

Economic Effects of Saltwater Intrusion for the People at Service Area of Kethhena Intake in Kalu Ganga Lower Basin

D. I. W. Kodithuwakku¹, K. D. N. Kumari², C. P. S. Pathirana^{2*}, and B. C. L. Athapattu³

¹Central Environmental Authority, District Office, Kalutara, Sri Lanka.

²Department of Mathematics and Philosophy of Engineering, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka.

³Department of Civil Engineering, The Open University of Sri Lanka, Nawala, Nugegoda Sri Lanka.

*Corresponding Author: email: cppat@ou.ac.lk, Tele: +94740137783

Abstract – Saltwater intrusion can be described as the movement of saline water into freshwater aquifers, which leads to contamination of drinking water sources and other consequences. In the past decades' saltwater intrusion in the Kalu Ganga has increased considerably due to natural disasters and human activities which has become a significant issue in the Kalutara area. This study mainly focused on identifying the social and economic impact faced by the people residing in the Kalutara area where pipe borne water supply by Kethhena water intake due to saltwater intrusion. Furthermore, the economic impact faced by the National Water Supply and Drainage Board (NWS & DB) and sand ferry owners were also focused.

Preliminary data were collected using a questionnaire which was presented to NW & DB water consumers in Kalutara, Beruwala and Dodangoda Divisional Secretariat Divisions (DSD), where water supply by the Kethhena Water Treatment Plant. A simple random sampling method was used for data collection. To assess the economic impact on sand miners, information was collected from the sand miners and sand ferry owners in Kalutara, Millaniya and Dodangoda DSDs where the sand ferry located below the Kethhena water intake. GIS mapping was done with GPS Coordination of the data collection area. Data analysis was done using SPSS; 22 and MS Excel. Almost all the people in the area have issues while drinking, cooking, bathing, and washing activities due to saltwater intrusion. Hence, society has to bear the cost of obtaining water. Distributions of fresh water via water bowsers during the saltwater intrusion period incur an additional cost on NWS & DB. Restricting sand mining duration becomes an economic loss to sand miners and the government.

It is revealed that the saltwater intrusion of the Kalu Ganga has a social and economic impact on the society, as well as an economic impact on the government. To minimize these issues, it is recommended that rehabilitate the eroded sand bars at the river mouth, the construction of a salinity barrier and moving water pumping points up in the river about a few kilometers, can be presented. In addition, improvement of water cleaning techniques, control of groundwater extraction and minimizing over pumping by industries, and conducting social awareness programs on the importance of minimizing water wastage, the effect of over pumping and lack of availability freshwater and also about the importance of rainwater harvesting can be suggested.

Keywords: Kalu Ganga lower basin, Kethhena intake, Saltwater intrusion, Sand mining, Socio-economic effect

1 INTRODUCTION

Kalutara District is situated in the Western Province and is bounded by Colombo District in the North, Ratnapura District in the East, Galle District in the South and the Ocean in the West. There are three major rivers in the district as the Kalu Ganga, Bolgoda Ganga and Bentara Ganga. The Kalu Ganga is the main source of potable and industrial water to the Colombo south area and coastal belt of Kalutara District from Wadduwa to Aluthgama. There are two water intakes located at Kethhena and Kandana, operated under National Water Supply and Drainage Board (NWS & DB). The service area of the Kethhena scheme includes the western coastal belt stretching over a distance of about 43 km along the Galle Road in the distribution zones Kalutara, Wadduwa, Payagala, Maggona, Beruwala, Darga Town and Aluthgama and hilly areas situated in Mathugama. The other intake and treatment plant is located upstream to the Kethhena intake in Kandana, Horana close to Naragala Bridge which is sufficiently elevated to prevent Saltwater intrusion (SWI).

The Kethhena water intake is located at Kalu Ganga around 17.4 km up stream of the river's outfall. At the present the water extracted from Kethhena water intake fulfill the water need of over 250,000 people using 73,000 water connections and proposals have been made to expand to serve 540,000 people under 130,000 water connections in 2025 in Kalutara District. SWI to Kethhena water intake has become a major problem for NWS & DB. During the dry weather conditions in several months, intake is badly affected by SWI which creates severe operational problem to water supply schemes. SWI can be described as the movement of saline water into freshwater aquifers, which leads to the contamination of drinking water sources and other consequences. The higher pressure and density of saltwater causes it to move into coastal aquifers in a wedge shape, which protrudes a long way up the estuary below the layer of fresh water. In the absence of any tidal fluctuations this wedge would remain stationary, and it has been shown that the main parameters that determine the length and thickness of the saline wedge are the density difference, the rate of fresh water outflow and the depth of flow in the river. In the presence of a tide, however small, the wedge would no longer be stationary. Instead it would be pushed up and down the estuary by the ebb and flood flow (Nanseer, 2016).

Certain human activities, especially sand mining have increased SWI in many coastal areas and these conditions intensified due to drought. Water extraction points the level of fresh groundwater, reducing its water pressure and allowing saltwater to flow further inland. At the coastal margin, fresh groundwater flowing from inland areas meets with saline groundwater from the ocean. The fresh groundwater flows from inland areas towards the coast where elevation and groundwater levels are lower. Saltwater has a higher content of dissolved salts and minerals. It is denser than fresh water, causing higher hydraulic head than freshwater. Hydraulic head refers to the liquid pressure exerted by a water column and a water column with a higher hydraulic head will move into a water column with a lower hydraulic head, if the columns are connected. Other contributors to SWI include navigation channels or agricultural and drainage channels which provide conduits for saltwater to move inland and sea level rise. SWI can also be worsened by extreme events like hurricane storm surges. SWI has become an ever increasing problem throughout the world. In the Sri Lankan context, mainly western coastal communities are facing several problems due to salinity intrusion such as contamination of water supply and this problem has been recorded during the last few decades. Kelani Ganga; due to salt water intrusion the Ambatale water intakes has been threatened several times by the past (Nanseer, 2016). Benthara Ganga also have been threatened several times in saltwater intrusion. As well as Gin Ganga and Walawe Ganga also has saltwater intrusion in the Southern Province (Ranjan, 2007).

In the past decades SWI in the Kalu Ganga has increased considerably due to natural disasters and human activities which has become a significant issue in the Kalutara area. SWI will affect the lives in the Kalutara area which will result the economical disaster for the people in the Kalutara area. This study mainly focused on to identify economic impact faced by the people residing in the Kalutara area where pipe borne water supply by Kethhena water intake due to saltwater intrusion.

1. METHODOLOGY

2.1. Location

This study was aimed to collect information from the DSDs which NWS & DB distributed water from the Kethhena water intake. There are several overhead water tanks in Kalutara, Beruwala, Aluthgama, Payagala, Wadduwa and Bombuwala areas for *supplying* domestic and industrial uses. These tanks are situated in Kalutara, Beruwala and Dodangoda DSDs and are fed by the Kethhena water treatment plant. The Survey was conducted in those DSDs.

2.2 Sampling Method

A simple random sampling method was used for data collection where DSDs received water from the Kethhena water intake. The sample size was two hundred & fifty-one (251) from the total population at Kalutara, Beruwala and Dodangoda DS divisions. The data collected sample percentage is proportionally equal to *the percentage* of public water supply by NWS & DB through DSDs.

2.3 Data Collection

Preliminary data were collected using a questionnaire which was presented to NWS & DB water consumers in Kalutara, Beruwala and Dodangoda DSDs, where water supply by the Kethhena Water Treatment Plant.

The data were collected through a questionnaire in five main areas: demographic detail, water consumption, saltwater intrusion, salinity problems and economic impact. This was used to demographic data, the water requirement of household level and industry level, a problem arises for the consumer at the period of SWI, consumer's satisfaction of the quality of water obtained from the pipeline during the SWI, issues related to sources of obtaining water for drinking and other activities, and also to identify the economic effect of the SWI. This questionnaire was also used to identify whether the existence of technology for purifying salt water, which supplies through the pipeline during the SWI, at the household level or industrial level.

2.4 Data Analysis

Data analysis was done using SPSS 22 and MS Excel. Presentation of the data includes a pictorial representation of the data by using graphs and charts, which help in adding the visual aspect to data which makes it much more comfortable and easier to understand. The Pearson Chi Square test is used to see the relationship among the variables.

2. RESULTS AND DISCUSSION

3.1 Primary Data Analysis

Primary data has been obtained from 30 GNDs lives within three DSDs of Kaluthara District, where the majority of the respondent (51%) are resident in Kalutara DSD. Beruwala DSD represents 44% and 5% of the sample represents Dodangoda DSD as shown in Fig. 1.

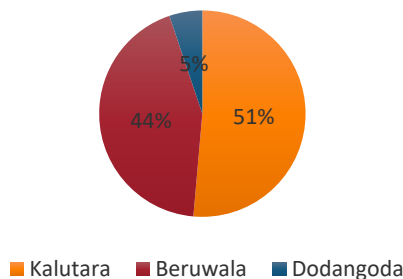


Fig.1: Data Collected Divisional Secretariat Divisions

This sample population and the number of water connections provided by NWS & DB in 2019 are proportionally related within the DSDs. The sample can be divided into two sectors as industrial and domestic households sectors. 90.4% of the respondents are fallen into the households sector. Kalutara and Beruwala DSDs are very popular in the tourism industry because of the coastal area. Hence the sample has included ten hotels and twenty of other different industrial activities and the industrial sector includes 9.6% of the respondents.

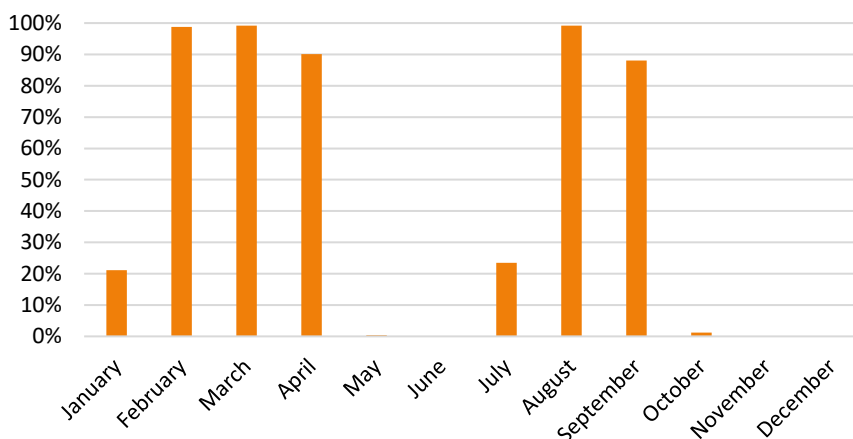


Fig.2: Data Collected Divisional Secretariat Divisions

The majority of the respondents have to face saltwater problem mainly in the months of February, March, April, August and September of the year 2021. Generally, the water flow of the Kalu Ganga is getting low in the months of January, February, March, April, July, August, November and December of the year also. In most of these months, Kalutara district experienced less precipitation during the dry season.

According to the primary data collected from the sample, generally resident and engaging in industrial activities in the area of Kethhena water supplying area use either pipe born water, bottled drinking water, well water and tube well water simultaneously for their drinking purposes as shown in Fig. 3.

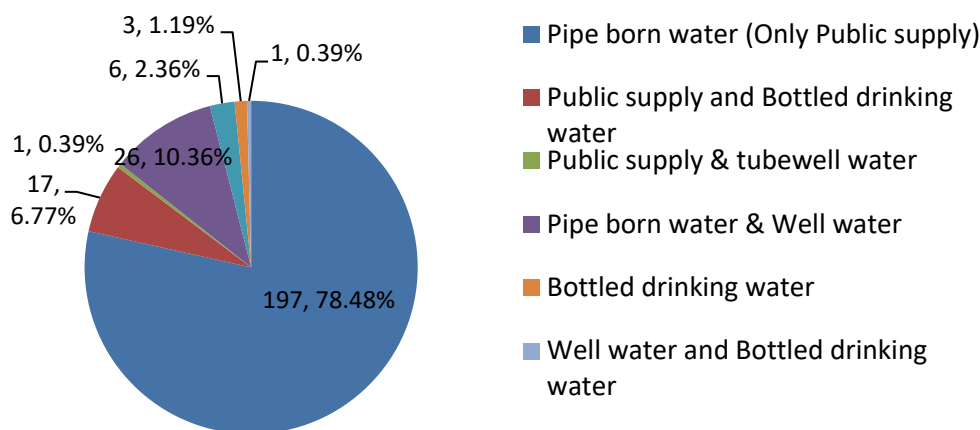


Fig. 3: Ways of Obtaining Drinking Water in Kalutara, Dodangoda and Beruwala DSDs

Therefore, it is revealed that 97% of the population have to face the SWI problem.

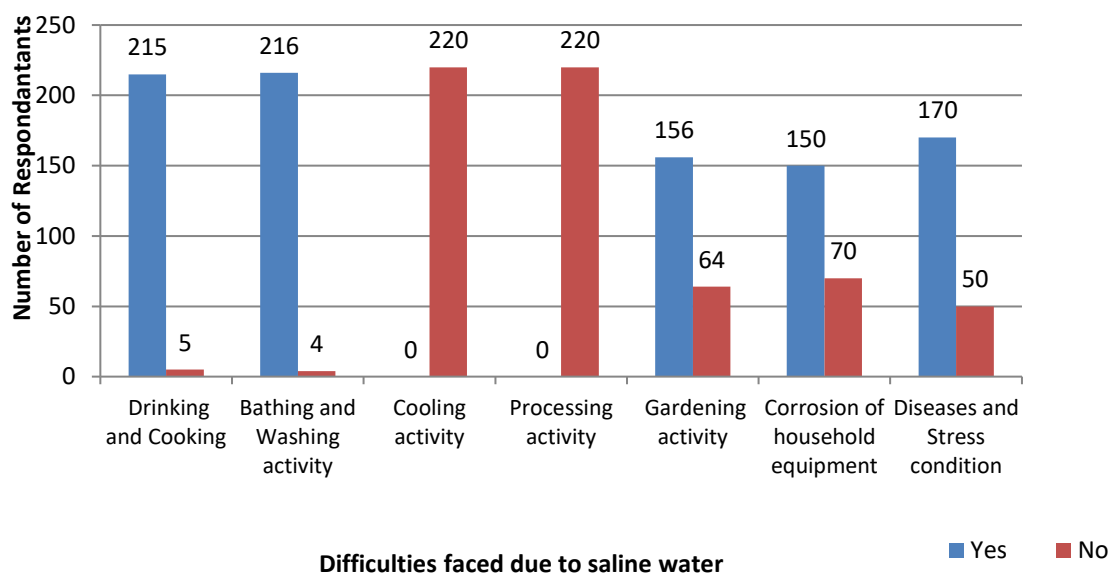


Fig. 4: Major difficulties faced by the domestic level due to saline water

When considering the water usage purposes of the sample population, most of the people use water for household chores such as cooking, bathing, washing and gardening activities other than drinking purposes. However, due to SWI, they have suffered with difficulties such as corrosion of household equipment, diseases and stress condition when they are involved in those activities as shown in Fig. 4. In addition to the above when considering the industrial sector they have to face difficulties in cooling activities and processing activities due to SWI problem.

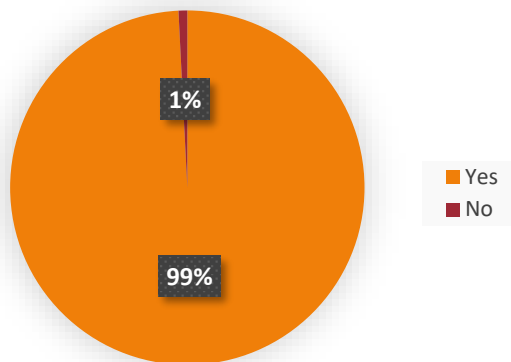


Fig. 5: Face the saltwater intrusion

On the other hand, 99% of respondents in the area have issues while drinking, cooking, bathing, and washing activities due to SWI. Hence, society has to bear the cost for obtaining water due to dissatisfaction of water quality with the taste, odor, color and solubility of soap in the water at the time of SWI. The vast majority of the population used bottled drinking water or the water supplied by NWS & DB, through tanks placed in the vicinity to meet drinking water requirements at the time of SWI. In percentage term it is 35% and 39% respectively as shown in Fig. 6. Others obtain their drinking water through wells, which are sourced from wells in the surrounding area or far away at the time of SWI.

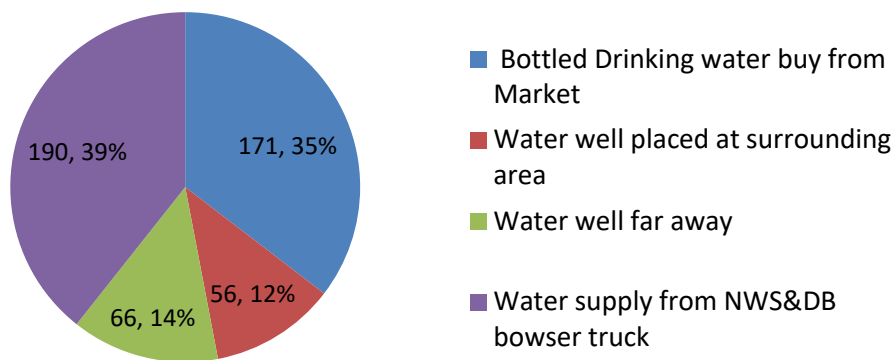


Fig. 6: The way of obtaining drinking water, during saline water supply in Household Level

According to data obtained, fifty percent (50%) of household level respondents use saline water provided by the public supply for activities other than drinking during SWI. Other fifty percent (50%) use water sources placed in the surrounding area or far away collectively at the time of SWI shown as Fig.7.

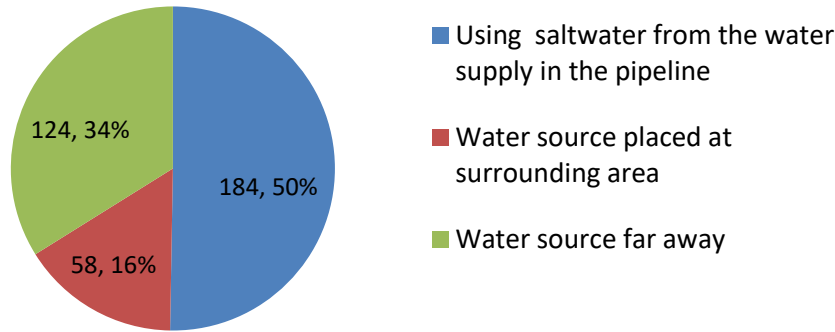


Fig. 7: The way of obtaining water for bathing and washing, during saline water supply in Household Level

At the industrial level, they also have to face the same problems. Instead of household activities, industries have to face problems when carrying out their cooling and processing activities. The majority of the industry (50%) fulfilled their drinking water requirement during the period of SWI by purchasing bottled water from the market. Others use other means to obtain drinking water during the period of SWI. About two percent of the sample indicated that their water requirement was fulfilled by buying an extra water bowser.

When considering about health issues arised during the SWI period, the majority of the people stated that, they did not face any physical health issues. But about 8.76% of the participants responded that they had to face physical illness such as skin rashes, waxy hair etc. as shown in Fig. 8. Although SWI does not affect people's physical health enough to seek medical attention as shown in Fig. 9.

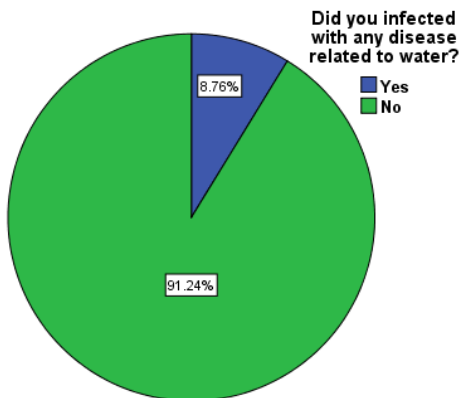


Fig. 8: Health effects due to saline water usage by people

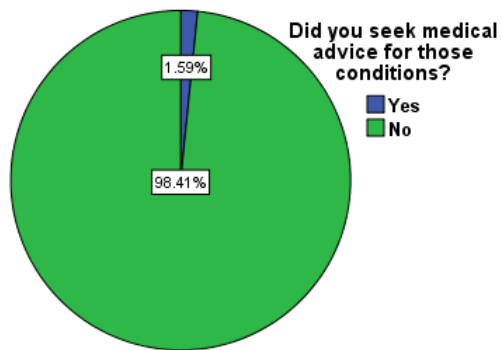


Fig. 9: Seeking medical advice for the health problem

When considering stress development due to SWI, almost all the categories in the population have to face stress conditions as shown in Fig. 10. According to the data collected, the majority of the population is depressed due to SWI, but only 0.4% of them receive medical treatment for stress as shown in Fig. 11.

Considering society, one can conclude that housewives who engage in everyday household chores suffer from salt water problems. Because they are the persons who have to use salt water in activities such as cooking/ food processing, washing clothes ect., However, all individuals in the sample population face stress as they attempt to overcome this SWI problem. Therefore, it shows that SWI causes people to become depressed and have health problems.

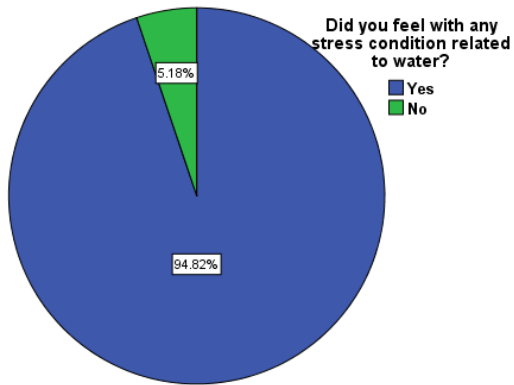


Fig. 10: Experiencing stressful condition

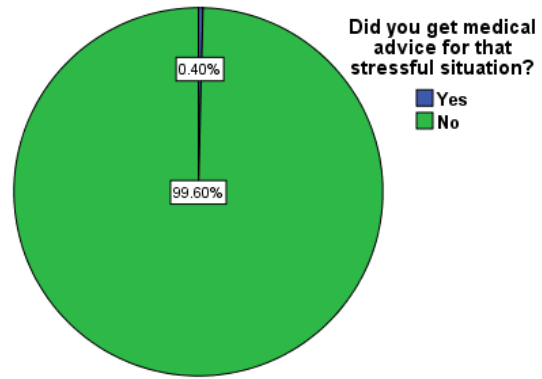


Fig. 11 : Seeking medical advice for stress

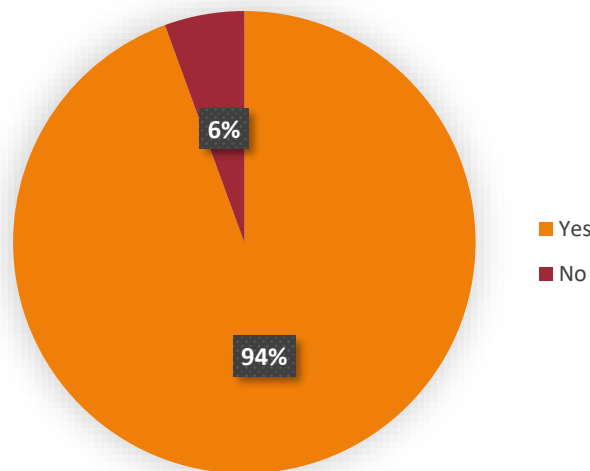


Fig. 12 : SWI cause to increase in monthly expenditure

The majority of the respondents in the household sector (94%) have to increase monthly expenditure due to SWI. From that 82 respondents have to increase their monthly expenditure by the range of Rs.5,000.00-10,000.00 as shown in Fig. 13.

According to the analyzed sample, all the industries (100%) have to face increase in monthly expenditure. The majority of them have to expend additional more than Rs.25,000.00 monthly due to SWI problem as shown in Fig. 14.

The sample has indicated in various reasons for incurring extra expenditure due to SWI such as buying bottled drinking water from the market, using vehicles to collect water, and repairing corrosion equipment which has shown in Fig. 15. Further it indicates that buying extra water bowser and pumping water from another water source will not affect the incurring of extra expenditure due to SWI.

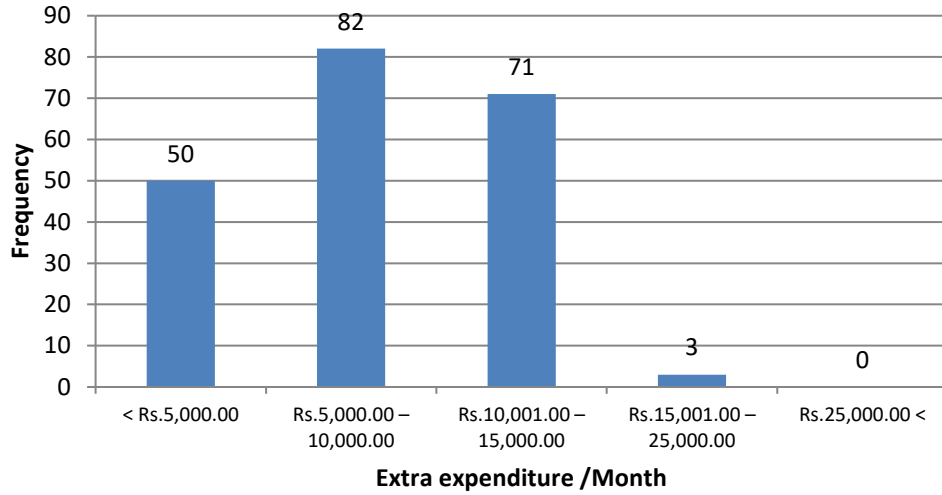


Fig. 13: Extra expenditure incurred per month due to SWI - Domestic Level

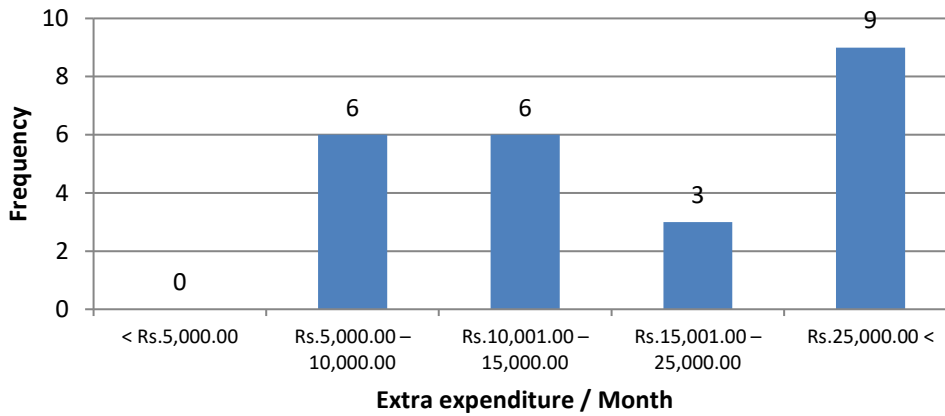


Fig. 14: Extra expenditure incurred per month due to SWI - Industrial Level

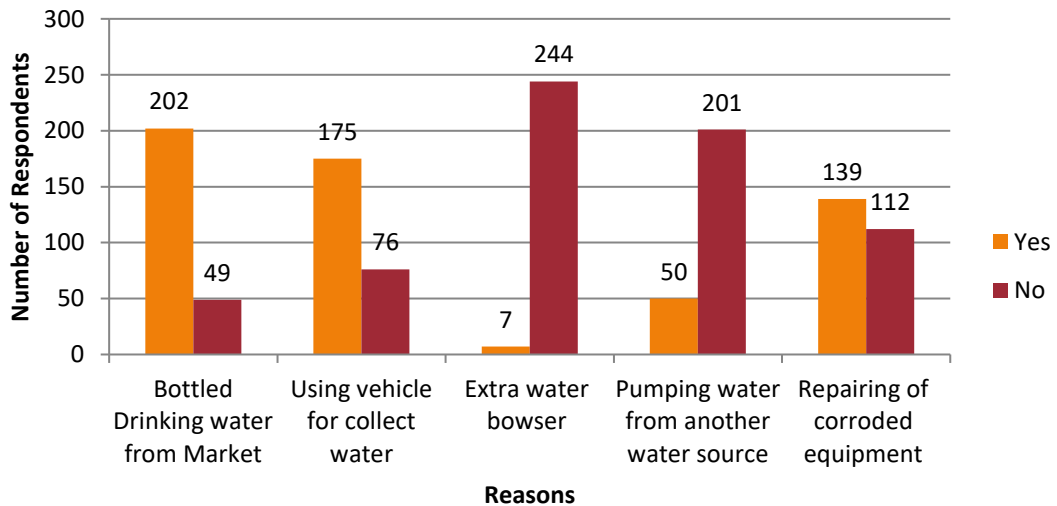


Fig. 15: Reasons for incurring extra expenditure due to saltwater intrusion

3.2 Factors affecting to increase in monthly expenditure due to SWI

In the preliminary analysis, it had observed that several social and economic aspects that the people in the service area of Kethhena intake in Kalu Ganga lower basin face due to SWI. However, it is essentials to see the factors affecting to increase in monthly expenditure due to SWI. Although, Fig. 15 explore the basic reasons for incurring extra expenditure due to SWI, there may be other factors that will increase the monthly expenditure due to SWI.

Pearson Chi-Square Tests

		Cause to increase in monthly expenditure
Member of Family	Chi-square	12.592
	df	4
	Sig.	.013*
Monthly Income Range	Chi-square	42.865
	df	4
	Sig.	.000*

*. The Chi-square statistic is significant at the .05 level.

According to the Pearson Chi- Square tests, the number of members in a family will affect the decision of whether there is an increase in monthly expenditure. Further, the monthly income range also affects the decision on increasement of the monthly expenditure.

Pearson Chi-Square Tests

		Cause to increase in monthly expenditure
the dissatisfied water qualities	Chi-square	66.557
	df	4
	Sig.	.000*

*. The Chi-square statistic is significant at the .05 level.

At the 5% significant level by using the Pearson Chi- square test, it can be observed that the qualities of the water such as Taste, Hardness / Dissolving of soap, Odor or colour that the people were dissatisfies with, at the time of salt water intrusion, will affect the decision whether there is an increase in monthly expenditure due to the SWI.

Pearson Chi-Square Tests

		Cause to increase in monthly expenditure
the difficulties of Drinking and Cooking	Chi-square df Sig.	11.478 1 .001*
the difficulties of Bathing and Washing activity	Chi-square df Sig.	11.478 1 .001*
the difficulties of Cooling activity	Chi-square df Sig.	.240 1 .624
the difficulties of Gardening activity	Chi-square df Sig.	2.627 1 .105b
the difficulties of Processing activity	Chi-square df Sig.	.876 1 .349
the difficulties of Gardening activity	Chi-square df Sig.	2.627 1 .105
the difficulties of Corrosion of household equipment	Chi-square df Sig.	22.601 1 .000*
the difficulties of Diseases and Stress condition	Chi-square df Sig.	43.323 1 .000*

*. The Chi-square statistic is significant at the .05 level.

Under the major difficulties faced due to saline water, the difficulties of drinking and cooking, the difficulties of bathing and washing activities, the difficulties of corrosion of household equipment and the difficulties of diseases and stress conditions only will affect the decision of whether the monthly expenditure will increase due to SWI.

In preliminary data analysis it is observed that the reasons for incurring extra expenditure due to SWI are buying bottled drinking water from the market, using vehicles to collect water and repairing of corrosion equipment. With a 5% significant level the Pearson Chi Square test will confirm that the monthly expenditure will increase for buying bottled drinking water from the market, using vehicles to collect water and repairing corrosion equipment.

Pearson Chi-Square Tests

		Cause to increase in monthly expenditure
Extra expenditure for -To buy Bottled Drinking water from Market	Chi-square df Sig.	61.124 1 .000*
Extra expenditure for - Using vehicles to collect water	Chi-square df Sig.	34.141 1 .000*
Extra expenditure for - To buy extra water bowser	Chi-square df Sig.	.425 1 .514
Extra expenditure for - To pump water from another water source	Chi-square df Sig.	3.688 1 .055
Extra expenditure for - To repair of corrosion equipment	Chi-square df Sig.	18.401 1 .000*

*. The Chi-square statistic is significant at the .05 level

Pearson Chi-Square Tests

		Cause to increase in monthly expenditure
Buying Bottled Drinking Water from the market,(liters per week)	Chi-square df Sig.	64.356 5 .000*
Buy extra water bowser for drinking purposes	Chi-square df Sig.	.425 1 .514
Frequency of filling the nearest water tank per week	Chi-square df Sig.	15.149 3 .002*,b,c
The distance to the nearest NWS&DB water tank	Chi-square df Sig.	18.840 4 .001*

*. The Chi-square statistic is significant at the .05 level.

At 05% significant level, it can be said that the buying bottled drinking water from the market, frequency of filling the nearest water tank per week and distance to the nearest NWS&DB water tank will affect the decision on whether there is an increase in monthly expenditure due to SWI or not.

3. CONCLUSION

This study mainly focused to identify economic effects, faced by the people residing in the Kalutara area where the pipe borne water supply by Kethhena water intake due to SWI. People who are living in the area, where the water supply facilitate by the Kethhena water treatment plant have to face the problem of fulfilling their water requirements during the dry season. They also have to face physical and mental health issues due to SWI. Every level of society has to incur an extra expenditure due to SWI.

With the preliminary analysis, it was identified several social impacts on the people residing in the Kalutara area where the pipe borne water supply by Kethhena water intake due to SWI which will course in an extra expenditure for the people. With this study it can be concluded that the number of family members and the average monthly income level will affect the decision that whether there is an increase in monthly excentre due to SWI or not. Further, it was found that the quality aspects of the water will affect the decision of whether there is an increasement in monthly expenditure due to SWI or not. Most of the people in the Kalutara area where the pipe borne water supply by Kethhena water intake, worry about the difficulties of drinking and cooking, the difficulties of bathing and washing activities, the difficulties of corrosion of household equipment and the difficulties of diseases and stress condition due to SWI. Further, it can be confirmed that the monthly expenditure will increase for buying bottled drinking water from the market, using vehicles to collect water and repairing of corrosion equipment.

Finally, it can conclude that the results of the study clearly indicate that the saltwater intrusion of the Kalu Ganga has an economic impact on society.

4. RECOMMENDATIONS

The following recommendations can be implemented to mitigate the social and economic problems arising from the results of this study due to saltwater entering the Kalu Ganga.

After 2017 due to the erosion of the sand reefs, sea out fall has got widened and river directly linked to the sea. Although Kethhena water intake situated about 17.5 km upstream of the Kalu Ganga from the sea outfall, due to the above reasons impact of the SWI has a significant on the Kethhena water intake. Because of that, it can be recommended to move the water pumping points up in the river. It also can be suggested that to rehabilitate eroded sand reefs, to minimize SWI.

Instead of rehabilitateing eroded sand bars at the river mouth, it can be also suggested to build up a brand new sand barrier at the mouth of the river to stop the tidal effect.

The problem can be solved by constructing a salinity barrier in the same manner as a salinity barrier was constructed to minimize the SWI impact of the Kelani River.

It also can be suggested to further minimize or halt the sand mining activity for the period of time, until the coastal sand line and river bed naturally generate to their optimal level.

Most of the catchment area of the Kalu Ganga was covered by cultivations like tea, and rubber but in the recent past rubber cultivation began to replace by introducing palm oil cultivation. It has been revealed that palm oil plants cause to increase depletion of groundwater levels. Hence it can recommend taking actions to discourage palm plantations.

Rainwater can be used to recharge the depleted ground water level. It can be done by constructing water bodies such as ponds and pumping rainwater in to the deep of the ground. Hence it is important to make aware of rainwater harvesting, among the people, especially people that are engaging in industries. And encourage them to harvest the rainwater and construct ponds, to recharge the ground water level.

As per the findings, most industries obtain water for their processing activity by pumping groundwater from wells or tube wells. So it is better to make them aware of the consequences that can arise due to the over pumping of groundwater and the importance of reducing water wastage.

Unauthorized low land, the filling can be also identified as a reason for the depletion of the ground water level which cause to increases in SWI. Because lowlands, wet or marshy land help to recharge the ground water level. So it can be recommended to strengthen the rules and regulations related to unauthorized land fill to discourage low land/wet land filling.

Implementing further research can be also recommended, in the areas such as the Biological effect on the flora and fauna species and fresh water bodies due to SWI in Kalu Ganga, the effect on soil fertility of agricultural area related to Kalu Ganga due to SWI etc.,

An Environmental Impact Assessment (EIA) is required when implementing recommendations such as the construction of salinity barriers, the buildup of sand barriers etc,. It is helpful to identify the environmental condition and implement the best suitable alternative. Awareness programs, relevant research articles, rules and regulations subject to the scope of the relevant government agencies are helping to implement other recommendations.

REFERENCES

- Central Environmental Authority (1988). An Environmental Profile of the Kalutara District.
- Central Environmental Authority (2014). An Environmental Profile of the Kalutara District.
- Central Environmental Authority (2016). Preliminary Perception survey on water safety Kelani River Basin. UNICEF.
- Central Environmental Authority (2018). Guideline for Determination of Environmental Flows (E-flows) for Development Projects that Result in Impounding of Water in Streams/Rivers.
- Central Environmental Authority (2018). A Study to Identify Environmental and Social Issues of Oil Palm Cultivation in Sri Lanka; Observations and Recommendations; <http://www.cea.lk/web/images/news/2018/katupol/Oil_Palm_Report_28.05.2018_03-ilovepdf-compressed.pdf>.
- Davison, A., Howard, G., Stevens, M., Callan, P., Fewtrell, L., Deere, D. and Bartram, J. (2005). Water Safety Plan, World Health Organization, Geneva.
- Department of Census & Statistics (2018). District Statistical Handbook – Kalutara District.
- Lanka Hydraulic Institute Ltd. (2017). Environmental Impact Assessment Report (EIAR), Construction of salinity barrier at Kalu Ganga.
- Nanseer, N. K. M. and Rajkumar, S. G. G. (2016). Kelani Ganga Conservation Barrage and result of Model studies. DOI: <http://doi.org/10.4038/engineer.v39i2.7185>., pp. 42–49.
- National Water Supply & Drainage Board (2015). The Preparatory Survey on Water Sector

- Development Project I(ii) in The Democratic Socialist Republic Of Sri Lanka Final Report.
National Water Supply & Drainage Board (2017). Annual Report, Ratmalana, Sri Lanka.
- Panabokke, C. R. and Perera, A. P. G. R. L. (2005). Groundwater Resources of Sri Lanka, Water Resources Board. pp. 3-26.
- Ranjan, S. P. (2007). Effect of Climate Change and Land Use Change on Saltwater Intrusion. *Journal of Environmental Management* 80(1), pp. 25-35.
- Ranjan, S. P. (2007). Numerical Modeling of Salinity Intrusion: Case Study from Southern Coastal Aquifer in Sri Lanka.
- Ratnayakage, S. M. S., Sasaki, J., Suzuki, T. et al. (2020). On the status and mechanisms of coastal erosion in Marawila Beach, Sri Lanka. *Natural Hazards* 103, pp. 1261-1289.
- Samarasinghea, S. M. J. S., Nandalalb, H. K., Weliwitiyac, D. P., Fowzed, J. S. M., Hazarikad, M. K. and Samarakoon, L. (2010). Application of remote sensing and GIS for flood risk analysis: a case study at Kalu- Ganga river, Sri Lanka. *Research journal of Applied Sciences, Engineering and Technology* 6(10), pp. 1884-1894.
- UNEP (2003). Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management, pp: 46-93.
- Wijesundara, K. and Piyadasa, R. U. K. (2013). Saline Water Intrusion along the River Benthera and its Impact on Irrigation Water. pp. 35-45.*