based in a given volume of the rock, which is termed as the porosity of the rock. The consequence of having more pore spaces results with higher porosity and it leads to store more water under the earth surface.Based on research studies, it has beenfound that only a certain part of water which contains the fully saturated pores have the ability to be extracted for practical use6.

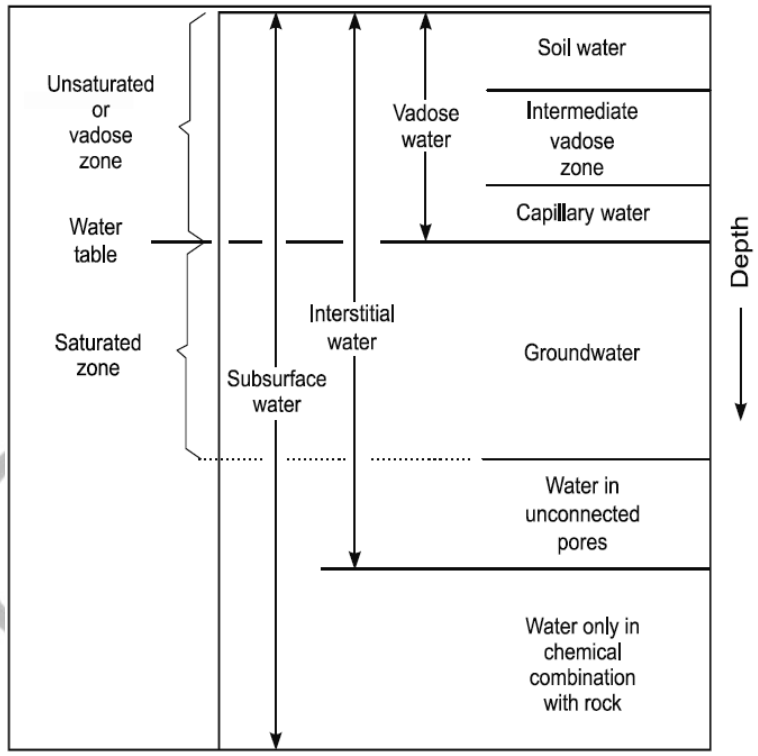


Figure4-1: Cross Section of Groundwater source (Panabokke 2008)

When there is rain falls, some of it infiltrates into the soil. In the unsaturated zone, the downward movement of water is very slow 17. At greater depths, all the empty spaces are completely filled with water and this is called the saturated zone 53. If the hole is dug or drilled down to this saturated zone, water will flow from the ground into the hole. Simultaneously, the water will be settled at the depth below which all the pore spaces are filled with water. This level above illustrated is termed as the water table, and notably the term groundwater refers only to the saturated zone below the water table. All water which situated naturally beneath the earth surface, including the saturated and unsaturated zones isaddressed as sub- surface water, according to the figure 4-163.

The volumes of the water stored in underground are generally very large; thus the time- scale of groundwater movement is generally very long. Below the water table, water flow occurs at rates ranging from 10m/day to less than 1m/annum 63.

4.3 Groundwater in the hydrological cycle system

The continuous movement of water among oceans, atmosphere and land is known as the hydrological cycle124. Considering the freshwater component of the hydrological cycle system, it is an importantpart of thegroundwater movement. Besides, inflow of the water is formed by precipitation (rainfall) and melting of snow and ice. Primarily, water outflow occurs in the form of stream flow or runoff and as evapo-transpiration; which is explained as a combination of evaporation from water surfaces and the soil as well as transpiration from soil moisture by plants 64.

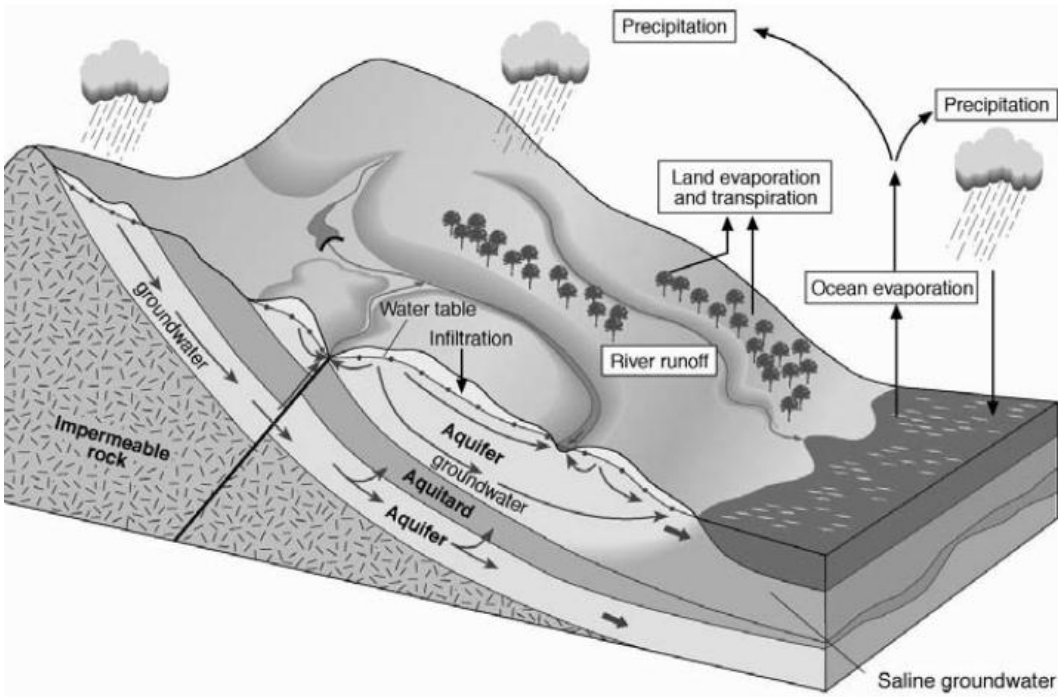


Figure 4-2: Hydrological Cycle 6

Precipitation reaches both streams and rivers on the land surface as overland flow to tributary channels. By the time, water interflows through the subsurface routes, the base flow infiltrates into the soil. Part of the precipitation that infiltrates deeply into the ground may accumulate above by an impermeable bed. Meanwhile, the infiltrated precipitation saturates the available pore spacesin order to form the underground water layer, which is called an aquifer 63. The water contained in the aquifers contribute to the groundwater component of the cycle, from which natural discharge reaches streams, rivers, wetlands and the oceans78.

4.4 Aspects of Groundwater Quality

The presences of different concentrations of several constituents determine the quality of groundwater and cause problem for water extraction. The relative abundance of these constituents which are dissolved in groundwater is given in the tablebelow 63**Error! Reference source not found.**. Meanwhile when the different elements exceed the certain standard values, it will lead to the groundwater contamination.

Table 4-1: Different level of elements that determine the quality of groundwater (modified from Panabokke 2008)

Major constituents 1.0 to 1 000mg/l	Secondary constituents 0.01 to 10.0 mg/l	Minor constituents 0.0001 to 0.1mg/l
Sodium	Iron	Arsenic
Calcium	Aluminum	Phosphate
Magnesium	Potassium	Manganese
Sulphate	Carbonate	Barium
Chloride	Nitrate	Strontium
Bicarbonate	Fluoride	Lithium
Silica	Boron	Cadmium
	Selenium	Chromium
		Nickel
		Copper
		Cobalt
		Lead

4.5 Basic Considerations on the Study of Groundwater Contamination

It is now recognized that the more rewarding approach to the study of various aquifer types in countries (specifically countries where there are abundant source of disappearing standard groundwater) is established from the position of their geomorphic settings in the regional landscapes 69.Appreciating this distinction is especially important in relation to protect the groundwater from pollutants originating from anthropogenic activities; at the surface level. Such pollutants can either be retained in the soil or carried downwards by infiltration of ground water; depending on the physicochemical properties of both the soil material and of the pollutants 51. Meanwhile, the soil and the unsaturated zone beneath the soil layerare considered to serve as the reactive filter, which in returndelay or even remove the pollutants by the range of processes of natural filtration 56. Groundwater contamination collapses the whole natural system of groundwater and it causes imbalance between the surroundings.

4.6 Scenario of Jaffna Peninsula, Sri Lanka regarding Ground water resources

In Sri Lanka, more than 90% of people in the towns of Jaffna, Batticaloa, Mannar, Vavuniya and Puttalam are being dependent on the groundwater aquifers through municipal well fields and private boreholes 55. During the early seventies, the hydrogeologists in Sri Lanka found the significant reservoirs of groundwater that were present in the multitude of joints and fractures of the basement crystalline rocks of the country.These reservoirsare drawn by drilling into the rocks, which brought up the concept of tube wells 82.

Jaffna is one of the main districts of the pearl of Indian Ocean, Sri Lanka, which forms the far north most part of Sri Lanka in the Northern Province 117. Jaffna is known as Jaffna Peninsula with the area of 1,129.9 square kilometers in which lagoons covers 45.7 square kilometers **Error! Reference source not found.Error! Reference source not found.**. Jaffna Peninsula lies between the latitudes of accordingly, 9^0 41’ 12 ″ N to 9^0 68′ 67″ N and longitudes of accordingly80^0 06′ 02″ E to 80^0 10′ 06″ E 117116.

TheJaffna area consists of the whole Peninsula and the seven inhabited islands nearby **Error! Reference source not found.**. The north, east and west boundaries of the district are surrounded by the Indian Ocean. On the South part, there is the Jaffna Lagoon which connects the Kilinochchi district 56 as the only main land. Jaffna district is one of the most densely populated districts in the country with the highest population density reported from the city limits of Jaffna 127. Other areas are sparsely populated, except for local townships such as Point Pedro and Kankesanthurai, where population density is low to intermediate. Jaffna district's population was 650 720 in 2009 according to the census of Sri Lanka **Error! Reference source not found.**.

4.7 Geological Pattern

Jaffna peninsula is mainly underlain by Miocene limestone 110. Limestone is exposed at the North Central part, extending in a NNW to SSE direction from Urumpirai to Palaly 82. Bordering this on the western side, are patches of red earth formations 82. Encompassing these two formations, the brown sand formations are found on the western side than the eastern sideof Jaffna Peninsula, which occupy a larger area 79. Enclosing these geological patterns along the western coast and the lagoon areas, unique lagoonal deposits are accompanied 79 as geological patterns. The east area of the lagoon is occupied mainly by brown sandy loams in the south and the sand dunes in the north along the eastern coast of the Peninsula, stretching from Thumpalai to Nagarkovil and beyond. Recent coralline reefs have been found along the northern coast of the Peninsula 79.

The four main aquifers in Jaffna; Thenmarachchi, Vadamarachchi, Valigamam and Kayts fulfill the water supplies of 90% of people who be dependants of groundwater in that particular region 41. The groundwater which is trapped inside this Miocene limestone layer is used for different daily functions such as irrigation, drinking and other livelihood purposes. Particularly, the water supply is provided to the whole peninsula irrigations with the help of the reservoirs wells and boreholes 40117**Error! Reference source not found.**.

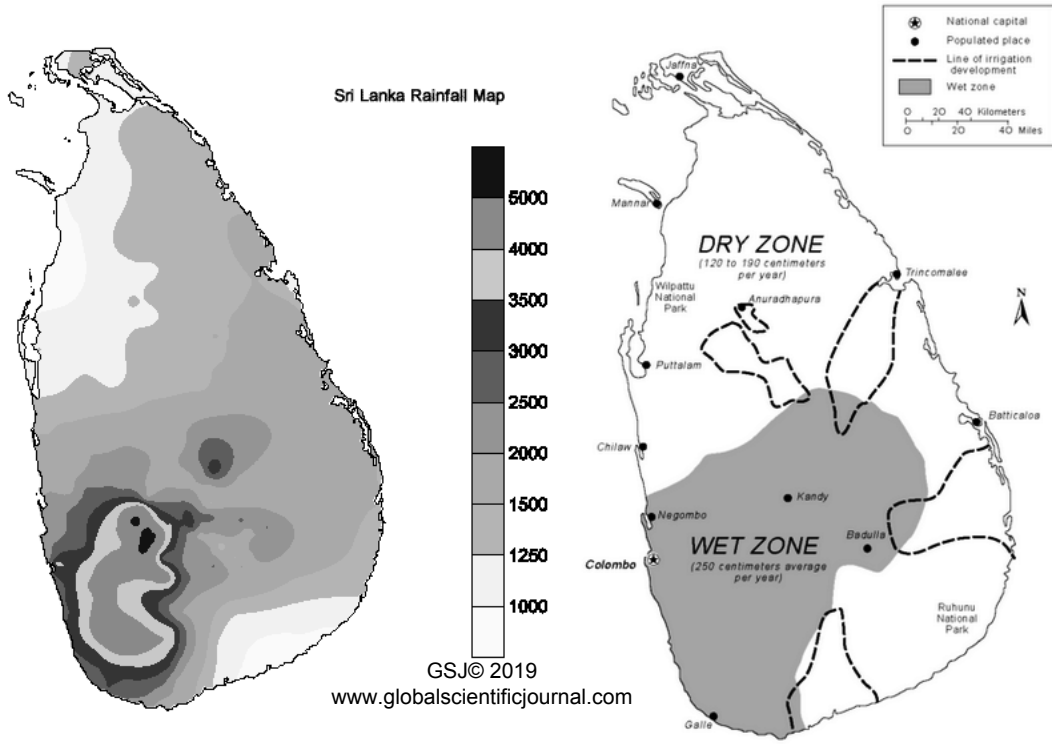
4.8 Climate

The area covered by Jaffna district falls under the dry zone of Sri Lanka where tropical dry climate is prevalent 3. Lying in the equatorial and tropical zone, Jaffna is influenced by mainly two monsoons; North-east and South-west monsoon 41. The average temperature generally reaches highs of around 31^0C during day time and at night it reaches minimum temperature of 20^0C 125.

On the other hand, the average daily relative humidity is found to be around 65-80% 125with the average monthly precipitation of 1255mm (approximately) which mainly falls during the inter-monsoonal (October to November) by the North-east monsoon116.

The seasonal rainfall exhibits a definite pattern. For instance, the north east monsoonal rainfall occurs from the month of October to month January which is making up around 82% of the mean annual rainfall of 1250mm 17. February to March and June to August are dry months and they contribute to the annual evaporation amounts of 2000mm 17. The year to year variation for the Peninsula is at high scale with a low of 625 mm recorded in the years of 1875 and 1963 and a high of 1750mm recorded in the years of 1885 and 1932 respectively 82.

Throughout it can be see rain drizzle fall- of the is estimat- past fore- that the an average per day in ning of the maximizes mid sum- year 56. sents the number of day time



each month, expected to drops or ing on 1 day month 3. It ed from the casted data sun shinesat of 10 hours the begin- year and during the mer of the This repre- average hours in the that the sun

is visible and not obscured by clouds annually.The average daily wind speed has been found around 13km/h in the beginning of the year 125. In recent years, the maximum sustained wind speed has reached to 74 km/h that is equivalent of around 46mph 10. At the same time, the months of December, January and February are affected by foggy conditions 3.

Figure4-3: Climate comparison of Jaffna Peninsula with the other places in the country (Adapted from Sunday Observer Newspaper 2012)

4.9 Hydrology

Rainfall is the only source of all groundwater in the Jaffna Peninsula 115. The rainfall infiltrates into the thin layer ofwell drained soil (calcic red- latosols) and moves down into the rock openings and then enters into the zone of saturation115110. Recharge to the aquifers occurs mainly during the north-east monsoon season in the month of October to January. During these months, the excess water is received 1725 as inflow. Water table levels at Jaffna Peninsula rise from a low in August to a high in January 29**Error! Reference source not found.**.

Again, the water is generally occupied within the secondary openings along bedding planes and fractures that have been enlarged by the solution of limestone 124. During rainy days, rain water percolates downwards into the soil to join the freshwater that is supported by the heavier sea water, forming a shape like a lens 82. This water gets drawn out by pumps or other devices to the earth surface. The thickness of the lens of freshwater at any instant in a locality is dependent on the height of the water table above sea level as the height of the column of fresh water must be balanced with the salt water pressure of the bottom of the lens according to the Gyben- Herzberg relationship6341.

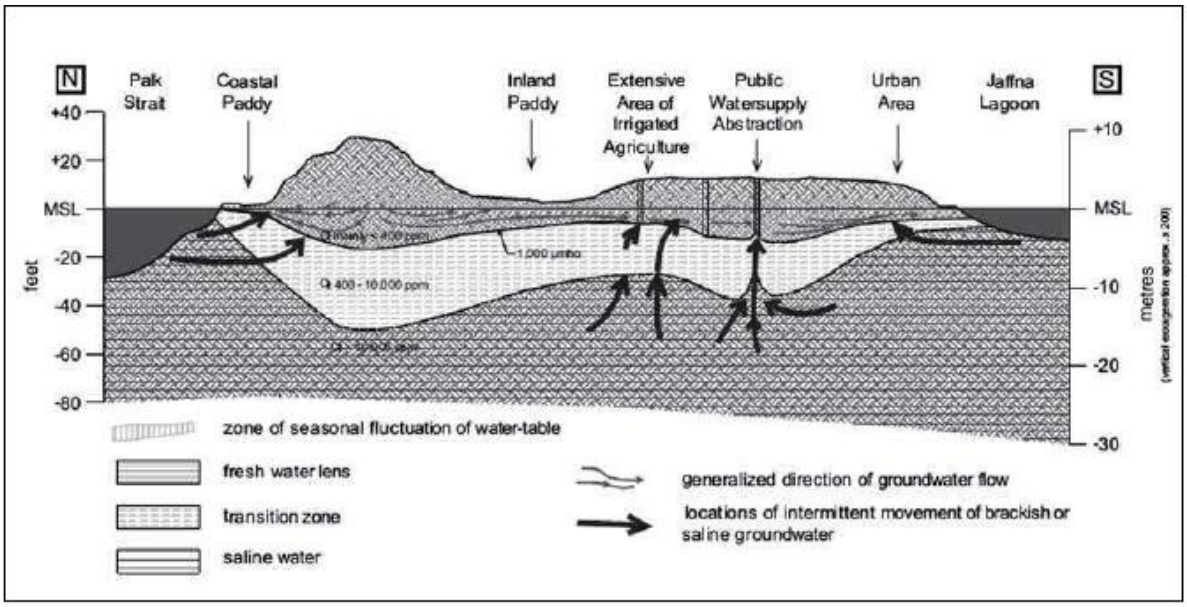


Figure 4-4: Cross section of Water table in Jaffna peninsula (modified from Joshua et al 2012)

4.10 Benefits of Aquifers in Jaffna Peninsula

Considering the extensive presence of shallow and rocky soils throughout the Peninsula, it is only the relatively easy availability of high-quality groundwater from the underlying sedimentary limestone aquifer. It makes successful agricultural functions where the famers have used appropriate methodsand adopted irrigation practices to reclaim rocky and shallow lands that make intensive agriculture as a reliable source of livelihood income4159.

Aquifers in Jaffna district are divided into four sub divisions as Valikamam, Vadamaradchi, Thenmaradchi, and Kaytsfrom where the water is supplied for the whole district 110. These aquifers are being as great source for the people's daily life that fulfills

their needs and demands without any payment through the dug wells and boreholes. As well, the people in Jaffna never face water scarcity as a result of this gifted source of groundwater 70.

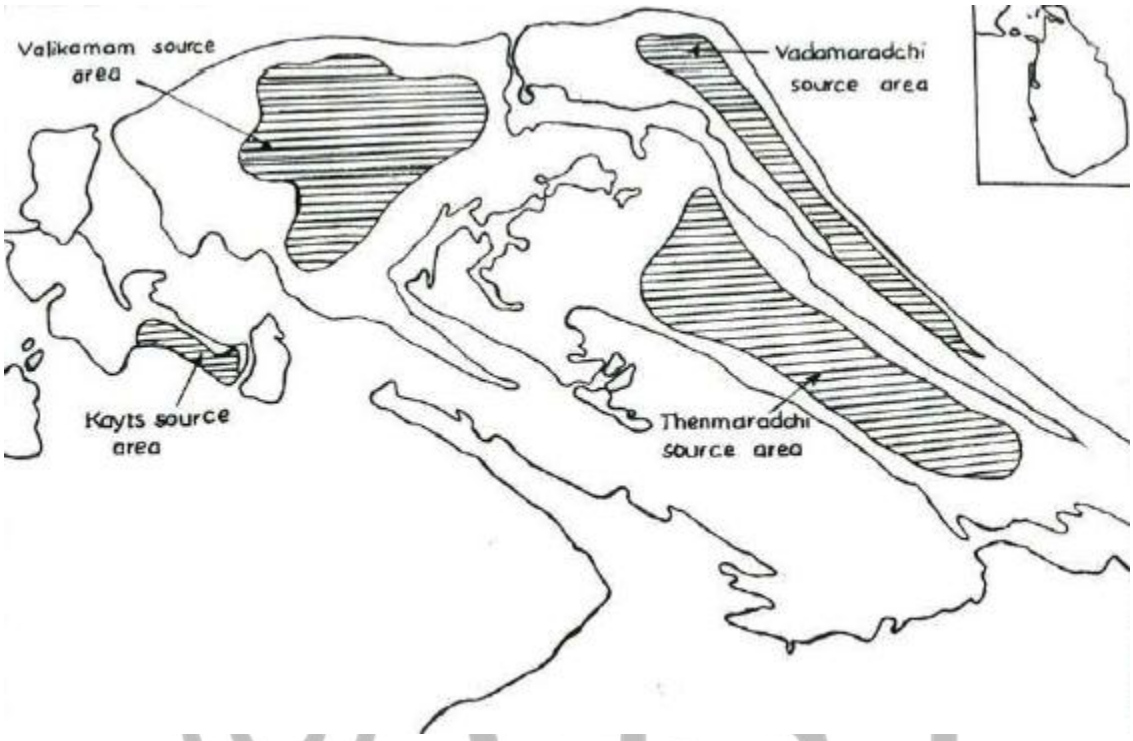


Figure 4-5: The main Aquifers in Jaffna Peninsula (Adapted from Pathmarajah S at el 2012)

In the case of reservoirs built for flood control, a consistent relationship between degree of impoundment and change in flow variables can be expected. However, for reservoirs built for irrigation and hydroelectric generation, we should expect the relation to be noisy because flood reduction is not a purpose and the volume of floodwater stored will be a function of how much water happens to be in the reservoir when the flood begins (Walker, 1985). Floods will tend to be reduced more in dry years and early in the season, when reservoir levels are lower. Moreover, it can be expected that reservoir effects are more pronounced in drier climates because of greater storage needs and greater likelihood that the reservoir will be drawn-down when floods enter.

Andrés Calizaya (2010) pointed out that the Integrated Water Resources Management has been recognized worldwide as the only currently feasible way to ensure a sustainable perspective in planning and managing water resources systems. It is the main reference for all water related activities in third world countries. Sufficient water supply might be considered to be one of the most important factors for improving quality of life in these countries.

5.0 METHODOLOGY

Number of wells from each of the main aquifers in Jaffna Peninsula will be selected for the study. The wells will be identified by Global Positioning System (GPS) for their correct latitude and longitude and will be numbered starting from 1. The elevations of the wells above mean sea level (MSL) will be determined. However, there could be small errors in the elevation values arising from this method of estimation.

5.1 Well water sampling

After well water from different locations in the particular aquifers are collected, the water samples will be under taken to the sampling. Sampling will be done after making sure that the well is sufficient for the water level to recover to the natural water table level. The water samples will betaken at the midpoint between the surface of the water and bottom of the well with a help of buckets. The water will be then transferred to clean glass/plastic containers after rinsing them with the same sampled water. The water will be collected from different locations and from different depth of wells of those aquifers. The past data of the parameters that influence the water quality will be also collected from the Department of Agriculture Meteorological Stationand the study will be analyzed.

5.2 Water analysis

The further water analysis will be carried out with the water samples within 24 hours from the time of sampling. All the parameters such as chloride, pH, EC, nitrate, BOD and other ion presence in the water samples will be determined by the electrode meter.

5.3 Climate Analysis

The climate study will be done with the help of Meteorology department. First, 30 or 50 years of record for each factors; temperature, rainfall and sunshine in the region will be gathered and then will do analysis and prediction with the data of factors.

6.0 DATA COLLECTION AND ANALYSIS

The following data are being collected for this research (for past 10 years) Primarily data needs to be collected in order to get an efficient result for the hypothesis. For this specific topic, two sets of information are required. First set is related to the parameters of groundwater. Therefore, the first set includes BOD, DO, ions present in the water which all have to be collected by sampling of water. Here, the below parameters are mainly checked in the water sample;

- Biological Oxygen Demand
- Dissolved Oxygen
- NO_3^-
- Cl^-
- PH
- Electrical Conductivity

At the same time, the second set of data contains climatic factors that affect the groundwater quality overall. The below list is needed to be collected

- Temperature
- Sunshine
- Rainfall
- Wind flow

These data can be collected with the software or with the help of Meteorological Department. While we collect these data by doing our own research and sampling, the past data and charts would beneficial to compare the trend and to get adequate result and conclusion. Thus, collecting past data from relevant departments and organizations could develop the accuracy of the project.

The collected data will be analyzed and compared with the past data. Then the co-relation will be studied in terms of ground water quality with the climate change. Along with the study, hypothesis will be established then new model will be evaluated periodically. The analyzed charts and figures will be displayed to demonstrate the hypothesis at the same time the data will be taken into the consideration to inaugurate the recommendation or suggestion.

For the analysis, certain software, models and tools can be applied along with the data. Since it's an experiment, the tools and models could give precise and accurate result at the end. Therefore, this analysis could be carried with several tools.

6.0 Results and Discussion

First of all, the assessment study will demonstrate the real scenario of groundwater in Jaffna Peninsula so that the better understanding will be spread enough among the students as well the public. In addition, this study will be fruitful to the researchers to explore more in their further researches on groundwater contamination in the region of Jaffna peninsula, because the findings derived from this particular study would help to analyze the current condition regarding groundwater scenario in those regions.

As less researches carried out in this particular field, it would have been also helpful to get more data to conclude the statement generally. The young generation will be benefited to carry their case studies and researches.

Finally, the study could suggest the government and related organizations to be aware of groundwater contamination that has emerged in the recent years. Not only to be aware of groundwater but also take initiative to face the issue and to step up for mitigation in these areas. Besides, the study would provide the proper management plans on groundwater in the Jaffna Peninsula which would impact positively on both the environment and living beings.

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