



# *Applied Bio-Systems Technology*

Faculty of Agriculture & Plantation Management

Wayamba University of Sri Lanka

**Vol. 2, No. 2, 2022**



**Vol. 2, No. 2, 2022**

**Editorial Board**

*Dr. K.H. Sarananda: Editor-in-Chief*

*Dr. N.W.B.A.L. Udayanga: Administrative Editor*

*Prof. Udith Jayasinghe K. Mudalige*

*Prof. J.C. Edirisinghe*

*Prof. D.P.S.T.G. Attanayaka*

*Prof. M.M.M. Najim*

*Prof. K. Yakandawala*

*Prof. D.C. Abeyasinghe*

*Prof. K.K.D.S. Ranaweera*

*Prof. S.B. Navarathna*

*Prof. Geng (Frank) Bai*

*Prof. H.M.L.K. Herath*

*Dr. R.H.M.K. Ratnayake*

*Dr. J.A.A.C. Wijesinghe*

*Eng. A.H.N. Chamara*

**Editorial Office:**

*Editor-in-Chief,*

*Applied Bio-Systems Technology,*

*Faculty of Agriculture & Plantation Management,*

*Wayamba University of Sri Lanka,*

*Makandura, Gonawila, 60170,*

*Sri Lanka.*

*Tel : +94-31 229 7075*

*E-mail : abse@wyb.ac.lk*

*Fax : +94-31 229 9248*

**Editorial Assistant:** *Ms. L.H. Nadeera De Silva*

**E - ISSN:** 2806-5220

**Publication:** *Published semi-annually by the Wayamba University of Sri Lanka*

**Copyright:** © *Wayamba University of Sri Lanka*



# *Applied Bio-Systems Technology*

---

*Vol. 2, No. 2*

*2022*

---

## CONTENTS

- Perceptions on Wellbeing among Small Pelagic Dried Fish Processors in South and West Coasts of Sri Lanka: A Qualitative Analysis** 1-12  
*Sujani A. Adikary and Dilanthi N. Korlagama*
- Labour-related Causes Controlling the Construction Efficiency in Sri Lankan Building Projects: The Viewpoint of Site Supervisors** 13-24  
*Kesavan Manoharan, Pujitha Dissanayake, Chintha Pathirana, Dharsana Deegahawature and Renuka Silva*
- Impact of Processed/Refined Foods on Oral Health: A Mini-Review** 25-29  
*Priyake D Palipana*
- Evaluation of Nutrient Leaching Losses in Red Onion Grown on Sandy Regosols in Kalpitiya under Intensive Farming Systems** 30-36  
*Gayathri Swarnathilake, Indika Herath, Radhika Gimhani and Lahiru Udayanga*



## Perceptions on Wellbeing among Small Pelagic Dried Fish Processors in South and West Coasts of Sri Lanka: A Qualitative Analysis

Sujani A. Adikary\* and Dilanthi N. Korlagama

### Abstract

**Background:** Wellbeing, the renowned term is now being used worldwide to assess the living standard of people, which goes beyond the development measurement indices, including the human development index. The notion of wellbeing described over three dimensions; material, relational, and subjective is a widely used concept in assessing wellbeing in development studies. This study aims to explore on three dimensions of wellbeing parameters valued by small pelagic dried fish processors in Negombo, Kalpitiya and Matara, which remain as the main small-pelagic dried fish producing areas in the South and West coast of Sri Lanka.

**Methods:** Qualitative data collection methods including in-depth interviews (n = 20) key informant discussions (n = 06) and participant observations were employed to gather primary data. Snowball sampling was used to select small pelagic dried fish processors from Negombo, Kalpitiya, and Matara Districts. Contextual data analysis was applied for interpretation, while field observations and transcripts were coded and analysed using Atlas.ti software.


**Results:** Income level and profit, education and skills, possessions, resource availability, food availability and healthy lifestyle were recognized as the key determinants of material wellbeing valued by the respondents. Life satisfaction with happiness, aspirations, mental serenity, leisure time and entertainment, time spent in places of worship were identified as the key determinants under the subjective dimension. Family, relatives and community, customer interactions, relationships with traders, co-worker and other processors were found to be the key drivers of relational wellbeing in male and female dried fish processors.

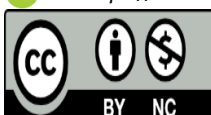
**Conclusions:** The dried fish processors were able to acquire all three dimensions of well-being aspects, either differently or similarly. However, the achievement of these aspects was at different levels depending on their gender and religion. Despite, the material aspects are towards their occupation and accessibility, the relational aspects are mostly focused on family and the community.

**Keywords:** Dried Fish, Material, Relational, Small Pelagic, Qualitative Analysis

Department of Agricultural Economics, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka.

\* Correspondence: [anuupamaadhikari@gmail.com](mailto:anuupamaadhikari@gmail.com)

 <https://orcid.org/0000-0003-1490-1507>



© The Author(s). This article is published under the Creative Commons Attribution License (CC 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

“Wellbeing” is a broad term that encompasses a variety of outcomes, including material goals of food supplies, economic output, employment and non-material concerns such as secured life, decent and non-discriminatory work conditions [1]. McGregor [2] has defined wellbeing as,

*“A state of being with others that occurs when human needs are met, where people and organizations may act meaningfully to accomplish their goals, and where they are content with their way of life”.*

Thus, wellbeing has been related to professional, personal, and interpersonal success, with people who are well-adjusted demonstrating higher workplace productivity, more effective learning, enhanced creativity, more prosocial actions, and positive interpersonal relationships [3]. Wellbeing is a critical aspect of the present development agenda to meet individual and community ambitions and requirements for a better and more content existence [4]. Despite number of definitions, this research follows three dimensions of wellbeing, material, subjective and relational to explore the wellbeing factors for small-pelagic dried fish producers in Sri Lanka. Three dimensions, material, relational, and subjective wellbeing have been first introduced by Alister McGregor in 2007 [5]. Material wellbeing refers to the “welfare and standard of living” [6] for example requirements, resources, quality of life, financial reward, environment and governance [7-9]. The pursuit of human wellbeing in relation to others is referred as relational wellbeing [10] for example social network, love, care and peace. Subjective wellbeing refers to how individuals evaluate their life on an emotional and cognitive level [10]. Happiness, satisfaction, goals, and beliefs are determinants of subjective wellbeing.

Dried fish or ‘karawala’ in Sinhalese and ‘karavadu’ in Tamil is known as the poor man's protein, because it is the primary

source of animal protein of low-income quintiles [11].

The dried fish industry is mostly a cottage industry; especially women produce dried fish as a secondary source of income using conventional home-scale techniques [12-13]. The dried fish industry is one of the value adding industries that provides benefits to both men and women, particularly in coastal areas [14]. Dried fish industry enlarges opportunities in coastal communities, such as potentially increasing household income for both men and women [15-16], improving the living conditions of fishermen [17-18], increasing employment opportunities [19] and ensuring food security [20]. Globally, women play important roles in the pre and post-harvest sectors due to men's dominance in fishing operations [21].

Increased resilience, improved employee engagement, and higher performance and productivity can result from investments made in the well-being of persons working in the sector. There are no significantly documented studies, which analyse the wellbeing of small pelagic dried fish processors in Sri Lanka. Therefore, to determine the existing industrial background of small pelagic processors, wellbeing studies are crucial. In this background, this study focuses on material, subjective and relational wellbeing among small pelagic dried fish processors zooming into gendered preferences.

## METHODOLOGY

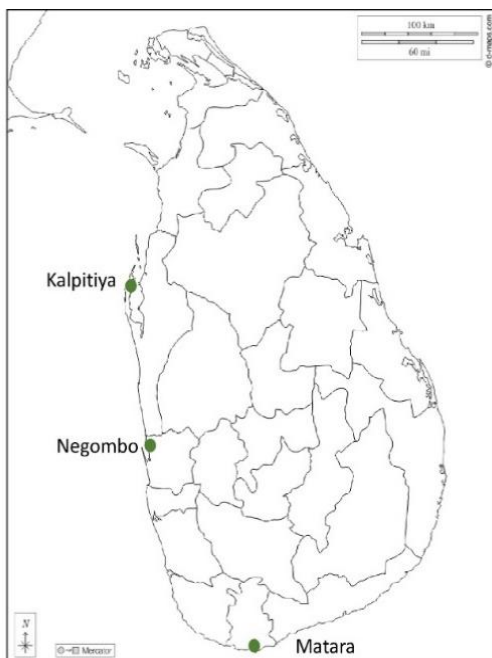
### Study Location

This study was conducted in Negombo, which is a fishing town and one of the country's major commercial hubs. Negombo provides an insight into coastal Sri Lankan life and is the finest spot to witness the centuries-old fishing industry. Negombo has a fishing population of 42, 280 people. A total of 51, 800 and 51,470 population [22] lives in Puttalam and Matara, respectively with fishing being the principal source of income for the majority of coastal, local households. Some of the techniques, used for



fishing, drying, and storing, have remained unchanged to this day.

The fishing sector is crucial to the economy, and Sri Lanka's second largest fish market is placed in Negombo accompanied by a dried fish processing yard. Roman Catholics make up the majority of the local population, particularly in fishing communities. In the Puttalam region of Sri Lanka's Northeast, along a stretch of lagoon, is the natural harbor known as the Kalpitiya Fishery Harbor. The city of Kalpitiya is composed of multi-ethnicities. Muslim is the primary ethnicity of Kalpitiya, followed by Christian. Sinhalese and Tamils are among the other ethnicities reside in Kalpitiya. One of Sri Lanka's hidden treasures is Kalpitiya Beach, which is surrounded by a closely-knitted fishing community and is largely untouched by the tourism industry. Kalpitiya dried fish is different from those of others and uniquely branded since, they use first quality fresh fish for processing, while favourable climate conditions (wind and sunlight) lead to the nourishment of lagoon fish.



**Figure 1:** Study Locations

Matara is located in the Southern part, in Sri Lanka. The second-largest city in

the Southern Province. One of the districts that produce a significant amount of fish in the country. The main ethnic group in Matara is Sinhalese, but in the 16<sup>th</sup> and 17<sup>th</sup> centuries, Arab traders brought the Moors with them. Today, their ancestors live as a peaceful ethnic minority alongside Sinhalese.

### Data Collection and Data Analysis

Qualitative data collection methods were adopted to glean data from twenty small pelagic dried fish processors using the snowball sampling technique. Among the respondents, seven were from Negombo, seven from Puttalam and six from Matara. The study ensured a gender equalled sample. A qualitative data collection approach was adopted. Hence, several qualitative data collection methods were employed with in-depth interviews (n=20), key informant discussions (n=6), and participant observations for better triangulation. Satisfaction, aspirations, labours and family support, wages, gender relationships such as, constraints and opportunities were considered as the variables.

The privacy, safety, and dignity of the respondents were respected throughout the research. In-depth interviews were reported and transcribed using pseudo names to ensure the privacy of the respondents. Secondary data were obtained from reports published by the Department of Census and Statistics, Ministry of Fisheries and Aquatic Resource Development, and National Aquatic Resources Research Development Agency. Those were used to collect general information on dried fish industry in Negombo, Kalpitiya and Matara. Contextual data analysis was adopted using Atlas.ti software. Data was transcribed, coded and analysed.

## RESULTS AND DISCUSSION

### Socio-Economic and Livelihood Profile

In Negombo, Kalpitiya and Matara, people are involved in dried fish processing, wholesaling, retailing, *Jaadi* preparation (A kind of fish preservation technique, which is

practiced from ancient time), and maldive fish processing. In addition, a smaller portion of the population is engaged in other post-harvest fisheries-based livelihoods, which remain less widespread in these areas than dried fish processing and trading. The majority of processors are engaged in both trading and processing.

Dried fish preparation had started in these locations over 40-60 years back. Many of them have been processing and trading dried fish for over 20 years, learning from their previous generations or through personal experience. Processors were between the ages of 25 years to 70 years. Younger people make up the least number of processors in the dried fish processing industry, which is dominated by middle adulthood ranging from about 45 years to 64 years of age. Most of them just have an elementary or lower level of education. Few of others have obtained education up to Advanced Level (A/L) or up to secondary education. Most of the processors and workers were Sinhalese Catholic and Tamil Catholic in Negombo. However, almost all are Sinhalese in Matara. Muslim and Catholic workers were dominant in Kalpitiya.

Both men and women own processing centres. Nevertheless, it was observed that many women run small-scale processing centres in all the three locations. In Negombo, men account for 40% of drying plant owners, while women account for 60%. In Matara, men own 24% and women own 76% of drying plant ownership. In contrast, 80% of processors in Kalpitiya are men and only 20% are women. Fishermen's wives, widowed women, single or divorced women engage actively in post-harvest activities, such as dried fish processing and trading, while others support their husbands. In Kalpitiya, women participation is limited due to Muslim dominating socio-cultural background.

Sun drying is the most common way of fish drying in most of the areas. However,

it needs patience, while requiring a relatively lower amount of capital, and limited transportation. Hence, dried fish processing and trading widen the opportunities for women to engage with income generation that supplements the household economy. Besides, dried fish industry contributes to the national economy. Dried fish producers purchase second and third quality fish for processing. The average volume of production during the peak months (season) are 7000-8000 kg, especially in Negombo.

In Kalpitiya, the production ranges from 5000 to 6000 kg during the peak months. Sometimes, it goes beyond 1000 to 3000 kg per week/processor depending on the capacities of the processors. Similarly, the average production in Matara is around 5000-6000 kg of raw fish per month, and 1000-2000 kg in off-season months. The fish was processed two or three times per week, depending on the availability of raw materials, drying areas, demand, and sufficient sun light or favourable weather conditions. However, depending on the volume processed, dried fish processing was conducted cooperatively with the involvement of both men and women as supporters (hired employee workforce). Few of them were privileged with the co-operation of the family members in the household.

### **Dried Fish Varieties**

Small pelagic fish, known as Smoothbelly sardinella (*Amblygaster leiogaster*: Keeramin), Spotted sardinella (*Amblygaster sirm:* Hurulla), Glodstripe sardinella (*Sardinella gibbose*: Salaya) and Indian Scad (*Decapterus russelli*: Linna) were largely processed by dried fish processors in the selected study areas.

### **Material Wellbeing on Dried Fish Processors**

Both men and women processors in each area value income level and profit as the most important factors that contributes to the material wellbeing. However, men received higher wages than women, resulting women

to suffer a considerable level of a pay gap.

*"I pay labourers in daily work basis and fish quantity basis. If there are huge fish quantities to process, I adopt quantity basis to pay labourers amounting approximately Rs.1000-1500 per day for men employees and Rs. 1000-1200 per day for female employees".*

(Male processor, 71 years)

Their income level is fluctuating from time to time due to several factors. The inadequate quantity of raw material for processing, increased number of processors, increased number of traders, bad weather (rain, flood) and the impact of Covid-19 pandemic had resulted to decrease the dried fish processing business. Dried fish processors have perceived a changed climatic pattern following the Tsunami incident in 2004. The fish abundance, wind patterns, rain patterns have changed notably. Rain has negatively influenced the industry by hindering the dried fish processing and making huge losses for the processors. Fish get contaminated and susceptible for spoiling; hence processors have to throw away bad quality, spoiled dried fish.

During the first and second waves of Covid-19 pandemic, half of the processors participating in processing didn't continue regularly or just operated as per the demand. Further, processors and traders could not engage with their activities entirely during the first Covid-19 wave due to island wide lockdown. Subsequently, the lockdown was lifted and permitted the authorised actors to engage in the trade. However, the majority of processors and traders obtained the permission from the government to carry out their livelihoods. Subsequently, the government introduced Covid-19 management strategies, imposing travel restrictions or lockdowns in cluster basis. As a result, mobile vendors emerged. In that period government lifted some travel restrictions in complying with health safety regulations. Therefore, men and women processors enjoyed slight success.

The Covid-19 pandemic caused most processors to discard their dried fish because it had spoiled, with the exception of 10% of processors who did not process dry fish in their processing centers. Raw fish were scarce during the first wave of Covid-19 because fishermen did not engage in the fishing activities for the fear of encountering problems in selling them. However, because of the *Peliyagoda* fish market Covid-19 cluster, there was a high demand for the dried fish, one to two months after Covid-19 pandemic.

However, there were no sales like in the past and dried fish prices were fluctuating during that time. The low-income increased their level of precariousness in relations to their occupation, thus income level and profit are a significant factor for material wellbeing. About 20% of the female processors in Kalpitiya used to save money for their future, notably for the future of their children. They opened separate bank accounts for each of their kids to deposit money.

*"I dry processed fish on the beachside. It is sometimes risky, especially because of the water flow. Recently also I experienced it and the entire dried fish and drying process was hampered. During the rainy season, I don't get necessary amount of raw fish needed to prepare dried fish and most of the customers do not come to buy dried fish during the rainy season. There were huge losses of dried fish during covid-19 pandemic. Dried fish worthy of approximately Rs.45,000 - 60,000 amount was spoiled during the first wave of the corona and most of the customers didn't pay money for dried fish which they bought on credit."*

(Female processor, 65 years)

Possession is the factor that affects positively to achieve their material wellbeing. Respondents need a house and a vehicle of their own as their other assets. It was recognized that 40% of male processors have enough land area for processing, which some other men and women does not. While processors, who possess enough land area

partake material wellbeing, those who lack of enough land area are suffering from constraints due to the difficulties in processing a large volume of fish and drying them properly. Ample drying facilities, in addition to processing areas, contribute to higher-quality of finished small pelagic dried fish.

In Negombo, women processors trading in the marketplace were also had the same opinion. They were of the view that if they are provided with a suitable place to sell dried fish, it will take them on the path towards material wellbeing. For instance, in Kamachchodaya market traders were trading indoors and outdoors. People who sold outdoors had to undergo the impact of heavy rains and scorching sun. Sunrays caused to reduce the weight of dried fish. Therefore, people who are trading outdoors in the marketplace did not experience in good material wellbeing, when compared with indoor traders.

Processors, both males and females in study areas, highlighted education and skills as the fundamental requirement that helps to achieve social recognition and to secure better occupations in the society. The lack of proper education (children's education) and skills caused to increase the unemployment rate in the country on one hand and to decrease the family status on the other hand. Therefore, respondents are of the view that education and skills are inextricably linked with each other and it has a valuable role to improve material wellbeing in their life.

The majority of married processors, both men and women with children (40%), did not want their children to involve in the dried fish sector because of hardships and prevailing uncertainty. They prefer to see their children live with higher standards than they do, whereas 15% wanted to continue with their children, because they were of the notion that they were given extra potential when it is done as a family business. Others, (45%) the processing work is done alone, since their children are already

employed.

Male and female processors in Matara and male processors in Kalpitiya, emphasized the family status and structure as one of the most important factors to achieve material wellbeing. Both male and female processors without good family background find it difficult to win social recognition. Family structure is a very important component when they work as a team. During processing and trading, family members support each other to increase the living standards of their entire family.

Food security and healthy life are the other material wellbeing factors mentioned by male processors in Negombo and women in Kalpitiya and Matara. Food security and healthy life are the two aspects that are going in parallel. Respondents indicated that enough and healthy food fulfilled their consumption needs and guide them towards a healthy life. A healthy life is essentially needed to involve in dried fish processing and trading, as well as to brighten their children's life. Availability of resources for small pelagic dried fish processing is another factor to achieve material wellbeing as mentioned by male and female processors in all areas, except female in Kalpitiya. Availability of labour resources with well-experienced persons, adequate raw fish amounts and loan facilitating companies are the most important resources mentioned by the processors.

### **Subjective Wellbeing on Dried Fish Processors**

Subjective well-being describes how people feel about and evaluate their life, as well as specific categories and activities [23]. Male and female processors regarded happiness and life satisfaction as the most essential item that can be attained, in terms of subjective wellbeing.

Increases in sales and processing quantities increase their job satisfaction. Therefore, 75% of male and female processors are happy with their occupations.

They believe that this is the only thing they know and familiar with, and they have enough free time, and are content with what they have.

The rest of the processors are dissatisfied with the beliefs that dried fish processing and trading need really hard work to make a big profit, it has curtailed their independence, and they have to deal with some crucial financial issues. So, around 27% of female and 23% of male processors are unhappy about their occupation. This livelihood is not recommended for anyone by them. Dried fish processing is very difficult to learn and teach. They are satisfied with this job, as it needs tiresome, strenuous work to fulfill and in contrast earning a satisfactory margin and maintaining life is hard. However, 77% of male and 73% of female processors are happy and contented with this business. They said that they are used to continue this occupation for years.

Female processors in Negombo, indicated that the fair days, for no reason, they feel like staying at home. They want to do this business, especially because they can stand on their feet without depending on the money lenders. Few of the widows take care of their children, even after the demise of their spouse, merely by engaging in dried fish processing and trading sector. So, they have become independent individuals.

*"I have enough profit to spend my life. I'm happy with my business, my life and about my children's life. This business is fairly good. This is what I have practiced as my occupation. In the fair days, I never stay at home. I want to do this business and live without going after the money lenders like some other people have got used to do. I take care of my children without my husband, by just engaging in the dried fish trade. I did not depend on others. Therefore, I'm really happy."*

(Female processor, 58 years)

They have ambitions to improve their present living conditions. They have their life

objectives and strive hard to accomplish them. When they achieve their objectives one by one consciously or unconsciously their ambitions are gradually directing them toward subjective wellbeing. Some of their goals include providing a good education for their children, expanding the extent of processing land, increasing the production volume, and business, as well as building or repairing their home and purchasing their vehicle. Some dried fish processors and traders spend luxury life styles. The dried fish processing and trading have elevated them to a sophisticated position. According to their response, around 50-60% of people in the village are enjoying exceptionally a better life.

*"In this area lot of people spend luxurious lives. They have comfortable houses and their own vehicles. I also want to improve myself on to that level. In the future I will try hard to accomplish my goal, failing which at least to maintain the present level"*.

(Male processor, 35 years)

Mental calmness is essential to perform their assigned tasks, whether it is belonging to present or future and to maintain cordial relationships with others. When the mind is interrupted, the stress level rises, and it becomes difficult to work correctly. According to both male and female respondents, mental health is also one of the most important characteristics that can be classified under subjective wellness. Another thing they expect to keep them happy in their lives is leisure time and entertainment. They need to spend their free time with their families, children, friends, and neighbours and walk out to a better place to spend their time. They get together after concluding their work to exchange their experiences and information with one another. Other than the female processors in Negombo and the male processors in Matara, most small pelagic dried fish processors believe that entertainment and leisure time increase their subjective well-being.

They spend pleasant times with

people of their choice so that their subjective well-being would be boosted. The majority of responders are Buddhists, with only others being Catholic and Muslim. They have religious convictions, rituals, lessons, and events. Time spent in places of worship, the peaceful association with pastors gives people better feel as to how they should spend their lives properly and helps to create a clear awareness of their concerns and stress free mentality. Every Sunday, Catholics go to church and every Friday Muslims go to mosques as a habit that is endorsed in their minds for generations. Therefore, they spend time as if it is a holiday. Buddhists also visit temples and get involved in different religious activities such as alms giving and Katina festivals.

### **Relational Wellbeing on Dried Fish Processors**

Relational wellbeing is a technique of looking at individuals as subjects and trying to understand how people see the world in terms that are as close as to their own as possible [24]. Developing positive, helpful, and continuing interpersonal connections, associations and communities are required to achieve relational well-being.

The key relational wellbeing aspects reported by the participants were that they need to be happy through social interactions within their family. They work together to attain their goals and complete their unique roles within the family, allowing them to shine in the future and gain social recognition. Relatives and community relationships also making them happy, and they share information and knowledge.

These relationships need to build good social networks, interact with one another, and be aware of the social environment in which they live. Employers' relationships with employees are critical for creating a positive working environment for both.

*“Labourers come from Kalpitiya town and Anawasala area. They work around 5-10*

*years with me. There is a strong relationship among me and my employees. They work together and I supply medical facilities and accommodation. My wife helps to conduct all the processing activities such as drying, salting and packing of dried fish. Her contribution is important to run the business genuinely.”*

(Male processor, 71 years)

Delivering high-quality final products to customers, and working with the same individual for an extended period without dispute are immensely contributing to maintaining relational wellbeing. In addition, a comfortable and sufficient customer base is also required and the customer loyalty should be appreciated.

*“I have more than 50 regular customers. I do not provide credit facilities to my customers. However, I tend to do transactions and sell dried fish on trust without taking money at the time of transaction. Instead, allocate the buyer to pay the total amount by cheques after maximum one month period.”*

(Male processor, 35 years)

Good relationships among employees in the same occupational category make it easier to accomplish the same job in the same area, without the fear of being judged. According to male respondents in Kalpitiya, happiness is enhanced by their support among one another, and they must work together to build a better society for their children and future generations. In Matara, male processors mentioned that responsibilities motivate people to feel the necessity of working strenuously, working correctly, and producing money in the most efficient way possible. Finally, all of these factors assist people in achieving relational wellbeing in their community.

Due to the socio-cultural influence of Islamism, women in Kalpitiya do not explore deeper social relations outside of their families, friends, and immediate kin. Women also have fewer opportunities to socialize in Matara and Negombo, although males who work as processors have relatively more

opportunities in these three study areas.

### CONCLUSIONS

This study was designed to explore the gendered wellbeing factors of dried fish processors in Negombo, Kalpitiya and Matara in relation to the three dimensions, namely material, relational, and subjective. The respondents were able to obtain all three dimensions of well-being aspects; differently or similarly. Men and women processors highlighted income level and profit as the most important variables in maintaining their material well-being. Other determinants include possessions, education and skills mentioned by males and females in all areas. In addition, resource availability, family status and structure, savings, food security, and healthy lifestyle factors are experienced differently by men and women in certain areas.

In terms of subjective well-being, male and female processors viewed life satisfaction with happiness as the most important component, next to aspirations. Mental health, leisure time, entertainment and religious beliefs and practices were among the subjective wellbeing qualities undergone variously.

Social contacts within the family, relatives and community, customer interactions, relationships with co-workers and traders and other processors were the most vital aspects of relational wellbeing for both male and female respondents. Support for others and fulfilling responsibilities were identified to be the significant drivers of relational wellbeing for male processors. However, based on gender and religion, the level of experience in women is differently affected by their wellbeing.

### SUPPLEMENTARY INFORMATION

**Table 1:** Material Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas

**Table 2:** Subjective Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas

**Table 3:** Rational Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas

### CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

### AUTHORS' CONTRIBUTIONS

SAA and DNK: Carried out the investigations, data collection, qualitative analysis, and prepared the first draft of manuscript; DNK: supervised the study and revised the manuscript. All authors read and approved the manuscript.

### FUNDING

This project was funded by the Social Science and Humanities Research Council of Canada under the leadership of Professor Derek Johnson, Project Director, University of Manitoba, Canada. We thank the funding agency of Dried Fish Matters project and the Dried Fish Matters-Sri Lanka project for the financial support and enormous guidance rendered throughout the project.

### REFERENCES

- 1 ICSF 2007. ICSF Guidebook: Understanding the Work in Fishing Convention 2007. International Collective in Support of Fishworkers, Chennai, India, 2007: 49.
- 2 McGregor JA. Researching Human Wellbeing: From Concepts to Methodology. In: Well-being in developing countries: New approaches and research strategies 2007. Cambridge University Press.
- 3 Huppert FA, So TT. Flourishing across Europe: Application of a new conceptual framework for defining well-being. *Social Indicators Research*. 2013 Feb;110(3):837-861.
- 4 Woodhouse E, Homewood KM, Beauchamp E, Clements T, McCabe JT, Wilkie D, Milner-Gulland EJ. Guiding principles for evaluating the impacts of conservation interventions on human well-being. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2015 Nov 5; 370(1681):20150103.

- 5 McGregor A, Sumner A. Beyond business as usual: what might 3-D wellbeing contribute to MDG momentum?. *IDS Bulletin*. 2010 Jan;41(1):104-112.
- 6 White SC. Analysing wellbeing: a framework for development practice. *Development in Practice*. 2010 Apr 1;20(2):158-172.
- 7 La Placa V, McNaught A, Knight A. Discourse on wellbeing in research and practice. *International Journal of Wellbeing*. 2013 Mar 7;3(1): 116-125.
- 8 Stiglitz JE, Sen A, Fitoussi JP. Measurement of Economic Performance and Social Progress. In: *International Economic Association World Congress*. 2017.
- 9 Biedenweg K, Stiles K, Wellman K. A holistic framework for identifying human wellbeing indicators for marine policy. *Marine Policy*. 2016 Feb 1;64:31-37.
- 10 Gough I and McGregor JA. *Wellbeing in developing countries: From theory to research*. Cambridge University Press; 2007.
- 11 Department of Census and Statistics Sri Lanka. Household income and expenditure survey. Department of Census and Statistics Sri Lanka; 2016.
- 12 Koralagama DN. and Bandara SP. Socio-Economic Issues of Women Dried Fish processors in Southern Sri Lanka. Chiangmai, Thailand; 2018.
- 13 Gunawardana MU, De Silva WN, Aanesen M. Market potential for quality certified dried fish: A consumer choice experiment in the Galle District of Sri Lanka. *Tropical Agricultural Research*. 2022 Mar 30;33(2):223-33.
- 14 Koralagama D, Wickrama S, Adikari A. A Preliminary analysis of the social economy of dried fish in Sri Lanka. Literature review DFM/WP/08. DFM Working Papers. Dried Fish Matters/University of Ruhuna. 2021.
- 15 Bandara, VGSP. Supply chain analysis of selected marine dried fish varieties in Matara District [Undergraduate Thesis]. University of Ruhuna, Matara; 2018.
- 16 Amarasinghe O. Key Zone Identification: A Study to Identify the Key Dry Fish Producing Zones in Sri Lanka: Working Paper. Dried Fish Matters. University of Ruhuna, Matara. 2020.
- 17 Gopalakrishnan A, George G, Ignatius B. Supporting the Livelihood of four million fisher folk in Indian marine fisheries-ICAR-CMFRI's recent initiatives. In: *Proceedings of the 11<sup>th</sup> Indian Fisheries and Aquaculture Forum, 23 November 2017, Kochi; 2017*.
- 18 Belton B, Hossain MA, Thilsted SH. Labour, identity and wellbeing in Bangladesh's dried fish value chains. In *Social wellbeing and the values of small-scale fisheries*. Springer; 2018.
- 19 Weeratunge N. Gunatilaka R. Vanniasinkam N. Faslan M. Koralagama D and Vitarana N. *On the Move: Gender, Migration and Wellbeing in Four Fishing Communities in Sri Lanka*. International Centre for Ethnic Studies; 2020.
- 20 Mofizur R. *Dried Fish, Livelihood and Food Security: Global Snapshot; 2015*.
- 21 Singh A, Sahoo PK, Srinath K, Kumar A, Tanuja S. Gender roles and livelihood analysis of women in dry fish processing: A study in coastal Odisha. *Fishery Technology*. 2014;51:267-273.
- 22 Ministry of Fisheries and Aquatic Resources Development (MFARD). *Fisheries Statistics: Statistics report*. Ministry of Fisheries and Aquatic Resources Development, Sri Lanka; 2021.
- 23 Stone AA, Mackie CE. *Subjective wellbeing: measuring happiness, suffering, and other dimensions of experience*. National Academies Press; 2013.
- 24 White SC. Relational wellbeing: A theoretical and operational approach. *International Development and Wellbeing; 2015; 1-30*.



**SUPPLEMENTARY INFORMATION**

**Table 1:** Material Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas

<b>Area</b>	<b>Men</b>	<b>Women</b>
<b>Negombo</b>	Income level and profit Possessions Education and skills Resource availability Healthy life Food security	Income level and profit Possessions Education and skills Resource availability
<b>Kalpitiya</b>	Income level and profit Possessions Education and skills Resource availability Family status and structure	Income level and profit Possessions Education and skills Savings Healthy life Food security
<b>Matara</b>	Income level and profit Education and skills Possessions Family status and family structure Resource availability	Income level and profit Education and skills Possessions Family status and structure Healthy life Resource availability

Source: Field Data

**Table 2:** Subjective Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas

<b>Area</b>	<b>Men</b>	<b>Women</b>
<b>Negombo</b>	Happiness Satisfaction Aspirations Leisure time and entertainment	Happiness Satisfaction Aspirations Mental freedom Religiosity
<b>Kalpitiya</b>	Happiness Satisfaction Aspirations Mental freedom Leisure time and entertainment Religiosity	Happiness Satisfaction Aspirations Leisure time and entertainment
<b>Matara</b>	Happiness Satisfaction Aspirations	Happiness Satisfaction Aspirations Mental freedom Leisure time and entertainment Religiosity

Source: Field Data

**Table 3: Rational Wellbeing Factors of Small Pelagic Dried Fish Processors in Study Areas**

<b>Area</b>	<b>Men</b>	<b>Women</b>
<b>Negombo</b>	Family relationships Relatives and community Relationships with traders and other processors Customer interactions Relationships with employees	Family relationships Relatives and community Relationships with traders and other processors Customer interactions Relationships with employees
<b>Kalpitiya</b>	Family relationships Relatives and community Relationships with traders and other processors Relationships with employees Customer interactions Support to others	Family relationships Relatives and community Relationships with traders and other processors Customer interactions Relationships with employees
<b>Matara</b>	Family relationships Relatives and community Relationships with traders and other processors Customer interactions Relationships with employees Responsibilities	Family relationships Relatives and community Relationships with traders and other processors Customer interactions Relationships with employees

*Source: Field Data*

## Labour-related Causes Controlling the Construction Efficiency in Sri Lankan Building Projects: The Viewpoint of Site Supervisors

Kesavan Manoharan<sup>1,2\*</sup>, Pujitha Dissanayake<sup>2</sup>, Chinth Pathirana<sup>2</sup>,  
Dharsana Deegahawature<sup>3</sup> and Renuka Silva<sup>4</sup>

### Abstract

**Background:** Workforce efficiency has a significant impact on the profitability of construction companies. Construction industry in Sri Lanka has been facing a wide range of labour-related issues that reduce the efficiency and productivity of construction operations. The construction supervisors play a key role in managing a variety of project-level procedures. This study attempted to measure the effects of labour-related causes on the efficiency of construction operations in Sri Lankan building projects.

**Methods:** A comprehensive literature review was conducted to identify the significant labour-related causes that influence the efficiency of construction projects. Subsequently, a questionnaire survey was conducted among 64 building construction firms in Sri Lanka. The Relative Importance Index (RII) approach was used to determine the impact level of each element. Additionally, a number of industry consultative discussions were held to assess the key actions necessary in the construction site management processes, in comparison with the identified essential variables.

**Results:** A total of 27 causes were found to be critical, where the top five ranking labour-related criteria were found to be lack of thinking abilities, lack of knowledge in construction works, communication problems, lack of labour morale/commitment and labour discipline. Through statistical testing, the validity and reliability of the study findings were confirmed.

**Conclusions:** The study findings will substantially help to modernise the present industry procedures to increase the overall productivity and efficiency. Although the study findings are restricted to the Sri Lankan settings, some of them might be applicable to other developing nations also.

**Keywords:** Building Construction, Labour Efficiency, Sri Lanka, Supervisory Perspectives


<sup>1</sup>Department of Construction Technology, Wayamba University of Sri Lanka, Sri Lanka.

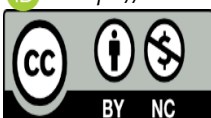
<sup>2</sup>Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka.

<sup>3</sup>Department of Industrial Management, Wayamba University of Sri Lanka, Sri Lanka.

<sup>4</sup>Centre for Quality Assurance, Wayamba University of Sri Lanka, Sri Lanka.

\* Correspondence: kesavan@wyb.ac.lk

 <https://orcid.org/0000-0002-1985-348X>



© The Author(s). This article is published under the Creative Commons Attribution License (CC 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

The infrastructure development and facilities of a nation are greatly influenced by the construction sector. It significantly contributes to the growth of the economy of a country and creates a broad range of employment opportunities [1]. Since it integrates all other resources in different construction jobs, labour is the most valuable resource in the construction industry [2]. In a normal construction project, labour expenditures account for between 30% to 50% of the entire project costs [1]. Therefore, increasing the efficiency of labour is essential for long-term performance of construction enterprises [2]. The construction industry has been losing the efficiency of labour in many emerging nations, which hinders the physical pace of construction projects [3, 4-6]. Numerous studies claim that a variety of labour-related issues are the primary factors causing the low efficiency in building operations [7-12].

Construction companies have struggled with the lack of skilled labour, which has a negative impact on workers' performance and reduced construction output [2, 4-5, 10, 13-15]. According to previous studies, one of the main causes of labour skill shortages in the construction industry has been the lack of job experience among workers [5-6, 11-12, 16-17]. Poor educational backgrounds and inadequate training facilities for labourers have also been discovered to have a substantial impact on labour skills [6, 18-20]. Due to the lack of skilled labourers, many developing nations like Sri Lanka employ unskilled labourers to perform skilled labour operations [10, 21-22].

According to recent studies conducted in various countries, namely Iran [1], India [7, 14, 16], Vietnam [11], Indonesia [23] and Qatar [24], labourers' physical capabilities have an impact on the efficiency of work operations in many construction projects. The concerns with labourers' physical capabilities are attributed primarily to the age of the workforce [10, 14, 18, 20, 25]. Studies show

that the increased burden on workers also has an impact on their physical capabilities [20].

Health issues and drug/alcohol usage among workers have been identified as the major causes affecting the labour efficiency in the Indian construction industry [20]. Notably, heavy alcohol and drug usage has been found to have a negative impact on how well Indonesian construction workers perform [23]. The labourers' capacity to adjust to changes in the workplace is significantly influenced by their health issues [3]. Further studies have revealed that labourers' performance in construction tasks is affected by their psychological and financial issues in India [16] and Turkey [26]. According to Shashank *et al.* [14], labourers' personal issues have a notable impact on their efficiency in construction sites.

In many nations, it has been discovered that workplace discipline needs to be enhanced among construction labourers [11, 16, 19]. The construction industry in India [22] and Nigeria [10] both have reported low labour morale and dedication. According to Hickson and Ellis [27], frequent unscheduled breaks, early departures and late arrivals have reported to cause a major negative impact on the efficiency of labour in numerous construction projects in Trinidad and Tobago. Furthermore, past studies reveal that Egyptian labourers waste a lot of time talking, eating and drinking, which has a substantial negative impact on labour efficiency in the construction industry [5, 28].

Overall, as indicated in Table 1, the current study has thoroughly analysed previous studies on labour-related issues affecting the productivity and the efficiency of construction operations in various developing nations.

### The Sri Lankan Context

Only a limited number of studies have investigated the labour-related problems influencing the construction productivity and efficiency in Sri Lanka. Widanagamachchi

[33] has found that the main causes of the lack of motivation among Sri Lankan labourers in construction projects are their inability to understand technical drawings, temporary nature of the job, demanding atmosphere and the absence of social recognition. According to Praveen *et al.* [34], the labourers' poor material handling skills and inability to grasp drawings are the main issues among Sri Lankan construction contractors.

**Table 1:** Previous Studies that Investigated the Problems Associated with Construction Labourers in Different Countries

Country	Studies
India	2, 9, 12, 16, 20, 22,
Indonesia	23, 29
Iran	1, 4
Nigeria	10, 30
Palestine	31
South Africa	18-19
Sri Lanka	6, 8, 15, 17, 21
Trinidad & Tobacoo	27
Turkey	25, 26
Turkmenistan	32
Vietnam	11
Zimbabwe	13

The Construction Industry Sector Council (CISC) of Sri Lanka has identified the poor cognitive and job-specific technical abilities of Sri Lankan labourers as the key obstacles in increasing labour productivity in the Sri Lankan construction industry [35]. According to Silva *et al.* [6], the main labour-related problems in the Sri Lankan construction projects are labour shortages, interpersonal conflicts among labourers, low motivation and morale, slow mobilization of labourers, inadequate experience and injuries.

A comprehensive investigation carried out by Manoharan *et al.* [36] has presented a wide range of labour-related factors that significantly affect the productivity and efficiency of construction operations in the Sri Lankan construction industry. Based on the state of the practices in the Sri Lankan construction sector, a total of

32 factors have been emphasized as shown in Table 2. The comparison of these elements with other studies from various international contexts is also shown in Table 2.

Overall, studies show how crucial it is for the building construction sector to address a variety of labour-related issues, in order to increase the efficiency of construction operations. Many construction companies invest more in the building construction than other sorts, while taking Sri Lanka's construction industry into account. On the other hand, the perspectives of construction supervisors are very important in the decision making on work site operations, as they are the human resources, who directly handle the labour operations [28]. Accordingly, this study intends to quantify the influence levels of labour-related causes on the efficiency of construction operations in the Sri Lankan building construction projects based on the perspectives of construction supervisors. This will facilitate the construction sector in many developing nations to modernize site practices to combat labour-related issues.

## METHODOLOGY

Based on the viewpoint of construction supervisors, this study used quantitative methodologies to measure the influence level of each component (given in Table 2) on the efficiency of building construction operations. This study also used extensive methodologies to evaluate the accuracy and dependability of the results. These are covered in the sections that follow.

### Questionnaire Survey

A questionnaire survey was conducted among 64 Sri Lankan construction companies, with one construction supervisory worker representing each company and answering questions based on their existing practices for undertaking construction projects.

The survey questions employed the Likert scale of five ordinal measurements, ranging from 1 to 5 (very low effect to very high effect) to assess the influence levels of

**Table 2:** Labour-related Causes Influencing Construction Labour Productivity and Efficiency Presented by Manoharan et al. [36]: Mapping with Other Past Studies from Different Countries

Code	Causes	Past Studies from Different Countries												
		India	Indonesia	Iran	Nigeria	Palestine	South Africa	Sri Lanka	Trinidad & Tobacco	Turkey	Turkmenistan	United Arab Emirates	Vietnam	Zimbabwe
L1	Lack of working experience	X		X	X	X		X	X	X	X		X	X
L2	Poor education background	X					X	X						
L3	Lack of knowledge in construction works	X					X	X				X		
L4	Poor ability of reading, understanding, speaking and writing	X					X	X						X
L5	Lack of thinking abilities	X				X	X	X	X					
L6	Physical ability and fatigue	X	X	X									X	
L7	Health problems	X												
L8	Use of alcohol and drugs	X	X											
L9	Lack of labour morale/commitment	X			X									
L10	Labour discipline	X	X				X						X	
L11	Ageing workforce	X			X		X			X				
L12	Psychological problems	X								X				
L13	Economic problems	X					X			X				
L14	Personal problems	X												
L15	Communication problems		X											
L16	Misunderstanding with other workers	X				X								
L17	Skill shortage	X	X	X	X			X	X			X		X
L18	Mixture of three levels (Skilled, Semi-skilled and Unskilled)	X		X	X			X						
L19	Late arrival, early quit and frequent unscheduled breaks								X					

Code	Causes	Past Studies from Different Countries												
		India	Indonesia	Iran	Nigeria	Palestine	South Africa	Sri Lanka	Trinidad & Tobacco	Turkey	Turkmenistan	United Arab Emirates	Vietnam	Zimbabwe
L20	Unnecessary talks													
L21	Work overload	X												
L22	Work dissatisfaction	X		X	X			X				X		
L23	Inability to understand drawings							X						
L24	Inability to adapt to changes in new environments													
L25	Improper material handling							X						
L26	Poor equipment/tool handling							X						
L27	Changing nature of career expectation	X	X									X		
L28	Skill drain/emigration							X						
L29	Less job interest due to family and society	X		X				X						
L30	Other ways of earning money								X			X	X	
L31	Labour absenteeism	X	X											
L32	Labour strikes		X											

each element. Cognitive interviews with a few construction supervisory workers supported the questionnaires that had been created. The snowball sampling technique was employed to identify the building contractors for this questionnaire survey, taking into account the challenges in determining the actual sample size with desired features.

For this survey, the higher-grade contractors of the Construction Industry Development Authority (CIDA) were taken into consideration. The CIDA is the authorised organisation in Sri Lanka that

offers contractor registration with qualifications appropriate for the construction industry. According to CIDA's national registration and grading scheme, construction contractors are divided into 11 grades based on their financial stability, technical proficiency and practical experience. The minimum financial need to get the middle level of CIDA registration (grade C4) is 50 million Sri Lankan Rupees.

The Table 3 presents a complete profile of the respondents based on their CIDA grades and work experience in the building construction industry. The majority of the contractors were in the C4 grade (56%).

Notably, all the survey respondents had at least five years of work experience in the construction industry, with the majority having between five and ten years of experience (55%).

**Quantitative Analysis**

The Relative Importance Index (RII) approach was used to calculate the influence level of each listed cause on the efficiency of construction operations. As suggested by other studies [1, 11], RII values were calculated using Equation (1).

$$RII = \frac{\sum W}{A * N} \tag{1}$$

- W is the weight provided by the respondents to each element (1 - Very low, 2 - Low, 3 - Moderate, 4 - High, 5 - Very high).
- A stands for the maximum weight permitted (A equals 5).
- The total number of responses is shown as N.

The higher RII value shows that the corresponding component has a significant influence on the efficiency of construction operations. The associated element/cause

had to have a minimum RII value of 0.7 to be determined as critical. The coefficient of variation (CV) values for all the listed causes were determined to assess the validity and reliability of the findings. The reliability of the outcome for each listed cause is guaranteed by a CV value of less than 0.3, according to Statistics Canada [37].

Additionally, construction specialists from different working categories convened for a number of meetings and workshops, and the outcomes were discussed to decide what mitigation steps should be implemented in the site procedures. The outcomes of these discussions also served as the means of validating the findings.

**RESULTS AND DISCUSSION**

Table 4 shows the degree of the influence of labour-related causes on the efficiency of construction operations, based on the viewpoint of construction supervisors. Considering the RII scores of the listed causes, 27 of those 32 causes were identified as being critical (more than 0.7). The top five ranking labour-related causes included, lack of thinking abilities, lack of knowledge in construction works, communication problems, lack of labour morale/commitment and labour discipline.

**Table 3:** Detailed Profile of Survey Respondents

Profile	Variables	No. of Responses	Percentage
CIDA Grade of Contractors (Financial Limit of the Projects - LKR in Million)	CS2 / CS1 (X > 1500)	00	00%
	C1 (1500 >= X > 600)	08	13%
	C2 (600 >= X > 300)	06	09%
	C3 (300 >= X > 150)	14	22%
	C4 (150 >= X > 50)	34	56%
Experience in the construction field	Less than 5 Years	00	00%
	5-10 Years	35	55%
	11-15 Years	18	28%
	16-20 Years	04	06%
	21-25 Years	05	08%
	More than 25 Years	02	03%



**Table 4:** Influence Levels of the Labour-related Causes Controlling the Efficiency of Construction Operations

Codes of Causes	Mean	RII	SD	CV	Ranking	Level of Impact
L5	4.53	0.91	0.16	0.18	1	High
L3	4.44	0.89	0.15	0.17	2	High
L15	4.41	0.88	0.14	0.16	3	High
L9	4.34	0.87	0.16	0.18	4	High
L10	4.34	0.87	0.16	0.18	4	High
L17	4.34	0.87	0.15	0.17	4	High
L2	4.33	0.87	0.15	0.17	7	High
L1	4.28	0.86	0.16	0.19	8	High
L31	4.22	0.84	0.15	0.18	9	High
L4	4.09	0.82	0.14	0.17	10	High
L8	4.06	0.81	0.12	0.15	11	High
L7	3.97	0.79	0.14	0.18	12	High
L6	3.91	0.78	0.15	0.19	12	High
L22	3.84	0.77	0.14	0.18	14	High
L12	3.77	0.75	0.13	0.17	15	High
L16	3.75	0.75	0.11	0.15	16	High
L13	3.72	0.74	0.12	0.16	17	High
L14	3.72	0.74	0.13	0.17	17	High
L21	3.69	0.74	0.12	0.16	19	High
L23	3.69	0.74	0.14	0.19	19	High
L18	3.67	0.73	0.1	0.14	21	High
L19	3.67	0.73	0.13	0.18	21	High
L25	3.67	0.73	0.12	0.16	21	High
L26	3.61	0.72	0.12	0.17	24	High
L24	3.55	0.71	0.14	0.20	25	High
L27	3.52	0.70	0.15	0.21	26	High
L29	3.50	0.70	0.14	0.20	27	High
L20	3.48	0.70	0.11	0.16	28	Medium
L11	3.36	0.67	0.12	0.18	29	Medium
L28	3.31	0.66	0.11	0.17	30	Medium
L30	3.25	0.65	0.14	0.22	31	Medium
L32	2.34	0.47	0.19	0.41	32	Low

Notably, the skill shortage, poor education background, lack of work experience, labour absenteeism and poor ability of reading, understanding, speaking and writing were the other labour-related resolve issues in the workplace. These are crucial life skills for forming connections, adopting perspectives and communicating. According to industry consultants, the main causes influencing how well construction workers can think to include mental impairments, a lack of confidence, social

conditioning, work pressure and personal issues. Critical thinking skills are important for labourers to make wise judgments.

The experts also emphasized the importance of regular brainstorming sessions and meditation routines for labourers at construction sites to develop their cognitive skills. Workers' ability to think, read, learn, retain knowledge, pay attention, solve issues, remember tasks and make judgments depend on their cognitive abilities. The results of the

current study show that labourers' poor cognitive abilities have a major negative influence on their performance and productivity in numerous building construction projects in Sri Lanka. The cognitive abilities of Sri Lankan labourers in various technical operations (particularly concreting, bar bending, plastering, tiling, welding, electrical works and equipment handling) need to be greatly increased, according to the industry consultation specialists.

The cognitive skills of labourers in those categories require specific attention from construction training institutions, as stated by Manoharan *et al.* [38]. According to Praveen *et al.* [34], the slow progress of building construction activities in Sri Lanka was mostly due to the labourers' inadequate comprehension of blueprints and material management.

According to this study, labourers' inadequate communication skills are the main obstacle to their participation in teams and collaborative work in many building construction projects in Sri Lanka. According to the consultation with industry experts, this has led to worker miscommunication, job mistakes, rework and construction delays. The experts also emphasized the need of connecting the quality control efforts with the communication strategies of construction businesses because inadequate communication facilities lead to subpar work in construction operations. This study also emphasizes how crucial it is for workers to understand safety communication procedures in order to avoid unanticipated injuries during work operations. The construction delays in numerous construction projects in Sri Lanka were considerably exacerbated by occupational injuries [15].

The sense of accountability that a worker has towards the objectives and expectations of the company is known as labour morale or commitment. This has a big impact on raising labour productivity and

efficiency in the building industry. However, the majority of Sri Lankan labourers' passion for their given tasks at work is insufficient. Manoharan *et al.* [38] underlined the critical need for strengthening the commitment of Sri Lankan labourers in construction by contrasting them with the Arabian, Chinese, Korean and Malaysian labour forces, who were the top foreign labour forces in the skill-based ranked list. The secondary education and vocational training institutions in Sri Lanka must pay attention to strengthening the soft skills and attitude domain components in their curricula, according to the industry consultation experts. The construction companies must also make sure the workplace is conducive to the increased level of labour engagement.

Worker discipline is crucial for carrying out work operations within a structure or framework. The majority of Sri Lankan labourers come from undereducated backgrounds and are not aware of the standards that must be upheld for behaviour and work performance. The professionals in the field emphasized how many building construction projects in Sri Lanka lack employee handbooks, standard operational procedures and employment agreements. Therefore, inadequate labour discipline has a big impact on how productive building operations are. Similar issues were also identified in other developing nations, including India [16], Indonesia [23], South Africa [19] and Vietnam [11].

According to the results of this study, the performance, productivity and quality of work operations in building construction projects in Sri Lanka are all negatively impacted by the labour shortage. The lack of labourers with the necessary skills and work experience has been a major issue for construction contractors in many nations, including Egypt [5], India [2, 12, 16], Iran [4], Nigeria [10], South Africa [18-19] and Zimbabwe [13]. The lack of emphasis on construction education in school curricula, especially in the Sri Lankan setting, may be

the main factor contributing to the skills gap among construction labourers [35]. Due to the lack of experienced labourers, many building construction projects in Sri Lanka employ unskilled labourers as skilled labourers. This hinders workers' ability to build their careers and get the necessary job experience, and it also leads to low-quality work outputs.

The Sri Lankan construction sector's labour training facilities need to be improved, according to the Industry Sector Skills Councils (ISSC) of Sri Lanka. ISSC also claimed that many public sector training programmes in Sri Lanka do not adequately address the needs of the industry [35]. The weak cognitive and job-specific technical skills of the Sri Lankan labourers are the other areas where ISSC stands out.

According to this survey, labour absenteeism has also been a major issue for the building construction contractors in Sri Lanka. Notably, it also caused delays in the Sri Lankan building construction sector [15]. According to the experts' debates, labourers' low levels of job interest, motivation, dedication and work satisfaction were found as the main causes of labour absenteeism in many building construction projects in Sri Lanka. The experts revealed that salary delays, lack of proper incentives, no labour rewarding mechanisms, improper promotion opportunities, lack of job security for labourers, fewer welfare facilities for labourers and other ways of earning money are the major elements contributing to Sri Lankan labourers' decreased motivation, lack of job interest and work dissatisfaction.

According to the study findings, the majority of labourers in the Sri Lankan building construction industry have poor job performance due to their weak reading, understanding, speaking and writing skills. This has been a significant obstacle for the labourers to handle the difficulties in their workplace. The development of the labourers' cognitive, transferable and self-management skills depends greatly on their ability to

acquire new things relevant to job operations. The above-mentioned poor skills of Sri Lankan labourers may be specifically caused by their lack of early schooling. Past studies that looked at labour forces working on construction projects in India [12, 16], South Africa [18-19], Turkey [26] and Zimbabwe [13] have all revealed similar issues.

This study clearly states that labourers' workload intensity affects how well they perform throughout construction operations. The mood and behaviour of employees are impacted by their workload, which also results in poor mental focus, low motivation and difficulties focusing on job duties [39]. Relationships with co-workers and managers may be strained as a result. According to Semaksiani *et al.* [39], an excessive workload also lowers employee morale and motivation, which results in work tiredness. The experts' discussions highlighted that the main causes of the excessive workload of labourers in Sri Lankan building construction projects are the unrealistic project timetables and sequences of construction jobs.

A well-planned project schedule increases productivity and ensures that resources are distributed efficiently, which lowers costs and speeds up the process. The experts' discussions further revealed that the primary causes of unrealistic project schedules include disagreements in subcontractors' schedules, delays in subcontractors' work and delays in acquiring permits/approvals from necessary authorities. Additionally, conversations among experts found that inadequate time management skills of supervisors and a dearth of trained labourers employed are other reasons contributing to the high workloads of labourers.

Overall, the CV values of each cause guarantee the accuracy and dependability of these results. The CV values of all the causes with the exception of 'labour strikes (L32)' were within the permissible range, as per the

range of CV values listed in the Labour Force Survey Guide 2020 of Canada [37]. Since only a small number of projects may be affected by the labour strikes, the influence levels of L32 may greatly differ amongst projects. Furthermore, the L32 comes in last on the list. The high CV value of L32 may also be impacted by the low mean value. Therefore, it cannot be said that the CV value emphasises the lower level of precision for the result of L32. Additionally, the outcomes from the discussions with industry representatives ensured the authenticity of the results of this study.

### CONCLUSIONS

Based on the perspectives of construction supervisors, this study has identified the crucial labour-related causes that influence the progression of construction operations in Sri Lankan building projects. The influence levels of the causes demonstrate how much consideration should be given to each aspect of labourers in order to increase the productivity and efficiency of construction operations.

Overall, the study has shown significant labour-related causes that the construction site management should pay attention to increase the productivity and efficiency of construction operations. The study also emphasised the urgent need to improve the nation's vocational training programmes in order to improve the cognitive, interpersonal and task-specific abilities of construction labourers. This study highlights that future studies should concentrate on methods for enhancing labour skills in the construction industry. The overall study findings are anticipated to significantly alter site management practices and policies in the direction of the construction industry's long-term sustainability. The study findings are restricted to construction procedures in Sri Lankan building construction. However, some of these might also be tested in comparable circumstances in other developing nations.

### CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

### AUTHORS' CONTRIBUTIONS

KM: Conceptualized, designed the research, carried out the investigation, performed data curation and analysis, and wrote the manuscript. PD: Supervised the study and reviewed the manuscript. CP: Supervised the study and reviewed the manuscript. DD: Supervised the study and reviewed the manuscript. RS: Supervised the study and reviewed the manuscript.

### ACKNOWLEDGEMENT

The authors would like to thank the industry experts, who actively participated in the discussion sessions and questionnaire survey for this study. The authors also wish to acknowledge Tertiary and Vocational Education Commission of Sri Lanka, Construction Industry Development Authority, University of Peradeniya and Wayamba University of Sri Lanka for the necessary support provided to this study.

### REFERENCES

- 1 Shahab S, Audrius B. Application of fuzzy fault tree analysis to identify factors influencing construction labor productivity: a high-rise building case study. *J Civ Eng Manage.* 2018; 25(1): 41-52.
- 2 Ghatte PR, Minde PR. Labour productivity in construction. [https://www.researchgate.net/publication/307138481\\_labour\\_productivity\\_in\\_construction/download](https://www.researchgate.net/publication/307138481_labour_productivity_in_construction/download). Accessed 14 October 2019.
- 3 Robles G, Stifi A, Jose LP, Gentes S. Labor productivity in the construction industry factors influencing the Spanish construction labor productivity. *Int J Civ Env Eng.* 2014; 8(10): 1061-1070.
- 4 Ghoddousi P, Pourafshar O, Chileshe N, Hosseini MR. Labour productivity in Iranian construction projects. *Int J Prod Perform Manage.* 2015; 64(6): 811-830.
- 5 Nourhane MM, Ibrahim MM, Hesham AM, Ibrahim AR. Factors affecting

- construction labour productivity for construction of pre-stressed concrete bridges. *Int J Constr Eng Manage.* 2018; 7(6): 193-206.
- 6 Silva GASK, Warnakulasuriya BNF, Arachchige BJH. A review of the skill shortage challenge in construction industry in Sri Lanka. *Int J Econ Bus Manage Res.* 2018; 2(1): 75-89.
  - 7 Soham M, Rajiv B. Critical factors affecting labour productivity in construction projects: case study of South Gujarat Region of India. *Int J Eng Adv Tech.* 2013; 2(4): 583-591.
  - 8 Kesavan M, Gobidan NN, Gobishanker R, Dissanayake PBG. Proper project planning in avoiding construction project delays. Proceedings of the special sessions on sustainable design and construction, 5th international conference on sustainable built environment. Kandy, Sri Lanka. 2014; 77-84.
  - 9 Saravanan M, Surendar G. Analysis of various factors influencing labour productivity in construction project, *Int J Emerg Tech Comp Sci Electr.* 2016; 22(2): 179-181.
  - 10 Onyekachi VN. Impact of low labour characteristics on construction sites productivity in EBONYI state, *Int J Adv Res Sci Eng Tech.* 2018; 5(10): 7072-7087.
  - 11 Dinh TH, Nguyen VT. Analysis of affected factors on construction productivity in Vietnam. *Int J Civ Eng Tech.* 2019; 10(2): 854-864.
  - 12 Murari SS, Joshi AM. Factors affecting labour productivity in precast construction industry. Proceedings of fourth national conference on road and infrastructure. Bengaluru, India. 2019; 163-169.
  - 13 Chigara B, Moyo T. Factors affecting labor productivity on building projects in Zimbabwe. *Int J Arch Eng Constr.* 2014; 3(1): 57-65.
  - 14 Shashank K, Hazra S, Pal NK. Analysis of key factors affecting the variation of labour productivity in construction projects. *Int J Emerg Tech Adv Eng.* 2014; 4(5): 152-160.
  - 15 Kesavan M, Gobidan NN, Dissanayake PBG. Analysis of factors contributing civil engineering project delays in Sri Lanka. Proceedings of the session on construction management and tall building and urban habitat, 6th international conference on structural engineering and construction management. Kandy, Sri Lanka. 2015; 40-46.
  - 16 Dharani K. Study on labours productivity management in construction industry. *Int J Latest Trends Eng Tech.* 2015; 6(1): 278-284.
  - 17 Kesavan M, Gobidan NN, Dissanayake PBG. Planning & mitigation methods to reduce the project delays in Sri Lankan construction industries. Proceedings of the session on construction materials and systems, 6th international conference on structural engineering and construction management. Kandy, Sri Lanka. 2015; 102-107.
  - 18 Windapo AO. Skilled labour supply in the South African construction industry: the nexus between certification, quality of work output and shortages. *SA J Hum Res Manage.* 2016; 14(1): 1-8.
  - 19 Orlando M, Isabirye AK. Construction workers' skill development: a strategy for improving capacity and productivity in South Africa. *Int J Econ Fin Stud.* 2018; 10(1): 66-80.
  - 20 Mistri A, Patel CG, Pitroda JR. Analysis of causes, effects and impacts of skills shortage for sustainable construction through analytic hierarchy process, *Int J Tech Innov Mod Eng Sci.* 2019; 5(5): 168-176.
  - 21 Fernando PGD, Fernando NG, Gunarathna MACL. Skills developments of labourers to achieve the successful project delivery in the Sri Lankan construction industry. *Civ Env Res.* 2016; 8(5): 86-99.
  - 22 Saurav D, Satya NM, Anil S, Subhav S. Relationship between skill development and productivity in construction sector: a literature review, *Int J Civ Eng Technol.* 2017; 8(8): 649-665.
  - 23 Soekiman A, Pribadi KS, Soemardi, BW,

- Wirahadikusumah RD. Factors relating to labor productivity affecting the project schedule performance in Indonesia, *Procedia Eng*. 2011; 14: 865-873.
- 24 Jarkas AM, Kadri CY, Younes JH. A survey of factors influencing the productivity of construction operatives in the State of Qatar. *Int J Constr Manage*. 2012; 12(3): 1-23.
- 25 Kaya M, Keles AE, Oral EL. Construction crew productivity prediction by using data mining methods. *Soc Behav Sci*. 2014; 141: 1249-1253.
- 26 Kazaz A, Ulubeyli S, Acikara T, Er B. Factors affecting labour productivity: Perspectives of craft workers, *Procedia Eng*. 2016; 164: 28-34.
- 27 Hickson BG, Ellis L. Factors affecting construction labour productivity in Trinidad and Tobago. *J Assoc Profess Eng Trinidad and Tobago*. 2013; 42(1): 4-11.
- 28 Shehata ME, El-Gohary KM (2011). Towards improving construction labour productivity and projects' performance, *Alexandria Eng J*. 50: 321-330.
- 29 Adi HP, Ni'am MF. Improving skill's strategies of Indonesian construction labours to have global competitiveness, *Int J Civ Struct Eng*. 2012; 3(1): 150-157.
- 30 Ayegba C, Agbo AE. Assessment of craftsmen turnover in the construction industry. *Civ Env Res*. 2014; 6(7): 106-115.
- 31 Mahamid I. Contractors perspective toward factors affecting labour productivity in building construction. *Eng Constr Architect Manage*. 2013; 20(5): 446-460.
- 32 Durdyev S, Ismail S, Bakar NA. Construction productivity in Turkmenistan: survey of the constraining factors, *Int J e-Edu*. 2013; 3(1): 18-23.
- 33 Widanagamachchi UC. The labour motivation of construction industry in Sri Lanka. (A Thesis of the Master of Science in Construction Project Management). University of Moratuwa. Sri Lanka. 2013.
- 34 Praveen R, Niththiyananthan T, Kanarajan S, Dissanayake PBG. Shortage of skilled labour and professionals in the construction industry of Sri Lanka, *Transac Instit Eng Sri Lanka*. 2011; I(B): 239-247.
- 35 Tertiary and Vocational Education Commission. Construction industry sector training plan 2018 – 2020. Sri Lanka. 2018.
- 36 Manoharan K, Dissanayake P, Pathirana C, Deegahawature D, Silva R. Assessment of critical factors influencing the performance of labour in Sri Lankan construction industry. *Int J Constr Manage*. 2020; 1-12.
- 37 Statistics Canada. Guide to the labour force survey 2020. Canada. 2020.
- 38 Manoharan K, Dissanayake P, Pathirana C, Deegahawature D, Silva R. A labour performance score and grading system to the next normal practices in construction. *Built Env Proj Ass Manage*. 2022; 1-20.
- 39 Semaksiani A, Handaru AW, Rizan M. (2019). The effect of work loads and work stress on motivation of work productivity (empirical case study of ink-producing companies), *Scholars Bulletin*, 560-571.

## Impact of Processed/Refined Foods on Oral Health: A Mini-Review

Priyake D. Palipana


### Abstract

Since the evolution of the human beings, food habits and consumption patterns have been constantly changing. At the beginning, humans were depending primarily on hunting and gathering as nomadic hunter-gatherers. Subsequently, humans gradually started engaging in agriculture, which acted as the major reason for the evolution of dietary patterns among humans. At the early periods of human civilization, burning food with fire or charcoal was practiced as the widely used food processing technique. However, with time humans recognized the importance of processing food by different means to make them more palatable and ensure preservation. In addition, adequately processed food with correct techniques can avoid a variety of food borne diseases. Therefore, at present providing access to a sufficient amount of safe and nutritious food remains as a key requirement, which ensure quality of life and well-being. Beside ensuring the food security, using the appropriate food processing approaches play a critical role in this aspect. During the processing, natural ingredients undergo changes and various non-edible constituents could be added into the food products. Food processing can lead into notable increments in refined carbohydrates and lipids and decrease naturally occurring components such as fibre, vitamins, and minerals. Often, this can lead to a plethora of diseases. Based on the NOVA classification of foods, food products may be classified into four broad categories as unprocessed/minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods and drinks. Among numerous diseases that can be caused by the consumption of poorly processed foods, oral and dental diseases have been limitedly focussed and highlighted. Therefore, the current article attempts to cater for this knowledge gap by reviewing the common oral and dental diseases manifested by consuming processed ultra-processed food such as candidiasis, dental caries, dental erosion and periodontal disease. Conversely, consumption of more natural kinds of food are more favourable towards maintaining a healthy oral and dental environment. Substantial knowledge of this can effectively support the relevant authorities to prevent and manage common dental problems, which have become a major challenge to the individuals and the health system. In addition, the food processing industries can understand the importance of adhering to standard food processing techniques and conditions, to maintain the desired quality of food.

**Keywords:** Dental Caries, Dental Erosion, Periodontal Disease, Processed Food

Department of Restorative Dentistry, Faculty of Dental Sciences, University of Sri Jayewardenepura, Sri Lanka

\* Correspondence: priyakepalipana@sjp.ac.lk

 <https://orcid.org/0000-0002-5077-312X>



© The Author(s). This article is published under the Creative Commons Attribution License (CC 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

Processed/refined foods become significantly modified from their natural composition. The major changes are the increase in refined carbohydrates and lipids and the lack of naturally occurring components like fibre, vitamins, and minerals [1]. According to the American Dietetic Association, nutrition is a necessary component of oral health, and nutrition and diet affect oral health, which in turn affects the progression of oral diseases. Processed and/or refined foods can act as a major contributor to oral diseases such as dental caries (tooth decay), tooth erosion and periodontal disease [2]. However, the most significant effect of nutrition on teeth is the local action of diet in the mouth on the development of dental caries and enamel erosion. At present, dental erosion is increasing and is associated with dietary acids, a major source of which is soft drinks [3].

### Processing of Food

The NOVA classification of foods proposes four categories of food as, unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and Ultra-Processed Foods and Drinks (UPFDs). The overall purpose of ultra-processing is to create branded, convenient (durable, ready to consume), attractive (hyper-palatable) and highly profitable (low-cost ingredients) food products designed to displace all other food groups. Ultra-processed food products are usually packaged attractively and intensively marketed. Multiple sequential processes are used to combine many ingredients and create the final product, hence leading to the term of "ultra-processed". These industrial processes have no domestic equivalent to processes followed in domestic food preparation such as hydrogenation and hydrolysis, extrusion and moulding, and pre-processing for frying.

Classes of additives are found only in ultra-processed products that include those used to imitate or enhance the sensory qualities of foods or to disguise unpalatable

aspects of the final product. These additives include dyes and other colours, colour stabilizers; flavours, flavour enhancers, non-sugar sweeteners; and processing aids such as carbonating, firming, bulking and anti-bulking, de-foaming, anti-caking, glazing agents, emulsifiers, sequestrants and humectants [4]. Some countries use the NOVA grouping for their dietary guidelines or goals, for instance: Brazil's dietary guidelines has recommend limiting consumption of processed food and avoiding ultra-processed food and France's public health nutritional policy goals for 2018-2022 aim to reduce consumption of ultra-processed foods by 20%.

### Common Dento-Oral Manifestations

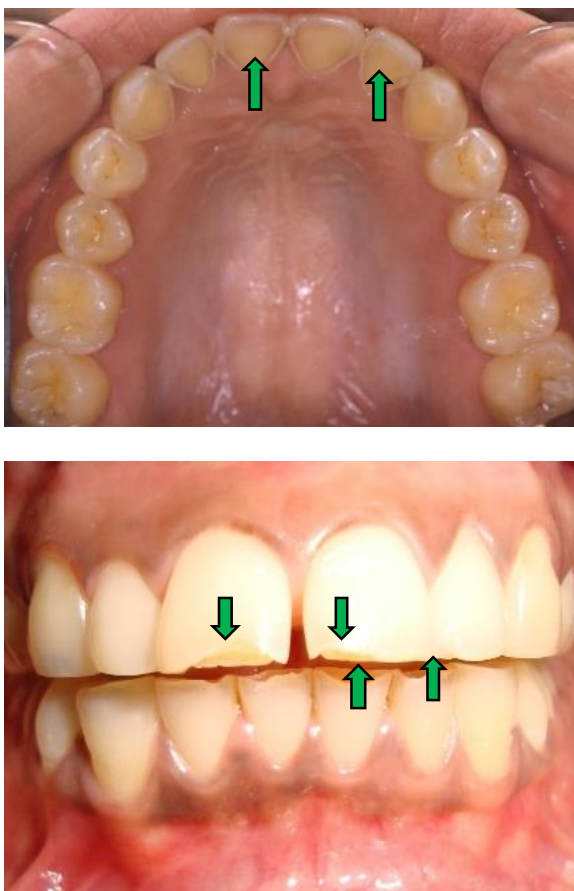
Consuming fermentable or refined carbohydrates leads to the development of dental caries [5]. These refined carbohydrates are commonly found in snacks like biscuits, and cakes etc. Increased consumption, both in frequency and amount, of these snacks, especially when taken as an in-between snack, escalates the incidence of dental caries [6]. A study conducted by Schroth *et al.* to find out the prevalence and risk factors of severe early childhood caries has concluded that dietary intakes of sweets, fast foods, and sugary drinks contribute to the increased risk of caries [5]. Figure 1 shows a photograph of a young child whose deciduous teeth (milk teeth) are extensively affected with dental caries.



**Figure 1:** Photograph of a Child Affected with Extensive Dental Caries, which are Marked with Green Arrows.



The chemical ingredients, especially acids in processed/refined foods, erode the enamel of the teeth (Figure 2). This leads to a rapid loss of tooth substance [7]. Furthermore, these acidic materials in the diet lead to gastritis and reflux disease (the travelling up of stomach contents towards the mouth), which leads to the oral environment being more acidic with greater dental erosion. In most cases, this erosion is associated with other types of tooth wear, like attrition and abrasion [8]. When combined, the effect and extent on the rate of tooth substance loss is more extensive and less controllable.



**Figure 2:** Photographs of a Patients Affected with Dental Erosion. Erosive Areas are Marked with Green Arrows.

Around two and a half decades ago, it was found that a significant fraction of the starch present in foods is not digested in the small intestine and continues to the large intestine, where it is fermented by the microbiota. This fraction was named

Resistant Starch (RS). It was also reported that there is a fraction of starch that is slowly digested, sustaining the release of glucose in the small intestine. Later, health benefits were found to be associated with the consumption of this fraction, called Slowly Digestible Starch (SDS). Researchers have reported both of these fractions to be "nutraceutical starch." An overview of the structure of both fractions (RS and SDS), as well as their characteristics, aver been intensively studied to determine methods and processes that will increase both fractions in starchy foods and prevent diseases that are associated with the consumption of glycaemic carbohydrates [9].

Glycaemic carbohydrates are the ones which increases the blood glucose levels quite significantly and the glycaemic index describes how quickly food affects the blood sugar (glucose) level after consumption. The link between carbohydrate intake and health is becoming increasingly important for the individual, particularly in the areas of Glycaemic Index (GI) and extended energy-releasing starches.

From a physiological point of view, SDS delivers a slow and sustained release of glucose along with the benefits resulting from low glycaemic response [10]. Scientific studies prove that consumption of refined/processed foods makes individuals more vulnerable to diabetes [11]. The consumption of highly refined carbohydrates in the absence of dietary fibre and the above-described RS and SDS contributes to oral diseases. The effects are two-fold. Firstly, the fermentable sugar concentration is high, and thus they are fermented by oral microbiota into acids, which results teeth decay in a more concentrated manner in the absence of the aforementioned dietary constituents. Secondly, they lead to diabetes and their complications indirectly affect the oral cavity and teeth.

Many studies have revealed that diabetic patients have advanced periodontal disease. The Periodontal disease is a type of

advanced gum disease, which would ultimately lead to loss of teeth [12]. Teeth will lose the bone and soft tissue attachment as shown in Figure 3. Periodontitis is said to be the sixth complication of diabetes [13]. According to the scientific analysis, the prevalence of severe periodontitis in diabetics as compared to non-diabetics has been found to be 59.6% compared to 39% [14]. In a vice versa scenario, the diabetic patients suffering from periodontitis have a poor glycaemic (blood sugar) control.

Control of periodontal disease may enhance glycaemic control in patients with type 2 diabetes. In turn, improved glycaemic control may contribute to better control of periodontal disease [15]. Uncontrolled diabetes also leads to xerostomia (dryness of the mouth). With xerostomia in oral cavity, the teeth become more vulnerable to diseases. Incidence of dental caries is very high under such conditions. Xerostomia also leads to many dental infections in addition to periodontitis mentioned above. Candidiasis (a fungal) is the commonest out of them all.



**Figure 3:** Photograph of a Patient Affected with Advanced Periodontitis. The Exposed Root Area is Marked with Green Arrows.

Imbalance and inadequacies of minor deficiencies in nutrients are associated with processed food. Such improper nutritional consumption also contributes to certain oral diseases and deficiencies manifested in the oral tissues [16]. Some Periodontal diseases are associated with deficiencies in vitamins C and D, and numerous clinical studies have

revealed that vitamin D deficiency affects the tooth development [17].

## CONCLUSIONS

In conclusion, consumption of refined/processed foods is detrimental to the oral and dental tissues. A variety of oral and dental diseases such as candidiasis, dental caries, dental erosion and periodontal disease etc. could be caused by the consumption of such food. Conversely, consumption of more natural kinds of food are more favourable towards maintaining a healthy oral and dental environment. Enhancing the knowledge on these aspects among the community, can effectively prevent and manage common dental problems, which have become a major challenge to the individuals and the health system.

## FUNDING SOURCES

No funding was received for the current study.

## CONFLICT OF INTEREST

Author declares that there is no conflict of interest regarding the publication of this paper.

## AUTHORS' CONTRIBUTIONS

Author conceptualized the study, collected the literature, reviewed and compiled the manuscript.

## REFERENCES

- 1 Weaver CM, Dwyer J, Fulgoni III VL, King JC, Leveille GA, MacDonald RS, Ordovas J and Schnakenberg D. Processed foods: contributions to nutrition. *Am J Clin Nutr.* 2014 Jun 1;99(6):1525-42.
- 2 Guizar JM, Munoz N, Amador N and Garcia G. Association of alimentary factors and nutritional status with caries in children of Leon, Mexico. *Oral Health Prev Dent.* 2016 Jan 1;14(6):563-9.
- 3 Moynihan P and Petersen P. Diet, nutrition and the prevention of dental diseases. *Public Health Nutr.* 2004; 7 (1A): 201-226.

- 4 Gibney MJ, Forde CG, Mullally D and Gibney ER. Ultra-processed foods in human health: a critical appraisal. *Am J Clin Nutr.* 2017 Sep 1;106(3):717-24.
- 5 Schroth RJ, Halchuk S and Star L. Prevalence and risk factors of caregiver reported severe early childhood caries in Manitoba first nations children: Results from the RHS Phase 2 (2008–2010). *Int J Circumpolar Health.* 2013: 72.
- 6 Lingstrom P, Van Houte J, Kashket YS. Food starches and dental caries. *Crit Rev Oral Biol Med.* 2000 Jul;11(3):366-80.
- 7 Scardina GA and Messina P. Good oral health and diet. *J Biotechnol Biomed.* 2012; 2012:720692.
- 8 Jajam M, Bozzolo P and Niklander S. Oral manifestations of gastrointestinal disorders. *J Clin Exp Dent.* 2017 Oct 1;9(10):e1242-e1248
- 9 Magallanes-Cruz PA, Flores-Silva PC and Bello-Perez LA. Starch Structure influences its digestibility: A review. *J Food Sci.* 2017 Sep; 82(9):2016-2023.
- 10 Ming Miao, Bo Jiang, Steve W Cui, Tao Zhang and Zhengyu J. Slowly digestible starch--a review. *Crit Rev Food Sci Nutr.* 2015.
- 11 Ashakiran and Deepthi R. Fast foods and their impact on health. *Ó Journal of Krishna Institute of Medical Sciences University.* 2012;1(2): 7-15
- 12 Daniel R, Gokulanathan S, Shanmugasundaram N, Lakshmigandhan M and Kavin T. Diabetes and periodontal disease. *J Pharm Bioallied Sci.* 2012; 4(2):280-282.
- 13 Loe H. Periodontal disease: Sixth complication of diabetes. Mellitus. *Diabetes Care.* 1993; 16:324–334.
- 14 Taba Jr M, Souza SL, Mariguela VC. Periodontal disease: A genetic perspective. *Brazilian Oral Research.* 2012; 26:32-8.
- 15 Martinez AB, Perez PM, Bermejo ME, GonzálezMoles MA, Ilundain JB, Meurman JH. Review periodontal disease and diabetes-review of the literature. *Med Oral Patol Oral Cir Bucal.* 2011 Sep 1;16 (6): 722-9.
- 16 Scardina GA and Messina P. Nutrition and oral health. *Recenti Progressi in Medicina.* 2008; 99(2):106–111.
- 17 Rahman N and Walls A. Chapter 12: Nutrient Deficiencies and Oral Health. *Monogr Oral Sci.* 2020; 28:114-124.

Research Article

Open Access

## Evaluation of Nutrient Leaching Losses in Red Onion Grown on Sandy Regosols in Kalpitiya under Intensive Farming Systems

Gayathri Swarnathilake<sup>1</sup>, Indika Herath<sup>1\*</sup>, Radhika Gimhani<sup>2</sup> and Lahiru Udayanga<sup>3</sup>

### Abstract

**Background:** Red onion is a short-term crop cultivated in Kalpitiya with excessive use of fertilizer, leading to contamination of groundwater. Therefore, the current study aimed to evaluate the leaching potential of plant nutrients from red onion cultivations managed under grower managed fertilizer practices, compared to Department of Agriculture (DoA) recommendations.

**Methods:** This study was carried out in Kandakuliya, where lysimeters were installed below the soil surface of separated plots. The variety Jaffna Local was used in the experiment. Growers' fertilizer practice was considered as the treatment 1 (T1). The DoA recommendation was used as treatment 2 (T2). The available P, total N, exchangeable K<sup>+</sup>, Ca<sup>2+</sup>, F<sup>-</sup>, NO<sub>3</sub><sup>-</sup> and NH<sub>4</sub><sup>+</sup> concentrations in the initial soil samples and leachate were analyzed using standard methods. The two-sample t test was used for statistical analysis.

**Results:** The mean cumulative Ca<sup>2+</sup>, NO<sub>3</sub><sup>-</sup> and P denoted significant differences, among the leachate collected from the two treatments. The concentration of NO<sub>3</sub><sup>-</sup> in both treatments ranged from 35.1 mg/l to 160 mg/l, which was higher than the WHO permissible level of NO<sub>3</sub><sup>-</sup> (50 mg/l) for drinking water. However, the mean values of cumulative leached NH<sub>4</sub><sup>+</sup> and K<sup>+</sup> did not indicate significant differences between the treatments. The highest mean cumulative values of Ca<sup>2+</sup> (659.6 kg/ha), F<sup>-</sup> (4.9 kg/ha) and P (26.4 kg/ha) were observed in the leachate collected from T1.

**Conclusions:** Among all the tested substances, NO<sub>3</sub><sup>-</sup> was found to be the critical element in terms of leaching and contamination of groundwater. This emphasizes the pressing need for an improved nitrogen management strategy for the sustainable production of red onion grown in Kalpitiya.

**Keywords:** Fertilizer, Groundwater Contamination, Nutrient Leaching, Sandy Regosols

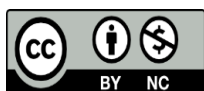
<sup>1</sup>Department of Plantation Management, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Sri Lanka.

<sup>2</sup>Department of Biotechnology, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Sri Lanka.

<sup>3</sup>Department of Biosystems Engineering, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Sri Lanka.

 \* Correspondence: @wyb.ac.lk

<https://orcid.org/0000-0002-7630-9894>



© The Author(s). This article is published under the Creative Commons Attribution License (CC 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

Fertilizer plays a significant role in increasing crop production while supporting to ensure food security in the world [1]. However, improper management and over usage of commercial fertilizers often lead to lower nutrient use efficiency, accumulation, and losses of nutrients from the soil. Leaching is the result of releasing ions in the soluble form and moving with percolating water. The magnitude of leaching loss is proportional to the element concentration in the soil and the amount of drained water. Nutrient leaching is becoming critically important due to the movement of nutrients out of the root zone, leading to an immediate loss of nutrients to crops and an economic loss to farmer. The nutrients applied to soil undergo a series of transformations by various physical, chemical, and biological processes within the soil, which make them available to crops as well as vulnerable to leaching losses [2].

Soil nutrient leaching is governed by various factors like soil type, available nutrient content, amount and intensity of rainfall, frequency of irrigation and the nature of the crop. Leaching of nutrients like nitrogen, potassium and phosphorus are a major environmental concern and cause potential risks to human health [2]. Overuse of fertilizers and consequent health and environmental issues have long been identified as major agriculture related environmental issues in many parts of the world, including Sri Lanka. The chemical fertilizer application rate has ranged from zero to 830% of the recommended level in different cropping systems in Sri Lanka [3]. Therefore, to fulfil the fertilizer requirement, Sri Lanka imports about 800 million kg of chemical fertilizers annually [4]. The usage of inorganic fertilizers has increased because of increased cropping intensity with high yielding varieties. Widespread and intensive use of inorganic fertilizers are common mainly in vegetable cultivation [5].

Kalpitiya is one of the highly productive agricultural areas of the country,

situated in North-Western Province of Sri Lanka, which contributes to a high percentage of vegetable and fruit production in the country [6]. Intensive agricultural practices and human settlements have already imposed a high demand for groundwater utilization in the Kalpitiya peninsula. Groundwater usage of the Kalpitiya peninsula is about 100% as there are no surface water resources available [6]. It is reported that the farmers devote around 35% of their cost of production for irrigation [7].

Sandy regosols is the dominant soil type in the peninsula, which is extremely permeable, consisting of 90-98% sand. Hence, drainage and water logging conditions are not major concerns in Kalpitiya. Farmers in Kalpitiya struggle with issues related to less water and nutrient retention, and low organic matter content in sandy soil. Due to this infertile nature of the soil, farmers apply excessive amounts of commercial fertilizer expecting better yields throughout the year. The agrochemicals which are used may not perform to their maximum potential in terms of crop development, since sandy Regosols are unable to retain more of them. Therefore, fertilizers leach into shallow groundwater sources due to the excess irrigation and causing a severe groundwater contamination level [8]. Therefore, attention of the responsible authorities should be placed on ways to improve the nutrient utilization efficiency and decrease nutrient leaching losses. For this, characterizing the exact nutrient leaching losses from different crops, which are widely cultivated in Kalpitiya, is essential. Hence, this study was conducted to quantify the nutrient leaching losses from red onion cultivation in Kalpitiya under grower-managed fertilizer practices compared to the Department of Agriculture (DoA) recommended practices.

## METHODOLOGY

### Study Location and Duration

The experiment was carried out in Kalpitiya peninsula as a field experiment within the period of 2021 to 2022. The experimental field

was located at an elevation of 1 m above the mean sea level. The site was established with lysimeters previously installed. The monthly mean temperature at Kalpitiya during the study period was 30 °C, while the mean monthly rainfall was 83 mm.

### Experimental Design

Leaching monitoring lysimeters each covering an area of 0.28 m<sup>2</sup> were installed at the experimental site, 90 cm below the soil surface. Jaffna local variety of red onion was taken as the planting material for the experiment. Six plots were prepared by 3 m\*2.4 m (7.2 m<sup>2</sup> plot) with two treatments replicated three times.

### Crop Establishment and Treatment Application

Prior to the planting of red onion bulbs, compost application was done at the rate of 10 t/ha for both treatments. Treatment 1 was applied with growers used rate of fertilizer, which was Urea- 100 kg/ha, TSP-250 kg/ha, Onion fertilizer (12:9:9-N: P: K)-125 kg/ha, Blue granules (12:12:7-N: P: K)-62 kg/ha and Calcium nitrate (N-15,5%, CaO-26%)-62 kg/ha applied at weekly intervals. Meanwhile, Treatment 2 was applied with the Department of Agriculture recommendation of fertilizer application (DoA) as shown in Table 1. According to the DoA recommendation, application of weedicides and the pesticides were done as needed. Irrigation was done two times per day, in the morning and evening using sprinklers.

**Table 1:** DoA Recommended Fertilizer Requirement of Red Onion in Kalpitiya

Fertilizer Application	Urea (kg/ha)	TSP (kg/ha)	MOP (kg/ha)
BD	68.5	100	50
TD 1 (3WAP)	65		
TD 2 (6WAP)	65		25

Note: BD- Basal Dressing, TD 1- First Top Dressing, TD 2- Second Top Dressing; TSP-Triple Super Phosphate, MOP- Muriate of Potash, WAP-Weeks after planting, DoA (Chemical fertilizer (100%) + Compost (10t/ha).

### Collection of Leachate Samples and Irrigation Water

Prior to planting, initial leachate samples were collected from each plot. For this, leachate samples from individual outlets of lysimeters were collected continuously using an electric pump. The volumes extracted from the lysimeters of each plot were recorded. Leachate samples were obtained at weekly intervals for analysis, which represented composite samples of the leachate that had drained for 7 days. In addition, irrigation water was also sampled weekly from the well throughout the cropping season.

### Analysis of Initial Soil Samples

Available phosphorus amount in soil was determined using the Sodium-bicarbonate extraction method [9]. The Kjeldhal method was used to determine the total nitrogen content in soil [10]. The soil exchangeable potassium, calcium and fluoride content were analysed using the Ammonium-Acetate extraction approach [11]. Further, the Walkley and Black method [12] was used to analyse the organic carbon content in soil. Soil pH and Electrical Conductivity (EC) were measured electrometrically, using a 1:5 soil-water suspension [13].

### Analysis of Leachate and Irrigation Water

NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, F<sup>-</sup> concentrations in the leachate as well as in the well water were determined using ion selective electrodes (CPI 505, Elmetron, Poland). K<sup>+</sup> and Ca<sup>2+</sup> concentrations were determined using a flame photometer (BWB-XP, UK). Available P in leachate was determined using the Sodium-bicarbonate extraction method [9].

### Statistical Analysis

For all the parameters, mean values ± Standard Deviation (SD) were calculated. The significance among the mean values of measured chemical parameters of two treatments were analyzed using the two-sample t-test. The R software package (version R 4.2.2) was used for the statistical analysis.

## RESULTS AND DISCUSSION

### Chemical Parameters of Soil

According to initial soil properties, the nutrient levels of the soil were very low, except for  $\text{Ca}^{+2}$ , indicating the need for an external supply (Table 2). Sandy Regosols in Kalpitiya contains a higher content of  $\text{Ca}^{+2}$  ions. This may be due to the deposition of tiny windblown shell fragments [14]. The mean pH of the initial soil was neutral, and the EC was  $39.46 \pm 3.58 \mu\text{S}/\text{cm}$ . Soil exchangeable  $\text{K}^+$  and  $\text{F}^-$  contents were  $6.5 \pm 0.25 \text{ mg}/\text{kg}$  and  $0.84 \pm 0.21 \text{ mg}/\text{kg}$ , respectively. Total N content of the soil was  $0.04 \pm 0.03 \text{ mg}/\text{kg}$ . Meanwhile, the mean soil available P level was as low as  $0.35 \pm 0.01 \text{ mg}/\text{kg}$ . It has been reported that most of the soils contain low concentrations of phosphorus in the soil solution, mainly due to poor solubility [15].

**Table 2:** Initial Soil Chemical Properties of the Experimental Site

Parameter	Mean $\pm$ SD
Soil pH (Soil : $\text{H}_2\text{O}$ = 1:5)	$7.17 \pm 0.02$
Electrical Conductivity ( $\mu\text{S}/\text{cm}$ )	$39.46 \pm 3.58$
Available P (mg/kg)	$0.35 \pm 0.01$
Exchangeable K (mg/kg)	$6.5 \pm 0.25$
Exchangeable Ca (mg/kg)	$608.7 \pm 64.7$
Exchangeable F (mg/kg)	$0.84 \pm 0.21$
Organic Carbon %	$0.135 \pm 0.05$
Total Nitrogen %	$0.04 \pm 0.03$

### Analysis of Leached Nitrate and Ammonium (kg/ha)

The average nitrate and ammonium concentrations of irrigation water were  $15.3 \text{ mg}/\text{l}$  and  $1.68 \text{ mg}/\text{l}$ , respectively. There were significant differences ( $P < 0.05$ ) among the mean values of cumulative nitrate leaching between the two treatments, throughout the cropping season (Table 3). Hydrolysis, volatilization, nitrification and denitrification are the main processes that decide the fate of applied urea in soil. Once urea is applied to soil, it hydrolyses to form  $\text{NH}_4^+$ . Nitrification converts  $\text{NH}_4^+$  into  $\text{NO}_2^-$  and subsequently, nitrite is transformed into  $\text{NO}_3^-$  [16]. Depending on the soil pH, moisture, and

fertilizer application methods, urea undergoes chemical transformation to produce either  $\text{NH}_4^+$  or  $\text{NO}_3^-$  [17]. Soils with high water infiltration rates and low water retention capacity are particularly conducive to nutrient leaching.

There were no significant differences ( $P < 0.05$ ) among the mean values of cumulative ammonium leaching between treatments, throughout the study period (Table 3). Because  $\text{NH}_4^+$  is positively charged, it is held by the negative sites of soils. Therefore,  $\text{NH}_4^+$  concentration in leachate was lesser than  $\text{NO}_3^-$  concentration in the leachate. The leaching loss of nitrogen through nitrogenous fertilizer can be reduced by minimizing the available amounts of  $\text{NH}_4^+$  and  $\text{NO}_3^-$  in the soil in at a given time [18], while supplying enough nitrogen to crops.

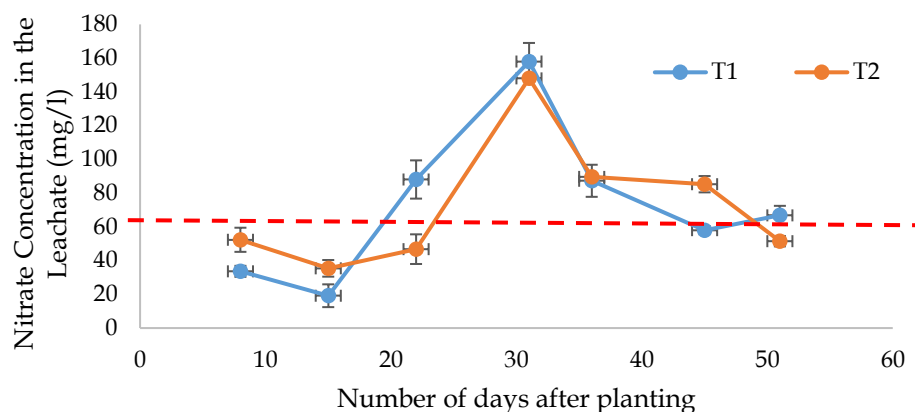
**Table 3:** The Cumulative Leached Nitrate and Ammonium (kg/ha) throughout the Season

Treatment	Mean Nitrate (kg/ha)	Mean Ammonium (kg/ha)
T1	$340.1^a \pm 21.4$	$9.2^a \pm 1.8$
T2	$311.4^b \pm 3.5$	$8.1^a \pm 0.9$

Note: Means with the same superscript letter in each column are not significant at  $P = 0.05$  level

### Concentration of Nitrate in the Leachate

The concentration of  $\text{NO}_3^-$  in both leachates fluctuated over the growing season (Figure 1). Both treatments showed higher concentration of nitrate in the leachate than the WHO recommended  $\text{NO}_3^-$  level for potable water ( $< 50 \text{ mg}/\text{l}$ ), as shown by the dashed line in Figure 1, especially in the latter part of the growing period. The rapid increase in leaching losses of nitrogen in the form of nitrate ( $\text{NO}_3^-$ -N) corresponded with the fertilizer application as shown in Figure 1, which was observed after a short duration from applying fertilizer (TD1 in 22 DAP). Furthermore, the T2 comparatively showed a higher concentration of nitrate ( $\text{NO}_3^-$ -N) in leachate up to 14 days, after application of basal dressing



**Figure 1:** The Temporal Variation of  $\text{NO}_3^-$  Concentration in the Leachate throughout the Cropping Season

**Table 4:** The Variation of Cumulative Leached Nutrients (kg/ha) from the Experimental Treatments throughout the Growing Season

Treatments	Nutrient			
	$\text{Ca}^{+2}$	$\text{K}^+$	P	$\text{F}^-$
T1	659.6 <sup>a</sup> ±17.7	72.1 <sup>a</sup> ±12.9	26.4 <sup>a</sup> ±1.7	4.9 <sup>a</sup> ±0.9
T2	524.3 <sup>b</sup> ±17.9	79.5 <sup>a</sup> ±12.1	11.9 <sup>b</sup> ±4.9	4.4 <sup>a</sup> ±0.9

Note: Means with the same superscript letter in each column are not significant at  $P=0.05$  level

#### Variation of Cumulative Leached Nutrients (kg/ha)

No significant differences ( $P<0.05$ ) were observed among the mean cumulative  $\text{K}^+$  levels in the leachates between treatments (Table 4). Substantially a higher cumulative leached  $\text{K}^+$  amount was observed in T2 (79.52±12.08 kg/ha), than T1 (72.06±12.96 kg/ha). This may be due to the application of muriate of potash as a potassium source for T2 at the basal dressing and top dressing 2. The  $\text{K}^+$  is usually leached in much smaller quantities than  $\text{Ca}^{+2}$ , when applied as fertilizer. Intensive cultivation without balanced application of potassic fertilizers into the soil could lead into gradual declining trends of potassium in soils [15]. Moreover, a higher cumulative  $\text{Ca}^{+2}$  amount was observed in the leachate of T1 (659.61±17.67kg/ha) compared to the leachate of T2 (524.28±17.97 kg/ha). Even though Calcium nitrate was applied for growers' application (T1), Ca application was not recommended in Department of Agriculture recommendation

(T2). Calcium is one of the elements that can be leached from agricultural soils in high amounts. The cation competition, especially between  $\text{Ca}^{+2}$  and  $\text{K}^+$  ions, plays an important role in determining the  $\text{Ca}^{+2}$  availability in soil solution and consequently to its leaching potential [14].

Similar to  $\text{Ca}^{+2}$ , the accumulation of phosphate was also significant in the leachate. The fertilizer treatments indicated a significant difference ( $P<0.05$ ) in the mean cumulative leached P levels, throughout the growing season. However, the highest cumulative leached P level was observed in T1 as 26.41±1.65kg/ha, while the leachate of T2 reported a P level of 11.94±4.93 kg/ha. Triple superphosphate was added as a P source for both T1 and T2 at the rates of 250 kg/ha and 100 kg/ha, respectively. Even though the agricultural lands in Kalpitiya have been fertilized for decades with phosphate fertilizers, the soil phosphate content of the study area remained low.



Phosphate is an immobile ion, and they react strongly with components on the surfaces of soil particles. Therefore, phosphate ions are very slow to move downward through the soil matrix with percolating water, thereby reducing the leaching losses [15].

Intense weathering of fluoride bearing rocks and minerals enhance the entry of fluoride into groundwater. When fluoride exceeds 1.5 mg/L in drinking water, it could cause dental fluorosis [19]. The average F<sup>-</sup> concentration of both treatments ranged from 0.26 mg/l to 1.84 mg/l. Leachates of both T1 and T2 showed lower concentration of F<sup>-</sup> than WHO recommended thresholds for potable water (<1.5 mg/l), except at few sampling points. The mean cumulative leached fluoride content of T1 and T2 were 4.95±0.86 kg/ha and 4.43±0.91 kg/ha, respectively. However, there was no significant difference in cumulative leached F<sup>-</sup> content between T1 and T2.

### CONCLUSIONS

Results revealed that, among all the tested elements, nitrogen remains as the critical element in terms of leaching and contamination of groundwater. The cumulative nitrate leached from grower's application was significantly higher, when comparing with the Department of Agriculture based fertilizer recommendation. Furthermore, the concentration of nitrate in leachate was above the accepted thresholds, irrespective of the treatments. Leaching of NO<sub>3</sub><sup>-</sup> is economically and environmentally undesirable. Therefore, findings of this study emphasize the pressing need for an improved nitrogen management strategy to ensure sustainable production of red onion in Kalpitiya.

### CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

### AUTHORS' CONTRIBUTIONS

GS: Conducted the investigations, data collection, statistical analysis, and prepared

the first draft of the manuscript; IH: Supervised the study and revised the manuscript; LU: Supervised the study and reviewed the manuscript; RG: supervised the study and coordinated the funding processes. All authors read and approved the manuscript.

### FUNDING

This research was funded by "Accelerating Higher Education Expansion and Development (AHEAD)" DOR No.51 grant awarded to Faculty of Agriculture and Plantation Management.

### ACKNOWLEDGEMENT

The authors wish to acknowledge the "Accelerating Higher Education Expansion and Development (AHEAD)" DOR No.51 (STEM) Grant (No 6026-LK/8743-LK) for providing financial assistance for the study.

### REFERENCES

- 1 De Silva LHN, Edirisinghe JC, Udayanga NW, Gimhani DR. farmer perception, environmental awareness, and overuse of fertilizer in Kalpitiya: A preliminary investigation using Bayesian Econometrics. *Applied Economics & Business*. 2020 Dec 30;4(1): 20-32
- 2 Rashmi I, Shirale A, Kartikha KS, Shinogi KC, Meena BP, Kala S. Leaching of plant nutrients from agricultural lands. In: *Essential Plant Nutrients: Uptake, Use Efficiency, and Management*; 2017:465-89.
- 3 Kendaragama KM. Crop growing environment in Sri Lanka with special emphasis on plant nutrient use. *J. Soil Sci. Soc. Sri Lanka*. 2006;18:1-8.
- 4 Department of Census and Statistics. Statistical Data Sheet - 2019, Department of Census and Statistics, Colombo. Retrieved from [http://www.statistics.gov.lk/DataSheet/2019DataSheet\\_En.pdf](http://www.statistics.gov.lk/DataSheet/2019DataSheet_En.pdf). 2019.
- 5 Padmajani MT, Aheeyar MM, Bandara MA. Assessment of pesticide usage in up-country vegetable farming in Sri Lanka. Colombo, Sri Lanka: Hector Kobbekaduwa Agrarian Research and

- Training Institute; 2014.
- 6 Jayasekera DL, Kaluarachchi JJ, Villholth KG. Groundwater stress and vulnerability in rural coastal aquifers under competing demands: a case study from Sri Lanka. *Environmental Monitoring and Assessment*. 2011 May;176:13-30.
  - 7 Melvani K, Chandrasekera K, Mudannayake R. The role of trees in the bioremediation of drinking water-a research experiment in Nawakkaduwa, Kalpitiya. In: *Proceedings of the 32<sup>nd</sup> WEDC, Loughborough University, United Kingdom*. 2006; 304-312.
  - 8 Aravinna AG. Assessment of impact of pesticides on water catchments and groundwater in some selected areas of Sri Lanka [Doctoral Dissertation]. University of Sri Jayewardenepura, Nugegoda; 2006.
  - 9 Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture; 1954.
  - 10 Bremner JM. Determination of nitrogen in soil by the Kjeldahl method. *The Journal of Agricultural Science*. 1960 Aug;55(1):11-33.
  - 11 Hanway JJ, Handy RL, Scott AD. Exchangeable potassium and clay minerals in selected Iowa soil profiles. In: *Proceedings of the Iowa Academy of Science*. 1960; 67(1): 215-231.
  - 12 Walkley A. An examination of methods for determining organic carbon and nitrogen in soils. *The Journal of Agricultural Science*. 1935 Oct;25(4):598-609.
  - 13 Dharmakeerthi RS, Indraratne SP, Kumaragamage D. *Manual of Soil Sampling and Analysis*. Soil Science Society of Sri Lanka, Peradeniya, Sri Lanka. 2007
  - 14 Lehmann J, Schroth G. Nutrient leaching. In: *Trees, crops and soil fertility*. CAB International 2003. 2003; 151-166.
  - 15 Weil RR, Bradley N. Phosphorous and potassium. In: *The Nature and Properties of Soils*. Columbus, OH, USA. 2017; 6433-695.
  - 16 Khalil MI, Gutser R, Schmidhalter U. Effects of urease and nitrification inhibitors added to urea on nitrous oxide emissions from a loess soil. *Journal of Plant Nutrition and Soil Science*. 2009 Oct;172(5):651-60.
  - 17 He ZL, Calvert DV, Alva AK, Li YC, Banks DJ. Clinoptilolite zeolite and cellulose amendments to reduce ammonia volatilization in a calcareous sandy soil. *Plant and soil*. 2002 Dec;247:253-260.
  - 18 Omar L, Ahmed OH, Majid NM. Improving ammonium and nitrate release from urea using clinoptilolite zeolite and compost produced from agricultural wastes. *The Scientific World Journal*. 2015 Jan 1;2015.
  - 19 Dharmagunawardhane HA, Dissanayaka CB. Fluoride problems in Sri Lanka. *J. Environmental Management and Health*. 1993; 14(2): 9-16.