Institute of Technology University of Moratuwa

Research Symposium

"Broadening Horizons"

ITUMRS2021

Volume: 8 ISSN: 2773-7055 Date: 29th Sept 2021

Proceedings of the 8th Annual Research Symposium

2021

Organized by
The Research Unit, ITUM

Wednesday 29th September 2021
Held online via Zoom

Institute of Technology University of Moratuwa

Research Symposium

"Broadening Horizons"

Proceedings of the

8th Annual Research Symposium – 2021

Organised by the

Research Unit, ITUM

Wednesday 29th September 2021

Held Online via Zoom

Institute of Technology University of Moratuwa

Research Symposium

"ITUMRS" proceedings book is an annual publication,
which carries the proceedings of the symposium conducted
for researchers, academicians, professional, practitioners and students
to impart and share knowledge in a variety of fields.

This book contains the extended abstracts of papers

presented at the 8th Research Symposium of the

Institute of Technology University of Moratuwa, Sri Lanka

held on 29th September 2021.

ISSN: 2773-7055

Editorial Committee

Mrs. S. Nagodavithana

Dr. (Mrs.) N.P.K. Semananda

Dr. (Mrs.) G.D.M.N. Samaradiwakara

Mrs. P. B. T.K. Premarathna

Mrs. H.A.S.L. Amarasinghe

Compiled by:

Mr. L.A.D.S. Nayanajith

Conference Committee

Dr. (Mrs.) W. P.S. K. Perera

Dr. (Mrs.) S.C. Mathugama

Dr. P.D.C. Kumara

Dr. (Mrs.) G.D.M.N. Samaradiwakara

Eng. (Mrs.) D.Y.T. Bambarawanage

Eng. K. Jinadasa

Mrs. I.R. Samarathunga

Mr. M.I.M. Amjath

Mrs. H.D. Wijerathne

Ms. W. V. W. H. Wickramaarachchi

Ms. G.K.P. John

Technical Session Coordinators

Dr. (Mrs.) K. Galappaththi

Mr. M.I.M. Amjath

Mrs. A.U.P. Athukorala

Mrs. H.M. Jayathilaka

Mrs. M.V. P.T. Lakshika

Mrs. D.A.S. Ruwanmini

Mrs. M. Dashantha

List of Reviewers

Abeysooriya Dr. R.P.	Dept. of Textile and Clothing Technology, Faculty of Engineering, University of Moratuwa
Alahakoon Dr. C.	Main Library, University of Peradeniya
Bambaravanage (Eng.) Mrs. D.Y.T.	Division of Electrical, Electronics and Telecommunication Technology, Institute of Technology, University of Moratuwa
Bandara Dr. M.M.H.W.	Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa
Chinthaka Prof. S.D.M.	Dept of Chemistry, Faculty of Applied Science, University of Sri Jayewardenepura
De Silva Dr. R.K.J.	Dept. of Textile and Clothing Technology, Faculty of Engineering, University of Moratuwa
Dissanayake Dr. D.G.K.	Dept. of Textile and Clothing Technology, Faculty of Engineering, University of Moratuwa
Edirisinghe Dr. D.	Dept. of Rubber Technology & Development Rubber Research Institute, Ratmalana
Egodage Prof. S. M.	Dept. of Chemical and Process Engineering, Faculty of Engineering, University of Moratuwa
Ekanayake Dr. D.	Marquette University, Milwaukee, USA
Galappaththi Dr. K.	Division of Information Technology, Institute of Technology, University of Moratuwa
Ganegoda Dr. N.C.	Dept. of Mathematics, Faculty of Applied Sciences, University of Sri Jayewardenepura
Hewa Dr. G.A.	University of South Australia, Adelaide, Australia
Harshani Dr. P.G.T.	Dept. of Mathematics, Faculty of Applied Sciences, University of Sri Jayewardenepura
Hemapala Prof. K.T.M.U.	Dept of Electrical Engineering, Faculty of Engineering, University of Moratuwa
Hewage Dr. S.	Dept. of Civil Engineering, Faculty of Engineering, University of Moratuwa
Jayasundara Mrs. D. R. T.	Dept. of Mathematics, Faculty of Engineering, University of Moratuwa
Jinasena Dr. T.M.K.K.	Dept. of Computer Science, Faculty of Applied Sciences, University of Sri Jayewardenepura
Ketheesan Dr. T.	Dept. of Physical Sciences, University of Jaffna
Kandamby Mrs. G.W.T.C.	Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa
Kumara Dr. P.D.C.	Division of Mechanical Engineering Technology, Institute of Technology, University of Moratuwa
Maduranga Mr. W.L.S.	Division of Civil Engineering Technology, Institute of technology, University of Moratuwa

Majeed Prof. M.A.	Dept. of Mechanical Engineering, Faculty of Engineering, South Eastern University
Manathunga Prof. J	Dept. of Civil Engineering, Faculty of Engineering, University of Moratuwa
Mathugama Dr.S.C.	Division of Interdisciplinary Studies, Institute of technology, University of Moratuwa
Nagulan Dr. R.	Dept. of Physical Science, Vavuniya Campus, University of Jaffna
Nanayakkara Mr. G.D.	Division of Electrical, Electronics and Telecommunication Technology, Institute of Technology, University of Moratuwa
Pannilawithana Dr. N.	Marquette University, Milwaukee, USA
Pathirana Prof. C. D.	Dept of Electrical Engineering, Faculty of Engineering, University of Moratuwa
Perera Dr. S.G.J.	Division of Chemical and Polymer Engineering Technology, Institute of Technology, University of Moratuwa
Perera Dr. W.P.S.K.	Division of Textile and Clothing Technology, Institute of Technology, University of Moratuwa
Priyadarshana Dr. G. I.	Dept. of Materials and Mechanical Technology, Faculty of Technology, University of Sri Jayewardenepura
Ramasinghe Ms. R.L.P.	Division of Chemical and Polymer Engineering Technology, Institute of Technology, University of Moratuwa
Samaradiwakara Dr. G.D.M.N.	Library, University of Sri Jayewardenepura.
Samarathunga Mrs I.R.	Division of Chemical and Polymer Engineering Technology, Institute of technology, University of Moratuwa
Samarawickrama M.N.C.	Dept. of Civil Engineering, Faculty of Engineering, The Open University of Sri Lanka
Sandaruwan Mr. C.	Sri Lanka Institute of Nanotechnology
Saparamadu Dr. D.D.G.A.D.S.	Division of Interdisciplinary Studies, Institute of technology, University of Moratuwa
Senthooran Mr. V.	Dept. of Information and Communication Technology, Vavuniya Campus, University of Jaffna
Sethunga Dr. G.S.M.D.P.	Dept. of Chemical and Process Engineering, Faculty of Engineering, University of Moratuwa
Sitinamaluwa Dr. H.	Dept. of Materials Science and Engineering Faculty of Engineering, University of Moratuwa
Somarathne Dr. M.C.W.	Division of Chemical and Polymer Engineering Technology, Institute of Technology, University of Moratuwa
Thisera Dr. N.	Sri Lanka Institute of Nanotechnology
Thoradeniya Dr. W.B.M.	Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa
Wickramaarachchi Dr. C.	Dept. of Statistics, Faculty of Applied Sciences, University of Sri Jayewardenepura
Wijesena Dr. R.	Sri Lanka Institute of Nanotechnology

MESSAGE FROM THE DIRECTOR, ITUM

It is my pleasure and privilege to send this message with my good wishes to the book of proceedings published on the event of the Annual Research Symposium of the Institute of Technology University of Moratuwa.

Even though the research symposium is an important annual event of the ITUM, it was unfortunate that it could not be held in the year 2020, due to the adverse health conditions prevailing in the country. However, the members of the newly appointed Research Unit were able to restructure and introduce a new mechanism for research activities at ITUM and a new format for the research symposium, broadening its purview.

I am impressed that the Research Unit of ITUM, headed by Dr. (Mrs.) W. P. S. K. Perera has taken a keen interest and the leadership to organize the symposium for the year 2021 to showcase the research talents of the ITUM staff and even to extend its purview to include participants from other universities and educational institutes as well as researchers from the industry to engage in this knowledge sharing session to present and discuss their research findings. This initiative will pave the way for new academic staff members as well as students of the ITUM to develop an enthusiasm for research.

I am extremely grateful to the Research Unit of ITUM for their untiring effort and to all those who have contributed in numerous ways to make this event a success.

Wish you all the Best.

Major General (Retd.) S. K. Thirunavukarasu RSP VSV USP,

Director,

Institute of Technology,

University of Moratuwa.

MESSAGE FROM THE CHAIRPERSON, RESEARCH UNIT

On behalf of the ITUM Research Unit, I am pleased to welcome all the participants to the Institute of Technology, University of Moratuwa Research Symposium 2021 (ITUMRS2021).

After eight successful research symposiums, ITUMRS2021 is now broadening its horizons to attract researchers from all parts of the country, for the first time. The symposium this time will be a forum for oral presentations not only from the disciplines coming under the eight academic divisions of ITUM, but also from other Technology and Engineering related disciplines from other Universities and Institutes in Sri Lanka.

On behalf of the organizing committee, I wish to convey my gratitude to the Dean of the Faculty of Graduate Studies, Prof. Ajith De Alwis of the University of Moratuwa for accepting our invitation to deliver the keynote speech and the Head of the Division of Information Technology, ITUM, Dr. (Mrs.) Kalpana Galappaththi for delivering the special speech.

I appreciate with gratitude the support and valuable guidance given by the Director of ITUM, Major General (Retd.) S. K. Thirunavukarasu. The dedication and support of the organizing committee contributed immensely towards making ITUMRS2021 another successful landmark in our efforts towards achieving research excellence. I also wish to thank the former acting Assistant Librarian of ITUM, Dr. (Mrs.) G.D.M.N. Samaradiwakara and the former Chairperson of the ITUM Research Committee, Dr. (Mrs.) S.C. Mathugama for their encouragement and guidance throughout.

On behalf of the organizing committee, I must express my deep appreciation to all those who contributed tirelessly towards this endeavour, including the editorial committee and the panel of reviewers for their unstinting and untiring efforts. Further, the immense support given by the IT Division of ITUM in conducting this online symposium successfully, and the valuable guidance given by the Senior Assistant Bursar of ITUM in managing ITUMRS finances is highly appreciated.

Finally, I would like to convey my heartiest gratitude to all the researchers who took an extra effort to present their findings in this online symposium via the zoom platform in these trying times.

I hope that the ITUMRS2021 will be a rewarding experience for both the presenters and the participants alike.

Dr. (Mrs.) W. P. S. K. Perera,
Head, ITUM Research Unit

FOREWORD

The Institute of Technology University of Moratuwa (ITUM), research symposium was launched in the year 2013 with the intention of enhancing the ITUM research culture, and since then has become an annual event in the ITUM event Calendar. From its inception, the ITUM research committee has successfully organized seven research symposiums till the year 2019 under the guidance of three chairpersons Dr. A.M. Muzathik, Mrs. P. S. Yatapana and Dr. (Mrs.) S.C. Mathugama, providing an opportunity for ITUM staff to document and discuss multifaceted and subject related research projects carried out by them. The BOS appointed Research Committee of ITUM organized and hosted this annual symposium till the year 2019.

In the year 2019, a limited number of spaces in the research symposium was opened to researchers from the industry, with the objective of giving them the opportunity to share their professional experiences in industry related research with ITUM staff.

The establishment of the Research Unit (ITUMRU) at ITUM in the year 2020 has made it possible to stretch ITUM research limits to a new level. The ITUMRU decided to open the ITUM research symposium 2021 to encompass researchers from other higher educational institutes and universities in Sri Lanka and also from the industry and invited them to share their research experiences in different technology related areas with ITUM staff. Thus, a total of 30 research projects were selected for presentation this year, after reviewing the extended abstracts. Further, we are delighted to present to you the ITUMRS2021 book of proceedings with an ISSN number, this year.

We take this opportunity to thank everyone who contributed passionately and enthusiastically to make this event a success.

Thank you.

ITUM Research Unit

ONLINE PROGRAMME

Research Symposium

on the theme,

"*Broadening Horizons*"

Organized by

the Research Unit, Institute of Technology University of Moratuwa (ITUM)

Wednesday 29th September 2021

Online via Zoom

https://learn.zoom.us/j/67554369484?pwd=WmNVczdvVTJyeHE5RERSOVZVSVJHdz09

08.45 to 08.55 AM	Registration & related Inquiries
08.55 to 09.00 AM	Conference Announcements
09.00 to 09.05 AM	Welcome Address by Dr. Srimala Perera, Head, Research Unit, ITUM
09.05 to 09.10 AM	Address by the Director of ITUM
09.10 to 09.40 AM	Keynote speech, Prof. Ajith De Alwis Dean, Faculty of Graduate Studies, University of Moratuwa
09.40 to 09.45 AM	Short Video presentation by Tee Jay Lanka PLC, sponsor ITUMRS2021
09.45 to 10.00 AM	Special speech, Dr. Kalpana Galappaththi, Head of the Division of Information Technology, ITUM
10.00 to 10.05 AM	Vote of Thanks
10.10 to 11.40 AM	**Technical Sessions** Presentations & discussions of peer-reviewed papers(online: 3 parallel sessions: 18 papers) Session 1, Session 2, Session 3
11:45 to 13:15 PM	**Technical Sessions** Presentations & discussions of peer-reviewed papers (online: 2 parallel sessions: 12 papers) Session 4, Session 5
13.20 PM	Invite to fill feedback End of Session.

ITUM Research Symposium, September 29th 2021 - SESSION PLAN

	SESSION 1	SESSION 2	SESSION 3
Zoom Link	https://learn.zoom.us/j/61612801142?pwd=cmdnUXFsbU9SVkVYMXdMU0VuUzYzdz09	https://learn.zoom.us/j/68490847285?pwd=WEpHQ2IvTnRtbHdzWm5GMFR5UW9Zdz09	https://learn.zoom.us/j/66854990984?pwd=NDVpR3EwU3g4eW85c002Tno4a3ZDUT09
Session Chair	***Dr. Samanthi Mathugama***	***Dr. Premila Semananda***	***Dr. Chandani Somarathna***
Time	**PAPER TITLE**, author(s), **Page numbers**	**PAPER TITLE**, author(s), **Page numbers**	**PAPER TITLE**, author(s), **Page numbers**
10.10 - 10.25 am	**THE RELATIONSHIP BETWEEN STUDENTS' PERFORMANCE IN CONTINUOUS ASSESSMENTS AND SUMMATIVE ASSESSMENTS: A CASE STUDY AT THE UNIVERSITY OF VOCATIONAL TECHNOLOGY** Suraweera D.D.D. & Alahapperuma K.G. **P-2**	**APPLICABILITY OF THE PLATE BEARING TEST IN THE PREDICTION OF DEFORMATION CHARACTERISTICS OF SHALLOW FOUNDATIONS** S. Kartheepan & L. I. N. de Silva **P-27**	**ENHANCEMENT OF THERMAL CONDUCTIVITY OF GRAPHITE FILLED NATURAL RUBBER LATEX DIPPED COMPOSITES** Gamlath G.R.V.S. & Etampawala T.N.B. **P-51**
10.25-10.40 am	**EVALUATION OF THE SUITABILITY OF THE METHODS OF ASSESSMENT USED TO QUANTIFY STUDENTS' ACHIEVEMENT OF LEARNING OUTCOMES IN ENGINEERING TECHNOLOGY EDUCATION** Samarasekara M. M. P. D. **P-6**	**ESTIMATION OF PARAMETERS OF THE 'abcd' MONTHLY WATER BALANCE MODEL FOR KALU AND GIN RIVER BASINS IN SRI LANKA** Gunasekara D.N. & Rajapakse R. L. H. L. **P-31**	**INVESTIGATION OF OPTIMUM DICYMUL PEROXIDE LOADING FOR THERMOPLASTIC VULCANIZATE FROM NATURAL RUBBER/HIGH DENSITY POLYETHYLENE FOR ROOFING APPLICATION** Wickramaarachchi W.V.W.H., Walpalage S. & Egodage S.M. **P-55**
10.40 - 10.55 am	**A CASE STUDY ON DIFFERENT APPROACHES USED IN THE ONLINE TEACHING AND LEARNING PROCESS TO FACILITATE SUSTAINABLE DEVELOPMENT GOALS (SDGs) IN DISTANCE LEARNING DURING THE COVID -19 PANDEMIC** Kuruppu K.A.D.D. **P-10**	**EFFECT OF INDOOR AIR QUALITY IN CLOSED SPACES FOR HUMAN COMFORT** Weerakoon W.M.D.S., Kumari P.A.C.S. & Suraweera D.D.D. **P-35**	**STUDY OF THE DETERIORATION OF MECHANICAL PROPERTIES OF POLYPROPYLENE SHEETS UNDER SRI LANKAN OUTDOOR ENVIRONMENTAL CONDITIONS** Alahapperuma K.G. **P-60**
10.55-11.10 am	**TECHNOLOGY STUDENTS' PERCEPTIONS OF THE HUMANITIES MODULES: A CASE STUDY OF NDT STUDENTS AT ITUM** Bandara J.A.S.D., Kumarasiri L.P., Iroshani W.E., Chathurangi A.K.D.K. & Samaraweera S.A.I.M. **P-13**	**SEASONAL VARIATIONS OF GROUNDWATER PH VALUE: INTERIM RESULTS OF A CASE STUDY IN GAMPAHA DISTRICT** Bulathsinhala A.U.V. B., Udayangana P. M. B. M. & Thoradeniya W. B. M **P-39**	**IMPLEMENTATION OF A NOVEL PROCESSING METHOD TO REDUCE CLAY AGGEGATION OF NATURAL RUBBER-CLAY NANOCOMPOSITE TO IMPROVE MECHANICAL PROPERTIES** Perera S., Egodage S. & Walpalage S. **P-64**

	SESSION 1	SESSION 2	SESSION 3
11.10-11.25 am	**AN ANALYSIS OF MENTAL STRESS OF EMPLOYED UNIVERSITY STUDENTS: A CASE STUDY OF STUDENTS OF THE UNIVERSITY OF VOCATIONAL TECHNOLOGY** Alahapperuma K.G. & Jayasekera B.M.T.D. **P-17**	**ATTITUDES TOWARDS THE GREEN SUPPLY CHAIN MANAGEMENT: A CASE STUDY ON MANUFACTURING AND AGRICULTURAL SECTORS IN SRI LANKA** Shisara M.A.K.K. & Wijewardana Y.N.S. **P-43**	**MODIFIED SILICA AND MULTI WALLED CARBON NANOTUBES AS ADDITIVES FOR ENHANCEMENT OF THERMAL CONDUCTIVITY OFNON-MARKING TYRE COMPOUNDS** Jayawardane Y.W. & Etampawala T.N.B. **P-69**
11.25-11.40 am	**STUDENTS' BEHAVIOR DUE TO RAGGING IN SRI LANKAN UNIVERSITIES WITH CULTIC ENVIRONMENTS & FINDING MEASURES FOR ERADICATING RAGGING: A REVIEW ARTICLE** Yatapana P. S. & Samaradiwakara G.D.M.N. **P-21**	**AREAS TO BE INVESTIGATED TO IMPROVE THE RELIABILITY OF THE RESULTS OF THE CROSS-HOLE SONIC LOGGING TEST** Priyankara W.M.D. **P-47**	**3D FINITE ELEMENT SIMULATION OF A SOLID RESILIENT TIRE FOR IMPACT ANALYSIS** Premarathna W.A.A.S., Jayasinghe J.A.S.C., Gamage P. &. Ranatunga R.R.M.S.K. **P-74**

	SESSION 4	SESSION 5
Zoom Link	https://learn.zoom.us/j/64658939322?pwd=RjBXSFk4MmY5TGdrc010UVFlVWtUUT09	https://learn.zoom.us/j/66387039315?pwd=bGV4ZGtjcGRXbjUzYUdrMnNrNm5JQT09
Session Chair	***Dr. Gimhani Madhushika***	***Dr. Kalpana Galappaththi***
Time	**PAPER TITLE,** author(s)**, Page numbers**	**PAPER TITLE,** author(s)**, Page numbers**
11.45 – 12.00 pm	**EXFOLIATION OF GRAPHITE INTO FEW-LAYER GRAPHENE USING DIFFERENT TYPES OF BLACK TEA AS SURFACTANT** Gamachchi G.G.D.M.G., Thennakoon T.M.A.A.B., Pemasiri[1] B.M.K. & Bandara T.M.W.J. **P-79**	**CLUSTERING ONLINE RETAIL DATA SET** Uduweriya R.M.B.P.M.[1] & Napagoda N.A.D.N. **P-106**
12.00 - 12.15 pm	**EFFECT OF CARBONIZATION CONDITIONS OF COCONUT SHELL CHARCOAL ON COLOR REMOVAL USING ADSORPTION IN WASTEWATER TREATMENT** Jayakody J.K.G.N., Manchanayake M.D.A.S., Hettiarachchi H.A.I.S., Karunaratne D.R.M.A., Ranwala, R.D.S., Aluthgama K.D.G.M. & Jayatunga G.K. **P-83**	**CRITICAL HURDLES OF BLOCKCHAIN ADAPTATION TOWARDS IMPROVING SUPPLY CHAIN INFORMATION SHARING** Dhananjaya D.D. & Balachandra K.M. **P-110**
12.15 - 12.30 pm	**MULTI-WALLED CARBON NANOTUBE SENSOR FOR DETECTINGPHTHALATES IN SOLUTIONS** Abeysinghe H., Etampawala N.B.T., Perera V.P.S., Wikramasinghe G. **P-87**	**DESIGN A CLUSTER BASED SMART MICRO-GRID CONTROL ALGORITH VIA HVDC LINE** Jayasekara M.J.A.M.S.S., Bandara K.V.D.K., Kariapper M.H.M.S., Juhaniya A.I.S. & Aashi.M.N.M. **P-115**

12.30 - 12.45 pm	**THE EFFECT OF A TYPE OF ELECTRON DONOR ON SULFATE REDUCTION** Samarathunga I.R. & Rathnasiri P.G. **P-92**	**STATISTICAL MODELS FOR LONG TERM TRAFFIC IN ENTERPRISE NETWORKS** Atugoda A.W.C. K. & Premarathna M.A.U. K. **P-120**
12.45 - 1.00 pm	**IMPACT OF THE QUALITY OF WASTE COOKING OIL ON BIODIESEL PRODUCTION** Thilakarathne D., Arachchige U.S.P.R., Jayasinghe R.A., Weerasekara N.A. & Miyuranga K.A.V. **P-97**	**CHARACTERISTIC EVALUATION OF PID CONTROL USING A DC MOTOR AS A DEMONSTRATION DEVICE** Gamage M.D.G.M., Arumathanthri R.B. & Gunasekara J.M.P. **P-124**
1.00 - 1.15 pm	**A COMPARATIVE STUDY OF GREEN RATING SYSTEMS IN JAPAN, SINGAPORE AND MALAYSIA WITH RESPECT TO CHARACTERISTICS OF GREENSL RATING IN SRI LANKA** Jayasooriya J.M.S.N. & Denagama T.D. **P-101**	

CONTENTS

Presentation of Extended Abstracts

Session 01

THE RELATIONSHIP BETWEEN STUDENTS' PERFORMANCE IN CONTINUOUS ASSESSMENTS AND SUMMATIVE ASSESSMENTS: A CASE STUDY AT THE UNIVERSITY OF VOCATIONAL TECHNOLOGY

Suraweera D.D.D.[1], Alahapperuma K.G.[2]

[1]Department of Electrical and Electronics
University of Vocational Technology, Sri Lanka
dimuthusiri@gmail.com

[2]Department of Mechanical and Manufacturing Technology,
University of Vocational Technology, Sri Lanka
gayanthi111@yahoo.com

ABSTRACT: Universities and higher educational institutions use Continuous Assessments (CA) to assess students' performances. CA comprises different assessments such as in–class assessments and take home assignments, given throughout a semester. Although the main purpose of CA is to measure students' progression, a certain percentage of marks obtained for the CA is used in calculating students' final performance in addition to the marks they obtain for the Summative Assessments (SA) conducted at the end of the semester. Therefore, if the CA fulfill their intention, there should be an improvement in students' performances. Also, the assumption is that, students who do well in the CA will do well in the SA as well. This study attempted to ascertain whether there is a relationship between the CA marks and the SA marks of the students following the Bachelor of Technology (B. Tech.) degree at the University of Vocational Technology (UoVT). The study employed an ex-post facto research design, and the Pearson's product moment correlation coefficient was used to measure the relationship. Results of thirteen modules common to the two fields of Manufacturing Technology and Mechatronics Technology of the 2017/2018 intake in the first and second semesters, were selected for analysis. The findings indicate a very high correlation in one module, a high correlation in two modules, a moderate correlation in five modules, a low correlation in three modules, a negligible positive correlation in one module and a negligible negative correlation in the other, when interpreted according to Guildford's rule of thumb. However, correlations of ten out of thirteen modules were significant at 0.05 level. Accordingly, it is recommended that the CA should be thoughtfully considered by both the lecturers and the students as they could be used to enhance and predict future academic performances of students.

Keywords: Continuous assessments; Students' performance; Summative assessments.

1. INTRODUCTION

With the introduction of the semester system in the higher education arena of Sri Lanka, Continuous Assessments (CA) became a mode of assessment of students' performance at higher educational institutions. CA comprises of different individual or group activities such as take home or in-class assignments. When calculating the final mark of a student in a module of study, 30% to 60% of marks are taken from the CA. (UoVT, 2010a; 2010b). There are different definitions available for CA, and CA are referred to as "assessment for learning" and the Summative Assessments (SA) are referred to as "assessment of learning" (Hernandez, 2012).

According to a study conducted, in a Nigerien university context, it was found that there is a significant relationship between the CA and the SA (Bitchi & Musa, 2015). Similar results were found by a study conducted at the University of Mauritius (Pudaruth et.al, 2013). However, according to a study conducted at the Spanish Public University, the CA were not found to be a good predictor of final performance of students for the reason that when students receive high marks for the CA of a module, they tend to pay less attention to that module in the SA due to being overconfident, with the exception of those who get very high marks (Reboredo, 2017).

However, the relationship between students' performance in these two modes of assessments has not received much attention in the Sri Lankan higher education context. Therefore, there is a gap in the literature in relation to studies that compare how well student perform in the CA and the SA in relation

to each other. If the CA are to fulfill their intentions the assumption is that they should improve students' overall performance as well. Hence, it is hypothesized that the students who perform well in the CA also performs well in the SA.

This study attempted to investigate whether there is a relationship between the CA marks and the SA marks of students who are following the B. Tech. Degrees at the UoVT.

2. METHODOLOGY

The study was conducted as a correlational study using an ex post facto research design, employing secondary data published by the Examination Division of the university. First and second semester modules common to both Manufacturing Technology and Mechatronics Technology of the B. Tech. degree program were selected as the sample, which consisted of thirteen modules; seven from the first semester and six from the second semester. Official approval was obtained from the university to use the results of the 2017/2018 intake for the study.

Data analysis was done using the Statistical Package for Social Science (SPSS) software. Pearson's product moment correlation coefficient was calculated to ascertain the relationship (Sekaran, 2003). Guildford's rule of thumb, given in table 1 was used to interpret the strength of the correlations (Guildford, 1973). Significance of correlations were tested at 0.05 level.

Table 1: Guildford's (1973) rule of thumb for interpretation of Pearson's correlation coefficient (r)

Range of values	Nature of the correlation
< 0.2	Negligible positive/negative correlation
0.2-0.4	Low positive/negative correlation
0.4-0.7	Moderate positive/negative correlation
0.7-0.9	High positive/negative correlation
> 0.9	Very high positive/negative correlation

3. RESULTS AND DISCUSSION

Correlations found for the modules of the first semester are given in table 2. According to the findings, there exists a very high correlation between student s' performance in the CA and their performance in the SA, in the module of Engineering Mathematics-1. A high correlation was observed in the module of Workshop Technology, moderate correlations were observed in the modules of Theory of Electricity, Communication Skills–1, Engineering Physics and Engineering Drawing, while the observed correlation between the CA and the SA is low in the module of Principles of Electronics when interpreted as per Guildford's rule of thumb. All these correlations were found as significant, at 0.05 level.

Table 2: Pearson's Correlation (r) between CA and SA in the first semester modules

Module name	Engineering Mathematics- I	Engineering Physics	Engineering Drawing	Principles of Electronics	Theory of Electricity	Communication Skills - I	Workshop Technology
r	0.922*	0.432*	0.447*	0.316*	0.592*	0.650*	0.746*
p	.000	.001	.000	.008	.000	.000	.000
N	68	54	62	70	58	71	62

Note: N = Number of students

*Correlation is significant at level of 0.05 (two tailed)

Table 3 illustrates the correlation coefficients of modules of the second semester.

Results show a high correlation between students' performance in the CA and their performance in the SA, in the module of Engineering Mathematics-II and a moderate correlation in the module of Electrical Technology. However, the module of Communication Skills -11 showed a negligible negative correlation between the CA and the SA. Correlations for the modules of Engineering Mathematics–11, Electrical Technology and Thermodynamics were only found to be significant at 0.05 level. The modules of Thermodynamics and Strength of Materials showed a low correlation while the correlation observed in the module of Engineering Mechanics was found to be negligible.

Table 3: Pearson's Correlation (r) between CA and SA of the second semester modules

Module name	Electrical Technology	Communication Skills - II	Engineering Mathematics II	Thermodynamics	Strength of Materials	Engineering Mechanics
R	0.658*	-0.034	0.856*	0.355*	0.224	0.179
P	.000	.801	.000	.000	.069	.0179
N	46	57	68	64	67	63

Note: N = Number of students

*Correlation is significant at the level of 0.05 (two tailed)

As per the findings, high values of Pearson's correlation coefficient, at 0.05 level of significance exist between the CA and the SA in ten out of thirteen modules. Further, in the case of the modules of Communication Skills-11, Strength of Materials and Engineering Mechanics, a detailed study is needed to identify the factors that lead to a weak correlation between the CA and the SA.

Based on the above, CA can be identified as a good predictor of students' performance in the SA, and hence the overall performance in the modules.

4. CONCLUSION

According to the findings of the study, it can be concluded that CA are a good predictor of students' performance in the SA. Therefore. lecturers as well as students should give due consideration for the CA in order to enhance students' performance.

5. REFERENCES

Bitchi, A.A & Musa, A (2015*). Assessing the correlation between continuous cssessment and examination scores of education courses*. Retrieved January 31, 2021, from https://www.researchgate.net/publication/277816951.

Guilford, J. P. & Fruchter, B. (1973). *Fundamental statistics in psychology and education* (5th ed). New York: McGraw-Hill.

Hernandez, R. (2012). *Does continuous assessment in higher education support student learning? High Educ(2012)*.Retrieved from http:/eprints.teachingandlearning,ie/2489/1/Hernandez%202012.

Pudaruth, S., Moloo, R., Chiniah, A., Sungkur, R., Nagowah, L., & Kishnah, S. (2013). *The impact of continuous assessments on the final marks of computer science modules at the University of Mauritius*. Retrieved January 31, 2021, from ttps://www.academia.edu/33290618/.

Reboredo, J.C (2017). *Do continuous assessment results affect final exam outcomes? Evidence from a microeconomics course*. Retrieved February 04, 2021, from http://polipapers.upv.es/index.php/MUSE/.

Sekaran, U. (2003). *Research methods for business*: *A skill-building approach.* New York: John Wiley & Sons.

University of Vocational Technology (UoVT). (2010). *Student hand book – Manufacturing Technology,* Department of Manufacturing Technology.

University of Vocational Technology (UoVT). (2010). *Student hand book – Mechatronics Technology,* Department of Electrical and Electronics Technology.

EVALUATION OF THE SUITABILITY OF THE METHODS OF ASSESSMENT USED TO QUANTIFY STUDENTS' ACHIEVEMENT OF LEARNING OUTCOMES IN ENGINEERING TECHNOLOGY EDUCATION

Samarasekara M.M.P.D.[1]

[1]Division of Civil Engineering Technology
Institute of Technology, University of Moratuwa, Sri Lanka
priyan0506@gmail.com

ABSTRACT: Engineering Technology education programs are designed and developed, incorporating attributes such as knowledge, skills and attitudes. These attributes are incorporated in such programs by forming program outcomes. The program outcomes are linked to the program curricula through the learning outcomes of modules. Quantification of learning outcomes achieved at the completion of a program are carried out by assessments. This study was conducted to analyze the suitability of methods of assessments included in the test module to quantify the achievement of learning outcomes. The analysis concludes that the assessment marks obtained by the students in the test sample represent the achievement of set learning outcomes in the test module.

Keywords: Attributes, Program outcomes, Learning outcomes, Assessments

1. INTRODUCTION

The ever-increasing competitiveness, due to the limited opportunities available in the industry,has contributed to the importance of possessing attributes such as knowledge, skills and attitudes by the employment seekers. Hence Engineering Technology education programs are designed and developed, incorporating such attributes (Subheesh and Sethy, 2020). These education programs have set program outcomes (PO) which are direct measurements of knowledge, skills and attitudes the students should have at the completion of the program.

The program outcomes are linked to the program curricula through the learning outcomes (LO)of modules which are broad statements of what students should be able to do at the completion of the module (Kulkarni and Barot, 2019). Quantification of what the students are capable of doing at the end of the module are carried out by assessments. Assessments are included in the curricula to measure the teaching – learning process or the students' achievement of LOs. The assessment conducted to quantify the achievement of LOs will also measure the achievementof the generic attributes of Engineering Technology education.

The National Diploma in Technology (NDT) Program in Civil Engineering Technology, which is the program considered in this study, was earlier conducted as a program with 02 academic years and 01 industrial training year. It was converted to a program with 04 academic semesters and 02 industrial training semesters, a few years ago. During this conversion, the attributes of Engineering Technology education: knowledge, skills and attitudes were explicitly incorporated into the program curricula through the learning outcomes of all modules.

Engineering technology education uses both formative and summative assessments. Both types can be made effective by considering the learning outcomes and learning activities, the purpose of the assessment, time of assessment, moderation of marking, student workload and class size (http://e3R.cetl.hku.hk, 2017). A combination of continuous assessments and semester-end assessments was used to measure the achievement of LOs in the test module on Soil Mechanics and Geology, selected as the case study. The objective of this study was to analyze the suitability of methods of assessments included in the test module to quantify the achievement of LOs.

2. METHODOLOGY

The test module on Soil Mechanics and Geology considered in this study was selected from the NDT second year, semester 3 curriculum. The test sample consisted of 118 students who were in semester 3 of the NDT second year Civil Engineering Technology study program.

This study is to be conducted as a continuing process of analyzing students' performance andthe improvements made in the assessments leading to further analysis and improvement until a direct relationship is obtained between the method of assessment/s of a module and the students' achievement of LOs. The students of 03 consecutive years (2019, 2020 & 2021) are to be the test group.

As the first step, the performance of students, as indicated by the marks obtained for the assessments, was analyzed to quantify the achievements of the LOs.

The test module contains 05 learning outcomes, which are to be achieved by the students through theory, tutorial and laboratory work/classes. Table 2.1 shows the weights assigned to each LO in the module descriptor of the test module.

Table 2.1 Weights Assigned to LOs in the Module Descriptor

Learning Outcome (LO)	LO1	LO2	LO3	LO4	LO5
Weight Assigned	0.1	0.1	0.5	0.2	0.1

The LOs of the test module were quantified using a combination of Continuous Assessments (CA) and an End Semester Examination (ESE). The final mark consists of 30 % CA marks + 70 % ESE marks. The details on CAs are as given below:

CA1 – based on conducting 06 laboratory tests to determine soil properties and presenting the results in the form of a report (10 marks)
CA2 – based on the application of determined soil properties to solve civil engineering problems (10 marks)
CA3 – based on relating the concepts of engineering geology to case studies of geotechnical failures (10 marks)
Table 2.2 indicates the learning outcomes and weights assigned to learning outcomes in assessments included in the test module.

Table 2.2 Weights assigned to LOs in the Assessments

LO	LO1	LO2	LO3	LO4	LO5
CA1				0.1	
CA2				0.1	
CA3					0.1
ESE	0.05	0.1	0.55		

3. RESULTS AND DISCUSSION

The performance of the test sample in both CA and ESE are shown in Figure 3.1, Table 3.1and Figure 3.2.

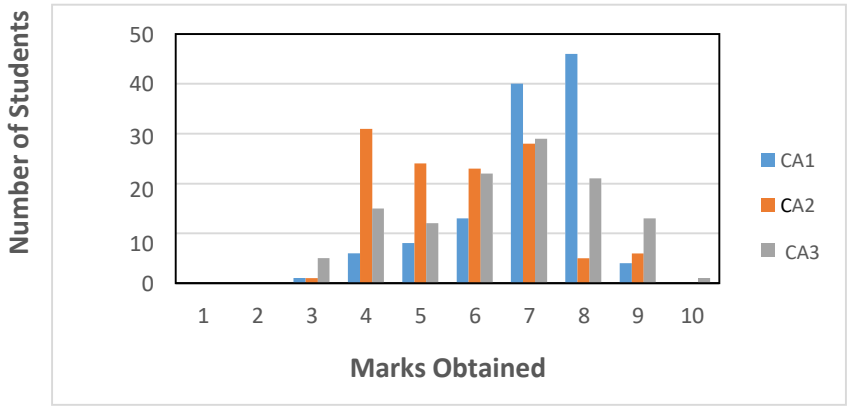


Figure 3.1 Student Performance in CA

Table 3.1 % of students obtaining high & low marks in CA

CA	% of students obtaining 7 marks or more	% of students obtaining 4 marks or less
1	76	6
2	33	27
3	54	17

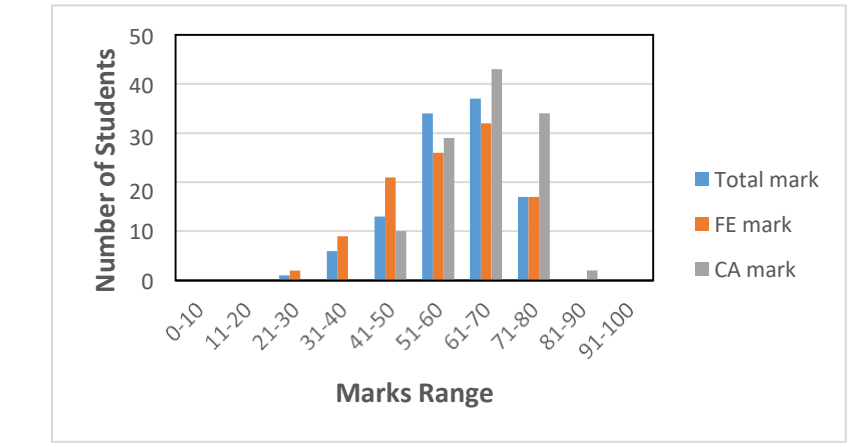


Figure 3.2 Student Performance in ESE

The analysis of the final marks obtained by students are shown in Table 3.2.

Table 3.2 Details of the final marks obtained by students(Note: Pass mark 40 %)

Type of Assessment	% of students obtaining Marks > 40%
CA	100
ESE	91
Final Mark	94

The weights assigned to LO1 – LO5 in the module descriptor mapped well in to weights assigned to LOs in CA1-CA3 and ESE as indicated in Table 2.1 and Table 2.2 except for minor discrepancies in LO1 and LO3.

Table 3.2 indicates a very high percentage of students obtaining over and above the pass mark.This concludes that the marks obtained by the students in the test sample represent the achievement of set LOs in the test module.
The findings in Table 3.1 show a large discrepancy in marks obtained in CA1 and CA2. This indicates that students are unable to apply the test results to solve civil engineering problems.The discrepancy in the marks obtained in CA1 and CA2 can be due to:

a. Students carrying out the laboratory experiments by only remembering the instructions
b. Students not understanding the theoretical background of the experiment and therefore being unable to apply the results to solve problems

Hence it is proposed to improve CA1 by firstly aligning the learning activity to the method of assessment and, secondly by preparing a structured marking sheet incorporating all attributes that are assessed and letting the students know how they can achieve the desired outcomes.

4. CONCLUSION

From the analysis of marks obtained for the test module it can be concluded that the combined assessments with 30% marks from CA and 70% marks from ESE are a suitable method to measure the LOs of the module considered. It is also proposed to reduce the large discrepancyin marks obtained in CA1 and CA2 by making the suggested improvements to both the learning activity and the method of assessment and continue the process of analysis.

5. REFERENCES

Chan, C. K. Y. (2015). Tips for Designing Effective Assessment in Engineering Curriculum, Engineering Education Enhancement and Research Asia (E3R Asia). Retrieved from https://hke3r.cetl.hku.hk/tips_assessment.php

Kulkarni, P.G., Barot, A.R. (2019). Methodology for Course Outcome Attainment Analysis foran Engineering Course. *International Journal of Scientific and Technology Research*, *8*(03), 16-19

Subheesh, N. P., Sethy, S. S. (2020). Learning through assessment and feedback practices: Acritical review of Engineering Education Settings. *EURASIA Journal of Mathematics, Science and Technology Education*, *16*(3). https://doi.org/10.29333/ejmste/114157

A CASE STUDY ON DIFFERENT APPROACHES USED IN THE ONLINE TEACHING AND LEARNING PROCESS TO FACILITATE SUSTAINABLE DEVELOPMENT GOALS (SDGs) IN DISTANCE LEARNING DURING THE COVID - 19 PANDEMIC

Kuruppu K.A.D.D.[1]

[1]Department of Aeronautical Engineering, Faculty of Engineering, General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka.
dulanik@kdu.ac.lk

ABSTRACT: As per UNESCO statistics, the global Covid-19 pandemic has made 91% of the world's student population to be at home without attending school or college. Educational institutes around the world had to completely shift to the online mode of teaching and learning. The objective of this paper is to emphasize on the different teaching and learning approaches which could be used in online learning and teaching to achieve quality education as per SDGs. The paper highlights tools, such as Zoom, Google Meet, Google Classroom, Padlet, Google whiteboard and the "assessments for learning approach" instead of the "assessments of learning" approach, which can be effectively used in the online mode. Perceptions of learners and the educators towards the approaches, which can be considered as feedback are pointed out. 100% of the students commented that they were quite satisfied with the new approach of conducting in-class assessments in the online mode using online tools. 98 % of students commented that student-lecturer interaction during the lectures was satisfactory. 100 % of the students commented that online submission of assignments was convenient and 91 % of the students commented that the "breakout room" option in the Zoom app. had given them ample opportunity to interact with their peers. All the students were of the view that they would be happy to take online lectures in future as the lectures could be arranged even on weekends, during late afternoons or early in the morning. In addition, all the students were happy about online lectures as the home or residing environment was favorable to listen to lectures. Furthermore, a majority of the students (99 %) were satisfied with student–teacher interaction in online mode. The study concludes that it was a guide towards understanding the approaches that can be used effectively in the online teaching and learning process to ensure SDGs related to quality education.

Keywords: Distance learning, Education, SDGs, Teaching and learning, Technology

1. INTRODUCTION

It is challenging to make distance learning work for all the students. It is even more difficult to replicate the in-person learning experience, in online mode. Mainly, adaption to the existing syllabi which were designed for lecture room settings, disparities in accessing new technologies, access to internet and the cost of internet data are only some of the challenging issues of online education. However, during the Covid 19 pandemic, the Lanka Education and Research Network (LEARN) being connected to university web servers and students being provided with free access to university web servers assisted immensely in boosting online teaching in Sri Lanka (Hayashi *et al*., 2020). This benefited both learners and educators in accessing reading material, following lecture slides, attending online quizzes and also when video conferencing via the Zoom app.

However, the educator who was a "sage on stage" in lecture room teaching might have been in difficulty when adapting to become a "guide on the side" which is a key factor in online teaching where the educators have to teach through the screen and not to the screen.

The fourth goal in SDGs refers to "quality education". The objective of this study therefore, was to emphasize different teaching and learning approaches which could be used effectively in online learning with the objective of ensuring quality education as per SDG (Otto and Becker, 2018). This research work share different approaches that educators can practice to facilitate peer learning through sharing knowledge in online mode. The study used online teaching and learning tools in assessing learning approaches. The "breakout rooms" option in the Zoom app. was used for discussions among

students. In addition, Google Meet, Google Classroom, Padlet and Google whiteboard tools were used to conduct online lectures, for illustrations, for discussions as well as for quizzes.

2. METHODOLOGY

The author conducted online teaching and online assessments for 40 university engineering undergraduates. The assessments were conducted online as small group discussion sessions using the "breakout rooms" option. There were 10 breakout rooms of four students in each. Being the host the author of this paper entered each and every breakout room while the students were conducting their discussions. After the group discussions were over, they were guided back to the main session where the evaluations took place with all 40 students in attendance. This allowed the students to share their knowledge by presenting what they had discussed for the given activity. In addition, several other software apps. Namely, the Google Meet software for video conferencing and the most interactive whiteboard were used to boost interaction with the students. A questionnaire was distributed among the students to get feedback.

3. RESULTS AND DISCUSSION

Students' feedback to the new way of conducting lectures and assessments in online mode clearly implies that they were highly impressed and satisfied with the new approach of conducting in-class assessments online, using online tools. However, at times, some students were not able to attend lectures due to internet issues. Once even the lecturer could not conduct the online lecture due to network issues. Further, the lecture recording facility helped students to re-listen to lessons and 100 % of students stated that they were satisfied with it. However, there was a drop in attendance when students were informed that the recorded lectures would be uploaded at the end of the lecture. The recorded videos therefore, were not uploaded thereafter, which significantly improved attendance for online lectures. 98 % students commented that student- lecturer interaction during online lectures was satisfactory. 100 % of the students commented that online submission of assignments was convenient. As per the students, 91 % of students commented that the "breakout rooms" option had given them ample opportunity to interact with their peers. However, the author is of the view that the remaining 9 % of students were dissatisfied with the above statement as they were given a measured time line for every discussion carried out using the "breakout rooms". This may have also been due to the lecturer visiting each "breakout room" while they were discussing the given activity or assignment. All the students stated that rather than just looking at the screen of the laptop, the new approaches helped them to learn more effectively, online. This also aligns with the findings in past literature (Fatani, 2020).

In addition, apart from laboratory practical sessions, some case studies were also given to students to read and analyze. Also, several guest lectures were organized in online mode with industry experts to give students at least virtual experience in the related field. Students' attendance was 100 % at these very productive webinars as it enabled students to get input for their research work as well. All the students commented that they would be happy to take online lectures in future as well as the lectures could be arranged on weekends, late afternoons or early in the morning. In addition, it was found that all the students were happy that the lectures were conducted online and that the home/residing environment was favorable to listen to online lectures. Furthermore, a majority of the students (99 %) were satisfied with the student–teacher interaction at online lectures.

4. CONCLUSION

Various applications can be utilized in online teaching and learning via internet to replace lecture room teaching and learning in a remote mode. However, by delivering lectures real-time and synchronous video conferencing help in learner – educator interaction which agrees with literature (Jena, 2020). Such online platforms could change the pedagogy of teaching and learning in the modern world (Armstrong-Mensah, 2020). As per the feedback received from students it is evident that the new approaches (teach via Zoom, Google White board, Google Meet, Padlet) used in teaching and learning online was highly beneficial for them to learn effectively. On the other hand, with these new approaches the educators can also guarantee that they teach through the screen and not to the screen. However, the COVID-19 pandemic facilitated Sri Lanka's tertiary education system to become more resilient against unforeseen challenges. This could be a catalyst for creating a more open mindset and attitudes towards online learning in Sri Lanka which would ensure that Sri Lanka is working towards making SDGs, a reality.

5. REFERENCES

Armstrong-Mensah, E., Ramsey-White, K., Yankey, B., & Self-Brown, S. (2020). COVID-19 and Distance Learning: Effects on Georgia State University School of Public Health Students. *Front. Public Health*, 8(576227), 1-10.

Fatani,T. H. (2020). Student satisfaction with videoconferencing teaching quality during the COVID-19 pandemic. *BMC Medical Education, 20* (396), 1-8.

Hayashi, R., Garcia, M., Maddawin, A., & Hewagamage, K. P. (2020). Online Learning in Sri Lanka's Higher Education Institutions during the COVID-19 Pandemic. *ADB Briefs, 151,* 1-12.

Jena, P. K. (2020). Online learning during lockdown period for Covid-19 in India. *International Journal of Multidisciplinary Educational research, 9*(5), 82-92.

Otto, D., & Becker, S. (2018). E-learning and sustainable Development: *Encyclopedia of Sustainability in Higher Education* (8). Springer: Germany.

TECHNOLOGY STUDENTS' PERCEPTIONS OF THE HUMANITIES MODULES: A CASE STUDY OF NDT STUDENTS AT ITUM

Bandara J.A.S.D.[1], Kumarasiri L.P.[1], Iroshani W.E.[3], Chathurangi A.K.D.K.[4], Samaraweera S.A.I.M.[5]

[1, 2, 3 ,4,5] Division of Interdisciplinary Studies
Institute of Technology, University of Moratuwa, Sri Lanka
shalinid@itum.mrt.ac.lk[1], laknip@itum.mrt.ac.lk [2*]

ABSTRACT: The Institute of Technology University of Moratuwa (ITUM) introduced two humanities course modules: Sports Studies and Aesthetic Studies to the National Diploma in Technology (NDT) curriculum in 2018 aiming at enhancing students' personal skills. The objective of this study is to identify NDT students' perceptions of the humanities modules and to evaluate their skills in the areas of communication skills, creativity, leadership, teamwork, presentation skills and critical thinking skills. A convenience sample of 252 second year students out of 763 students who were following the National Diploma in Technology (NDT) course in 2019 was obtained. Students' perceptions of the two modules were evaluated by means of an online questionnaire. The results indicated that the majority of students (69%) prefer to follow both Aesthetic Studies and Sports Studies modules and around 90% of students were satisfied with both modules. Moreover, 75% and 93% of students were of the view that the Aesthetic and Sports Studies modules were helpful in improving their personal skills. Apart from that, 58% of students have mentioned collectively that Aesthetic Studies and Sports had reduced their stress levels. Hence, it can be stated that the humanities modules offered by the ITUM had enhanced students' personal skills and would be helpful in producing technology diplomates with balanced personalities, capable of dealing with the industry as well as the society.

Keywords: Humanities Modules, Personal Skills, Satisfaction, Students' Perception

1. INTRODUCTION

Institute of Technology University of Moratuwa (ITUM) provides engineering technology diplomates with both theoretical and practical knowledge to the Sri Lankan engineering technology field. ITUM introduced two Humanities modules, i.e. Sports Studies and Aesthetic Studies to the NDT curriculum in 2018 aiming at developing students' personality in the areas of teamwork skills, leadership skills, creativity, communication skills as well as creating physically, socially, mentally and spiritually well-balanced diplomates.

In today's global world, in order to work with international partners and to run joint projects an engineer should be able to communicate with people from other cultures and social groups. As providing technical knowledge only in the field of study is not sufficient for engineering education curriculum developers should aim at producing a specialist who possesses all these skills. However, only humanities education can help in developing special traits necessary for performing all engineering functions, and it is through humanities that character development and ethics can be incorporated in engineering and technology (Sharma, 2013). Nowadays, the industry requires engineers with passion, systems thinking, communication skills, interdisciplinary skills, leadership skills and who have the ability to innovate, work in multicultural environments, understand the business context of engineering and adapt to changing conditions.

Khalid et al., (2013) has concluded that students should be trained not only in their technical areas of expertise but also in humanities as well. Furthermore, researchers have proved that this supplemental education will improve communication and personal skills of engineers and prepare them to fulfil their cultural and civic responsibilities. Dan Albert (2011) has also declared that the humanities modules emphasize social skills. Studying the humanities allows students to become familiar with and

use the creative ideas from great minds outside of their field of study which can help them generate new ideas and broaden their horizons.

Thus, the study investigates students' perceptions of the humanities modules introduced in 2018.

2. METHODOLOGY

This research was conducted as a cross sectional study. The research population was 763 NDT students of the 2018/2019 batch. Data was collected employing a structured online questionnaire. A total of 252 students from Chemical, Civil, Electrical, Electronics, IT, Marine, Mechanical, Textile and Polymer disciplines responded to the questionnaire. Students' views on the humanities modules were analyzed using tables and graphs obtained using Microsoft Excel.

3. RESULTS AND DISCUSSION

All the responses were analyzed and students' perceptions of the humanities modules are presented below:

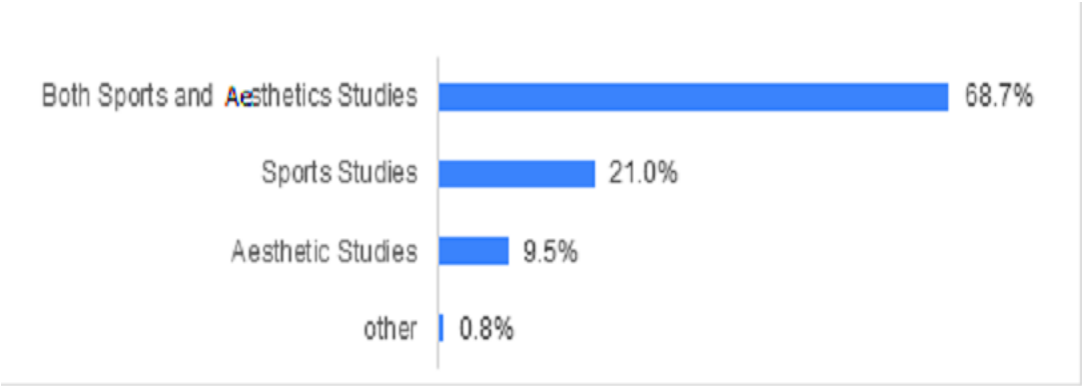


Figure 1: Students' Preference of the Humanities Modules

Results of the study reveal that the majority of students (69%) preferred to study both Aesthetic and Spots Studies modules. Only 2 students out of 252 (0.8%) stated that they prefer to study the humanities modules such as Engineering Law, Film and Photography.

Table 1. Students' Satisfaction with the humanities modules

Students' Satisfaction	**Response level as a percentage (%)**			
	Excellent	**Good**	**Satisfactory**	**Poor**
Preference of the Humanities Modules (Aesthetic and Sports Studies)	44	40	10	6
Stage Performance and Sports Meet	38	46	10	6

According to Table 1, around 90% of students are satisfied with both Aesthetics and Sports studies modules. Among them, 84% of students are highly satisfied with the stage performance and the sports meet which were organized at the completion of these humanities modules. Furthermore, they have

suggested organizing an arts festival including drama, dance, music and visual arts, increasing the number of practical hours, organizing the sport meet as a main event, and organizing a cricket carnival.

Table 2. Students' views on the improvement of their personal skills

Humanities Modules	Helpful to improve personal skills		
	Agree	Disagree	No Idea
Aesthetic Studies	75.00%	7.35%	17.65%
Sports Studies	93.02%	1.55%	5.43%

Improvement of personal skills of students from these humanities modules were then analyzed. It was noticed that 75% of students had stated that the Aesthetic module was helpful for them to improve their personal skills and 93% of students had stated that the module, Sports Studies was helpful in improving their personal skills.

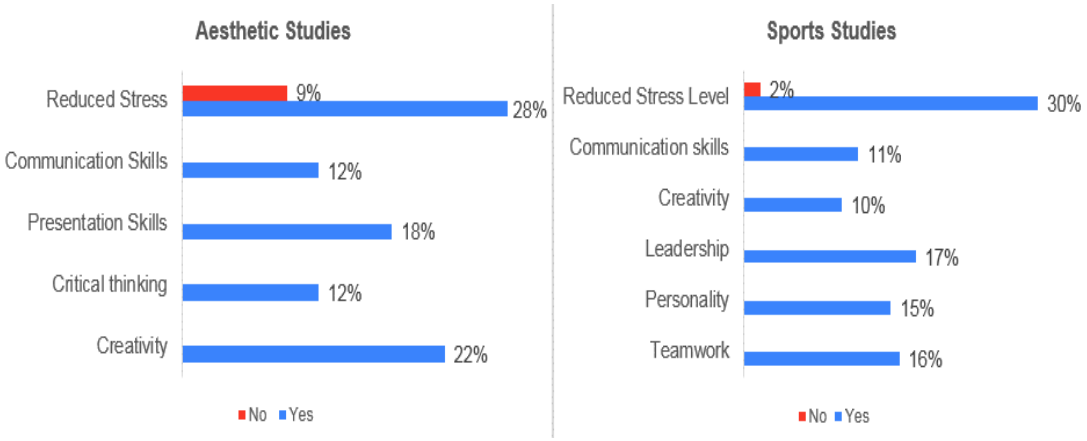


Figure 2. Students' perceptions of improved personal skills

According to Figure 2, 28% and 30% of students have specially mentioned that students' stress levels have reduced because of the Aesthetic studies and Sports Studies modules. Moreover, as reflected in the above figure a considerable number of students have stated that both modules were helpful in improving their personal skills. In addition to that, 22% of students had mentioned that their creativity improved due to Aesthetic Studies.

4. CONCLUSION

Based on the findings it can be concluded that NDT students at ITUM are satisfied with the newly introduced humanities modules, i.e. Aesthetic Studies and Spots Studies. The majority of students (69%) prefer to study both humanities modules. A very few students are interested in having other humanities modules such as Engineering Law, Film and Photography.

Around 90% of students are satisfied with both Aesthetic and Sports Studies modules. Around 10% of students have suggested organizing an arts festival including drama, dance, music and visual art, increasing practical hours, organizing the sport meets as a main event, and organizing a cricket carnival. Based on students' views, it is also found that 75% and 93% of students have stated that the Aesthetic and Spots Studies modules were helpful for them in improving their personal skills. Apart from that 28% and 30% students have specially mentioned that the levels of stress have reduced because of the Aesthetic studies and Sports studies respectively.

Overall, it can be concluded that the majority of students have enjoyed both Sports Studies and Aesthetic Studies modules during semesters 1 and 2 of the NDT course at ITUM and the humanities modules enhance their personal skills and reduce their stress level.

5. REFERENCES

Albert, D., (2011). Ten Important Reasons to Include the Humanities in Your Preparation for a Scientific Career, *Science Mag*, May 2011

Khalid, A., Chin, C.A., Atiqullah, M.M., Sweigart, J. F., Stutzmann, B., Zhou, W., (2013). Building a Better Engineer: The Importance of Humanities in Engineering. *120th annual Conference & Exposition.* Atlanta: American Society for Engineering Education.

Sharma, R. K. (2013). Lending Human Touch: The Role of Humanities in Engineering. *International Conference on Recent Trends in Applied Sciences with Engineering Applications*, 35-37.

AN ANALYSIS OF MENTAL STRESS OF EMPLOYED UNIVERSITY STUDENTS: A CASE STUDY OF STUDENTS OF THE UNIVERSITY OF VOCATIONAL TECHNOLOGY

Alahapperuma K.G.[1], Jayasekera B.M.T.D.[2]

Department of Mechanical and Manufacturing Technology,
University of Vocational Technology, Sri Lanka
gayanthi111@yahoo.com

Department of Management Studies
University of Vocational Technology, Sri Lanka
bmtdkum@yahoo.com

ABSTRACT: The aim of this study was to analyze factors affecting the stress level of students following the weekend degree programs of the University of Vocational Technology (UoVT) in Sri Lanka. The study sample consisted of sixty students from different weekend degree programmes and the data were collected through a structured questionnaire. Descriptive statistics were used to analyse data with the Statistical Package for Social Sciences (SPSS) software. The study addressed 32 possible stress raisers, belonging to 4 main categories: academic, employment, personal and relationship related issues. The study revealed the ways in which students cope with stress. Academic related issues are found to be the main cause of stress, followed by employment related issues among other factors. The main strategy used by students to cope with stress is to talk and share their difficulties with close friends. Despite this 48% of students were reluctant to do so, thus bearing the pain and difficulty by themselves. These findings imply the reasons for high dropout rates and highlights the importance of managing stress in order to achieve their study goals. On the other hand, it is the university's responsibility to implement a stress relieving action plan, especially for employed weekend students so that the university will be able to deliver its courses well, while students may improve their academic performance and maintain good health.

Keywords: Degree Programmes; Mental stress; Weekend students;

1. INTRODUCTION

UoVT was established by the parliament act number 31 of 2008, aiming to offer level 7 (degree level) courses according to the National Vocational Qualification Framework of Sri Lanka (NVQFSL), which was developed by Tertiary Vocational and Education Commission (TVEC) in 2004. UoVT is the only higher education institute that offers degree level courses for the National Vocational Qualification (NVQ) holders, who are an unconventional group of students. (UoVT, 2008; TVEC, 2004).

At present, the university offers 14 degree courses as weekday courses and weekend courses. Weekday courses have been designed for unemployed students, and the courses are conducted from Monday to Friday while the weekend courses which are conducted on both Saturdays and Sundays are for employed students. As a result, the semester duration of the weekend courses is relatively longer than that of the weekday courses. This longer term duration of the courses and the long delivery hours together with employment responsibilities keep the students busy and restless, compared to weekday students. In addition, most of the weekend students are adults and married. A majority of them spend long hours travelling back and forth between the work place, the university and home. Therefore, the context within which these weekend students study imply a possible higher level of stress compared to that of weekday students. The dropout rates in all weekend degree courses in the past is shown to be higher than in weekday courses (UoVT, 2010; 2011; 2013; 2014a; 2014b; 2015a; 2015b; 2017; 2018; 2019).

A knowledge of likely factors affecting the level of stress of weekend students might help in improving the quality of the degree programmes offered and in turn the performance of students.

Hence, this study was carried out with the main objective of analysing the causes of stress of undergraduates in the weekend programmes of the UoVT.

Stress among university students is a global issue, and the general findings of studies done regarding the stress levels of conventional university students indicate that academic matters were the main cause of stress. (Agolla & Ongori, 2009; Bataineh, 2013; Boke *et al.*, 2019; Icaro *et al.*, 2018; Karlsson, 2008; Pascoe *et al.*, 2019). Some findings further highlight that there is no significant difference between stress levels of students of different specializations (Bataineh, 2013). On the other hand, students who work at least six hours per work were found to have a higher level of stress than students who work less than six hours per week (Young, 2017). Another major adverse effect of high stress is health issues, which agrees with certain previous researches (Boke *et al.*, 2019; Karyotaki *et al.*, 2020; Pascoe *et al.*, 2019; Ribeiro *et al.*, 2018).

Accordingly, this study was conducted to analyze the factors affecting the mental stress of the employed, weekend degree students of the UoVT, and to suggest appropriate corrective action to reducing the number of dropouts from courses.

2. METHODOLOGY

The population of the study was 250 undergraduates belonging to the academic year 2016/17, following lectures during the weekend at UoVT and representing all disciplines of the university. The target sample was selected using a Simple Random Sampling Technique covering all fields of the degree courses. A questionnaire survey was adopted in this study. Accordingly, data were collected from 60 student participants, through a structured questionnaire. Descriptive statistics were used to analyse the collected data with the SPSS software package.

3. RESULTS AND DISCUSSION

Summary of the findings are given in figures 01 and 02 and table 01.

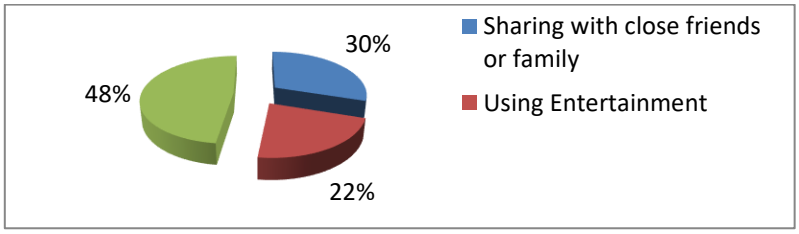


Figure 1. Coping Strategies of Students with Percentages

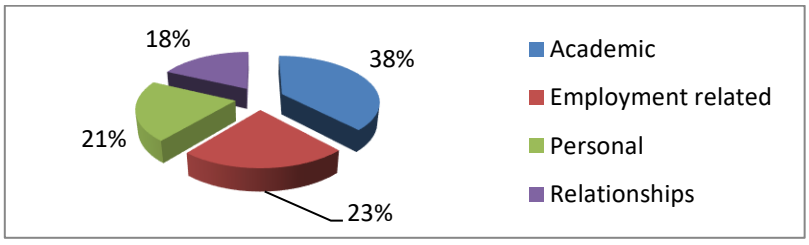


Figure 2. Main Stress Factors of Students with Percentages

Table 1. Academic Related Main Stress Raisers of Students with Feedback Percentages

Main stress raiser (during weekend)	Percentage of student feedback
Level of academic workload (limited time for self-studies, more take home assignments for the limited available time to work with)	36%
Tight course delivery schedule (long delivery hours during weekends, limited free time in between delivery sessions)	22%
Stress of traveling (long travelling durations from Friday evening to Monday morning, back and forth between the work place, the university and home)	24%
Accommodation issues (due to limited hostel facilities during weekends and the higher cost of outside boarding places)	18%

The results indicate that the major stress raiser of these employed undergraduates is academic related concerns, while employment factors are also found to be a considerable stress raiser. The obtained results above are found to be the main causes for the high dropout rate among weekend students.

If students receive support in advance to address these stress factors, it will succeed in reducing the number of student dropouts. (Pedraza, 2016).

4. CONCLUSION

Results reveal that academic reasons are the highest stress raiser of employed undergraduates of the university, followed by employment issues. Paying more attention to student counseling and adapting flexible learning methods may help in reducing related adverse effects. Further, the university can takes measures to improve students' accommodation facilities and develop a blended learning method to support weekend students' learning, and to minimize their level of stress.

5. REFERENCES

Agolla, J. E., & Ongori, H. (2009). An assessment of academic stress among undergraduate students: The case of University of Botswana, *Educational Research and Review, 4 (2),* 063-070.

Bataineh, M. Z. (2013). Academic stress among undergraduate students: The case of education faculty at King Saud University, *International Interdisciplinary Journal of Education, 2*(1).

Boke, B. N., Mills, D. J, Mettler, J., & Heath, N. L. (2019). Stress and coping patterns of University students, *Journal of College Student Development, 60* (1), 85-03.

Icaro, J. S., & Ribeiro. (2018). Stress and quality of life among university students: A systematic literature review, *Health Professions Education, 4*, 70–77.

Karlsson, T. (2008). Academic stress: A case of the undergraduate students, *Psykologi 3, C - uppsats*, (LIU-IBL/SOC-G--10/008—SE).

Karyotaki ,E., Cuijpers, P., Albor, Y., Alonso, J., Auerbach, R. P., Bantjes, J., Kessler, R.C.(2020). Sources of stress and their associations with mental disorders among college students: results of the world health organization world mental health surveys international college student initiative, *Frontiers in Psychology*, (doi: 10.3389/fpsyg.2020.01759).

Pascoe, M. C., Hetrick, S.E., & Parker, A.G. (2019). The impact of stress on students in secondary school and higher education, *International Journal of Adolescence and Youth, 25(*1), 104-112 (DOI: 10.1080/02673843.2019.1596823).

Pedraza, D. A., & Beruvides, G. (2016). The relationship between course assignments and academic performance: an analysis of predictive characteristics of student performance, Texas Tech University, *ASEE's 123rd Annual Conference and Exposition, New Orleans, LA*, 26- 29.

Ribeiro, I. J. S., Pereira, R., Freire, I.V., Oliveira, B.G., Casotti, C. A., & Boery, E.N. (2018). Stress and quality of life among university students: A systematic literature review, *Health Professions Education* 470–77.

Tertiary & Vocational Education Commission (TVEC). (2004). *National Vocational Qualification Framework of Sri Lanka.*

University of Vocational Technology (UoVT).(2008). *Act, No.31.*

University of Vocational Technology (UoVT).(2010). *Student register*.

University of Vocational Technology (UoVT).(2011). *Student register.*

University of Vocational Technology (UoVT).(2013). *Student register.*

University of Vocational Technology (UoVT).(2014). *Student register.*

University of Vocational Technology(UoVT).(2014). *Convocation booklet*.

University of Vocational Technology (UoVT).(2015). *Student register*.

University of Vocational Technology (UoVT).(2015). *Convocation booklet.*

University of Vocational Technology (UoVT).(2017). *Convocation booklet.*

University of Vocational Technology(UoVT). (2018). *Convocation booklet.*

University of Vocational Technology (UoVT).(2019). *Convocation booklet.*

Young, T. (2017). Are students stressed? A study of the impact of student engagement on student stress. Masters theses, Eastern Illinois University, Retrieved from https://thekeep.eiu.edu/theses/2696.

STUDENT BEHAVIOR DUE TO RAGGING IN SRI LANKAN UNIVERSITIES WITH CULTIC ENVIRONMENTS TO FIND MEASURES FOR ERADICATION OF RAGGING: A REVIEW ARTICLE

Yatapana P. S. [1], Samaradiwakara G.D.M.N.[2]

[1]Institute of Technology University of Moratuwa
[2]University of Sri Jayewardenepura, Sri Lanka.
padmayatapana@gmail.com[1*], mnsamara@sjp.ac.lk[2]

ABSTRACT: Cults violate human rights as they recruit members deceptively and keep them in the group dependent and obedient, using coercive mind control techniques. Many researches have disclosed insights into the hidden activities of cults which are devastating to mankind. The influence of cults spread in the society like a virus and ultimately converts the society unknowingly into robots. The robots cannot think but can be programmed to perform specific tasks similar to slaves. The University Grant Commission (UGC) of Sri Lanka had conducted research and concluded that ragging is prevailing in all universities and have taken strong measures to stop ragging. Despite this, ragging still continues in the same way, controlled by a hidden fist. This study aimed at performing a content analysis of cultic studies and student behaviour towards ragging. It was found that student behaviour due to ragging is associated with cultic characteristics using mind control techniques that make the newcomers dependent on and obedient to senior student leaders. This study recommends that the eradication of ragging at universities could be accomplished in a similar manner to the eradication of the Covid-19 virus from the society.

Key Words: Mind control, university ragging, destructive influences, coercive systems, Covid-19

1. INTRODUCTION

It is evident that a large number of students become psychologically crippled, physically disabled, and even commit suicide due to ragging at universities. Freshers are severely affected by ragging and many drop out from universities annually, due to this menace. Usually, the ragging period continues for more than six months during the students' first year at universities. Since, freshers do not have peace of mind during this time they are not in a position to acquire the essential knowledge given to them. This leads to a disruption of their university education, severely.

The foremost action against ragging in Sri Lankan universities was taken in 1974. Act No. 20 of 1998, Act No. 4 of 2015 and 2018 etc. are other actions taken against ragging. Every year university entrants are advised to comply with Act. No. 4, of 2015 and 2018 about prohibition of any form of ragging. Student counsellors, mentors and liaison committees are appointed from the academics to prevent ragging. Nevertheless, ragging is still rampant at universities.

Cults are abusive totalistic systems (coercive systems) which operate covertly in the society. These groups are apparently marvellous on the outside but are highly controlled by charismatic leaders on the inside. As our society does not have experience in cult activities and the damage done to mankind, our homes, educational institutes, different organizations and even the government do not know how to take preventive actions against the devastation that students face unknowingly. As depicted in Figure 1, cults comprise different levels of leaders and different levels of followers who exhibit excessive devotion to a charismatic leader, idea or thing. The leaders are mostly narcissist, psychopath and sociopath personality types. They have no conscience, no empathy and are grandiose and pathological liars with anti-social personalities. There are millions of people around the world unknowingly involved in and supporting cult activities. Cults exploit the victim's time, energy, wealth and even their spirits dishonestly, and day by day the cult and the leader flourish while the followers become weak and poor.

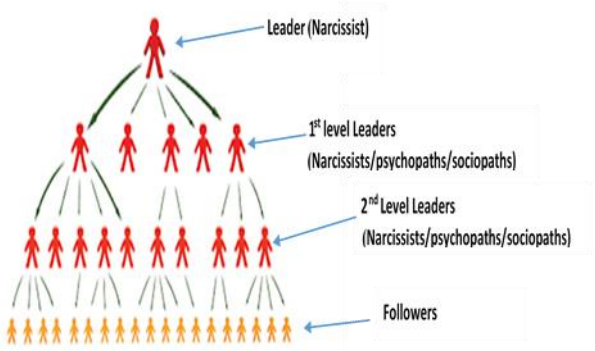


Figure 1: Structure of a Totalistic System

Many types of cults such as political, therapeutic, commercial, mystical, religious etc. exist which are of different sizes with two persons, small or large groups with thousands or even millions of people or regimes. Irrespective of the size of the group, they all use the same methods and coercive systems to keep their members under control. These techniques are applied as for a good purpose, but deceives everyone.

If the activities of cults and the damage they cause to the victims' lives are known in advance, no one will get into a cult. The cults influence their members covertly and unethically, with systematic minute steps so that the victims will not notice the changes in themselves and gradually lead to lose their ability to make their own choices and to exercise their own freewill. Their defense mechanism, intellectual processes, values, attitudes, their conduct and their reasoning power is damaged secretly by this "technological process". A victim's decent personality, developed throughout his childhood does not approve the unethical abusive system that he undergoes but accepts the cult activities to survive in the group.

The victim's real personality (authentic self) is split, suppressed and superseded by a pseudo personality which is evil (cult self). Without proper therapeutic intervention, ex-cult members live in a war within themselves between the two personalities which is a psychological disorder called Dissociative Disorder IV (Singer,1990). Their essential senses are impaired including the functioning within the society, the family, and the workplace (Hassan, 2000). The objective of this article, is to investigate whether, student behaviours due to ragging are similar to cultic characteristics and to suggest a method for eradicating ragging.

2. METHODOLOGY

This study is based on the theoretical perspectives of psychological studies on mind control such as (Lifton, 1961) Lifton's Eight Point criteria: 1. Milieu Control, 2. Mystical Manipulation, 2. Demand for purity, 4. The cult of confession, 5. Sacred Science, 6. Loading the language, 7. Doctrine over a person, 8. Dispensing of existence, (Singer, 1996) the six conditions for thought reforms, which carried out the pioneering work during 50 years in the field of cult mind control and (Zimbardo, 2004) the explanation of the results of the experiment on social psychology of imprisonment. These experiments and the theory of behavior of Zimbardo and Singer show the extent to which a person's identity depends, on the role he is playing.

Westermann (1989) Festinger's Theory of cognitive dissonance" If you change a person's behavior, his thoughts and feelings will change to minimize the dissonance, where, each component can be affected by the other two.

(Hassan, 2013) The stipulated theory on Mind control by Festinger, was refined by Steven Hassan in 1988 including the new component "Controlling of Information".

Accordingly, mind control is mainly categorized into controlling the victim's behavior, information, thoughts and emotions (B.I.T.E). By application of this model the person will be transformed into a clone of the leader as all the psychological conditions activated in a victim's mind depend on each other and cannot be differentiated. Therefore, in this study, the above findings classified under B.I.T.E model were used as devices to evaluate whether a person or a group controls the university freshers' lives by means of ragging. The data collecting tools of the study were books, articles, videos in the internet and the content analytical techniques were adapted as tools to compare the situations.

3. RESULTS AND DISCUSSION

It is evident that a totalistic system, (Figure 1) could be experienced in instances of ragging also, where the "followers" are new comers and the "2nd and 1st level leaders" are 2nd and 3rd year senior student leaders. There may be more higher-level leaders and a charismatic leader (in some movements) who regulates the system externally. Freshers cannot question the seniors. It is a one-way communication and the manipulated newcomers strictly follow the orders of the charismatic leader. By ragging, the personalities of new comers split into two, subjecting them into intense stress and anxiety. The cult self of all the victims is the same as the leader's narcissistic personality. It is seen that, some intelligent students become raggers who have anti-social characteristics. It is evident that those who were ragged become raggers in turn. This vicious circle is carried over from year to year by the "cult self" of the seniors who were subjected to ragging.

Table 1: Comparison of cultic characteristics in ragging situations

Mind Control Techniques in Cults	Destructive influences in Ragging
Behavior Control: Promote dependency and obedience, behavior modification with rewards and punishments, dictate association/isolation, controlled sexuality, clothing, hair style, regulate food, sleep deprivation, financial exploitation, restricted leisure, entertainment, vacation time, spending time with group indoctrination and rituals, require permission for major decisions, insist that thoughts, feelings and activities be reported to seniors, Discourage individualism and encourage group thinking, Rape/sexual exploitation, tattooing, impose rigid rules and regulations, threat of harm to friends and family, no medical treatment etc.	• Seniors befriend school children before entering the universities. •Start "Mal Samaya", love bombing, appear to be very friendly and supportive. •Develop 'batch fit' and empower freshers (to say like that), ask freshers to catharsis all their personal information, strengths and weaknesses, •Get official permission for activities or functions. Show that they are doing these activities for a good purpose, then using them for other purposes, subject freshers to physical and psychological abuse and instill intense fear and humiliation until the victims' spirit is broken. •Observations: Behavioral changes in freshers such as students refusing to talk with lecturers, looks exhausted and terrified, sleeping in classes, always move with a partner (to discourage individuality & spy). seems that they follow silly rigid rules, suffering with health issues, fever, cough, fainting, depression, commit suicide etc. Raggers are powerful only within the group, but individually they are very weak as they do not have critical thinking power. Talk with memorized statements. Their answers to questions are controversial. Their eyes are glassy, no emotions, no eye contact, they can answer only
Information Control: Deliberately withhold and distort information, forbid from speaking with ex-members and critics, discourage access to non-cult sources of information, divide information into insider vs. outsider doctrine, Generate and use propaganda extensively, use information gained in confession sessions against members, gaslighting to doubt one' own memory, report thoughts, feelings, & activities to superiors, encourage members to spy and report on others' "misconduct".	
Thought Control: Instill Black vs. White, Us vs. Them, & Good vs. Evil thinking, use loaded language and clichés to stop complex thought, induce hypnotic or trance states to indoctrinate, teach thought-stopping techniques to prevent critical thoughts, use excessive meditation, singing, prayer, & chanting to block thoughts, reject rational analysis, critical thinking, & doubt.	

Emotion Control: Instill irrational fear, questioning or leaving the group, label some emotions as evil, sinful, or wrong, teach emotion-stopping techniques to prevent anger and homesickness, promote feelings of guilt, shame, & unworthiness, love bombing, threaten one's friends and family, shun if disobey, teach that there is no happiness or peace outside the group.	direct questions, unable to answer open ended questions. They are not in a position to take any decision. (Sources: **UGC reports and University ragging videos/ Newspaper articles in the Internet and our first-hand experiences in the University**)

Cultic influences also transmit from person to person among the society like a virus. The ultimate result of a person who contracts the COVID-19 virus will be the risk of death and hence, immediate steps have to be taken to curb the spreading and save lives. The damage by the destructive influences of cults is more dangerous than the Covid-19 virus as its ultimate result is not visible like 'death' unless their behaviours are assessed and communicated by a skilled person. Due to cultic influences the society unknowingly transforms into zombies, who don't have critical thinking skills and are controlled by some narcissistic leaders. During the Covid-19 outbreak, countries world over went into immediate "lockdown", formed supportive teams of officers equipped with knowledge, skills and facilities, trained people for contact tracing, established hospitals and quarantine centres etc., and educated the masses on how the virus spreads, its symptoms, the danger of the virus to every person/family and how to prevent it. When a 'case' is identified from a test, the relevant teams flew to the place immediately and did contact tracing, isolation, quarantine and assigned the patients to different levels of treatment according to the patients' severity level (immunity level) and finally administered the vaccine. It became clear that the Covid-19 epidemic had to be eradicated by educating each and every individual and giving them the correct guidance to overcome the menace instead of applying force or instilling fear by the police.

4. CONCLUSION

It is concluded, that there exist numerous similarities between coercive systems and ragging. Eradication of ragging can be done in a similar manner to the eradication of the Covid19 virus. Before the new entrants are admitted to higher educational institutions, academic staff shall be empowered with the knowledge of coercive systems and the dangers of ragging. Next the new comers shall be prevented from getting influenced by the senior students, similar to Covid-19 lockdowns. Then the new comers should be educated about coercive systems and the danger and damage that ragging can do to their minds.

The freshers are intelligent young-adults having good personalities with high hopes for a good future. They are imaginative and possess good critical thinking and problem-solving skills similar to adults. The only thing that they do not have is "life experiences". When the freshers are empowered with the necessary knowledge, they will be immunized against destructive influences. Also, contact tracing should be done to identify peer raggers and direct them to authorities to empower them with counselling. This process has to be continued while engaging in the normal program orientation and other essentials for the freshers. Thus, ragging at universities can be eliminated completely if the vicious circle of ragging is disturbed for at least two years and vaccinating the freshers with the 'education package' of destructive influences of cults and ragging. No one will become culprits of ragging on their own. It is due to the coercive systems. They are not responsible for any act due to ragging and it is wrong to blame these victims.

5. REFERENCES

Hassan, S (1988) *Combatting Cult Mind Control, Freedom of mind: Park Street press. Rochester, Vermont 05767,* 0-89281-243-5

Hassan, S. (2013). *Freedom of mind: Freedom of mind press*. Newton: MA.

Lifton, R. J. (1961). *Thought reform and the psychology of totalism: A study of "brain washing" in China*. China: W. W. Norton & Company.

Singer, M. T. (1996), *Therapy, Thought Reform, and Cults, Transactional Analysis Journal, 26*(1) 15-22.

Zimbardo, P. G. (2004). A situationist perspective on the psychology of evil: Understanding how good people are transformed into perpetrators in A. G. Miller (Ed.), *The social psychology of good and evil.* New York: Guilford Press. http://pdf.prisonexp.org/evil.pdf

Westermann R. (1989) Festinger's Theory of Cognitive Dissonance: Westmeyer H. (eds) Psychology Theories from a Structuralist Point of View. *Recent Research in Psychology.* Springer, Berlin. Heidelberg. https://doi.org/10.1007/978-3-642-84015-9_3

Session 02

APPLICABILITY OF THE PLATE BEARING TEST IN THE PREDICTION OF DEFORMATION CHARACTERISTICS OF SHALLOW FOUNDATIONS

Kartheepan S.[1] and De Silva L. I. N.[2]

Department of CivilEngineering,
[1]Institute of Engineering Technology, Katunayake.
karthee2087@gmail.com

[2]Department of Civil Engineering,
University of Moratuwa, Moratuwa
nalinds@civil.mrt.ac.lk

ABSTRACT: Shallow foundations are widely used to support structures of various sizes to safely transfer structural loads to the ground without exceeding the safe allowable capacity of the ground and without causing excessive settlement. They are usually placed in the soil profile up to a few meters. In this study, the finite element method was used to analyse the numerical model of the raft foundation designed for the Killinochchi and the Paranthan water towers. Past studies on the applicability of the plate bearing test results in predicting the settlement and bearing capacity of large diameter circular foundations have been conducted. This study investigated the applicability of the plate bearing test in predicting the settlement, the modulus of elasticity, and the bearing capacity of shallow foundations of the Paranthan and the Kilinochchi water towers. The plate bearing test was carried out in the initial stage, and the actual settlement of the two water towers was monitored every month during the construction period. The predicted settlement was estimated through the elastic theory in soil, and the finite element analysis was performed using PLAXIS 2D. The conclusion drawn in the current study is that the Terzaghi's method is more applicable in the extrapolation of PLT test results for the larger size circular footings. Also, the measured actual settlement values were found to be in reasonable agreement with numerical results.

Keywords: Plate Load Test, Numerical Analysis of PLT, Finite Element Method (FEM)

1. INTRODUCTION

Currently, SPT-N values are used to estimate the elastic modulus of soil (ES), the settlement of foundation (SF) and the bearing pressure of foundation but, the plate bearing test can be used to estimate the field ES value and the bearing pressure of foundation. In addition, the settlement of foundation can also be estimated from the plate bearing test using the elastic theory and other extrapolation methods. In this study, the actual settlement of both towers was monitored in the construction stage. Settlement of foundation, back calculation of elastic modulus of the soil and the bearing pressure of the foundation were estimated from the plate bearing test result, settlement extrapolation methods, actual settlement data and the numerical analysis approach. In addition, numerical modelling of the foundation of both towers were done using the finite element method (FEM). The main objectives of the proposed research are to investigate the applicability of the plate bearing test in the prediction of the settlement and carrying capacity of shallow foundations of the Paranthan and the Kilinochchi water towers, to use the settlement monitoring records to back calculate the modulus of elasticity of soil underneath both the Paranthan and the Kilinochchi water towers and the numerical modelling of the foundations.

2. METHODOLOGY

In order to achieve the aim and objectives of the study, the methodology followed is presented in the following flow chart illustrated in Figure -01.

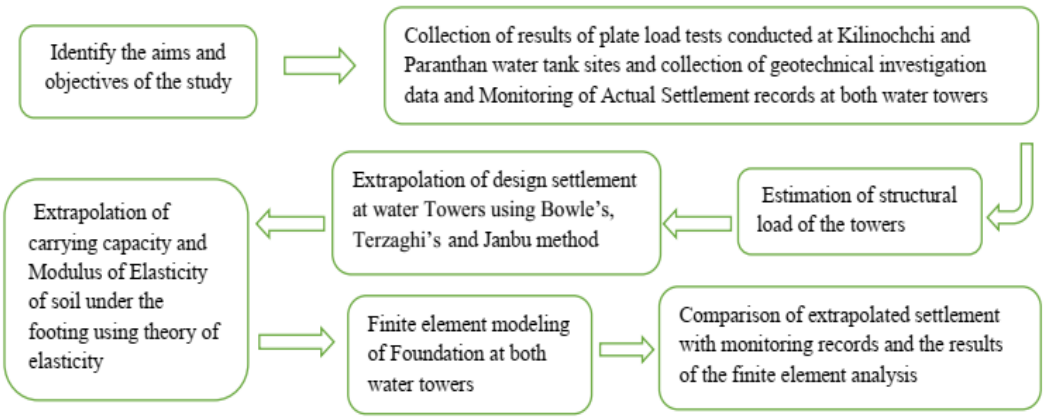


Figure – 01: Flow chart of the study

2.1 PLATE BEARING TEST

The plate bearing test was carried out at both water tower areas. Throughout the plate bearing test, vertical settlement of plate and the pressure were recorded. Figure – 02 shows the test arrangement of the plate load test at the Kilinochchi water tower area.

Figure – 02: Prepared arrangement of Plate Load Test (PLT)

2.2 MONITORING OF ACTUAL SETTLEMENTS

The actual settlements of both water towers were monitored every month at regular time intervals during the construction of the water tanks. To monitor the coordinates and the settlement in the tower, the momentum reflector was set out and the reference mark was erected in two corner station points at the Kilinochchi water tower as shown in Figure – 03.

Figure – 03: Momentum reflector and reference Point

3. RESULTS AND DISCUSSION

The Plate Bearing test was carried out by Engineering Laboratory Services (Pvt) Ltd. The settlements of the circular rigid plate were observed by monitoring all three dial gauges and finally the average settlement of the plate was calculated to determine the settlement in the plate. The design settlement

was calculated using Terzaghi's elastic theory. The detailed results of PLT and the design settlement of the Kilinochchi water tower are given in Table – 01 and Table – 02

Table – 01: Results of PLT

Applied Pressure (kPa)	Average Plate Settlements (mm)
0	0
84.88	0.41
169.77	0.78
254.65	1.18
339.53	1.62
431.49	2.23
516.37	3.01
599.84	4.33
403.19	3.83
198.06	3.45
0	1.31

Table: 02 – Results of design settlement

Applied Pressure (kPa)	design settlements of the foundation (mm)
0	0
84.88	20.5
169.77	39
254.65	59
339.53	81
431.49	111.5
516.37	150.5
599.84	216.5
403.19	191.5
198.06	172.5
0	65.5

Actual settlements of both water towers were monitored by momentum reflector during the construction stages. The variation between applied pressure, average plate settlement and design settlement using Terzaghi's equation are illustrated in Figure – 04.

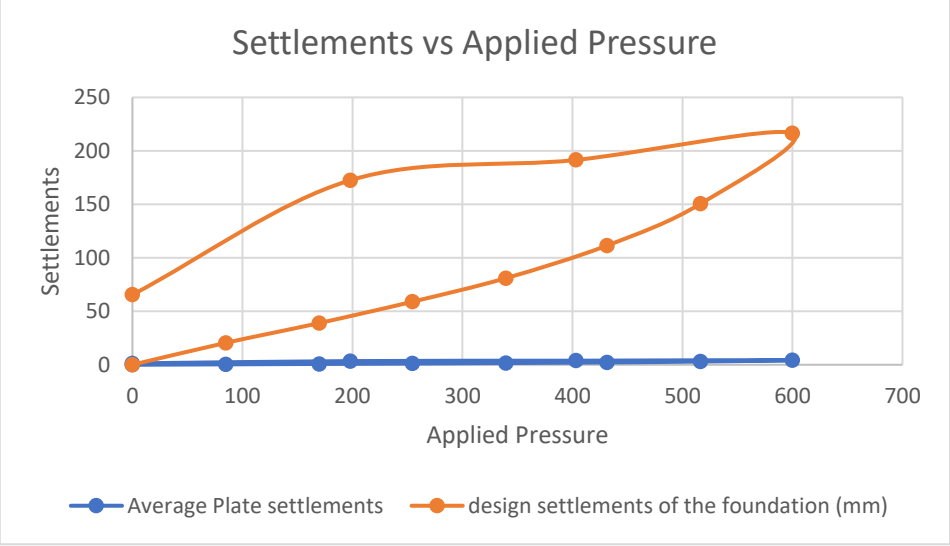


Figure – 04: Settlements vs Applied pressure

An attempt was made in the current study to model the behaviour of the raft foundations using the Finite Element Method. A commercially available software called PLAXIS Version 8.2 was used in the analysis. Both foundations were modelled using the axisymmetric idealization, using 15 node elements which are shown in Figure – 05 and Figure – 06.

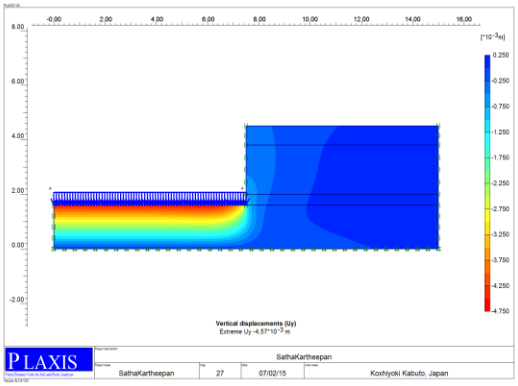


Figure – 05: PLAXIS modelling of foundation at Kilinochchi water tower

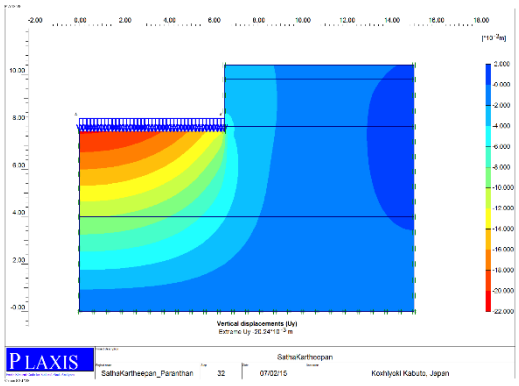


Figure – 06: PLAXIS modelling of foundation at Paranthan water tower

4. CONCLUSION AND RECOMMENDATIONS

This study reveals that the settlement predicted by Terzaghi's method is applicable for large diameter circular foundations. Moreover, Finite Element Model predictions were compared with the accepted variations of the settlement of the shallow foundations and verified even though there was no significant variation between the monitored actual settlements and the model settlements in this study. It was observed that the monitored actual settlements were not high because the base rock was very shallow at the testing location. In the numerical analysis, the maximum actual settlement at the Kilinochchi and the Paranthan tower were found to be 4.5mm and 20mm respectively. In this study, the observed maximum average actual settlements at the towers were respectively, 5.5mm and 6.0mm. Hence, the results generated through numerical analysis is close to the actual results.

Further, it is recommended that investigations should be conducted on the applicability of the plate bearing test on ring type circular foundations, smaller size shallow foundations in different soil profiles and the evaluation of modulus of sub-grade reactions.

5. REFERENCES

Bowles, J. E. (1997). *Foundation Analysis and Design*, 5th Edition, McGraw-Hill

Khanal, S. (2013), *Back calculation of Plate Loading Tests using PLAXIS 2D and the Hardening Soil Model* [Master dissertation], NTNU Open

El Sawwaf, M., Nazir, A. K. (2010), Behaviour of repeatedly loaded rectangular footings resting on reinforced sand, *Alexandrai Engineering Journal*, *49*(4), 349-356

"*Sri Lanka Iranamadu Irrigation Development Project*", Design Completion Report, October 2011

"*Preparatory Survey Report on Rehabilitation of Kilinochchi Water Supply Scheme in Democratic Socialist Republic of Sri Lanka*", December 2011

"*ICTAD Guidelines for Site Investigations for Foundation of Building*", (1994), ICTAD Publication No: ICTAD/ID/11, 1st Edition.

ESTIMATION OF PARAMETERS OF THE 'abcd' MONTHLY WATER BALANCE MODEL FOR KALU AND GIN RIVER BASINS IN SRI LANKA

Gunasekara D.N.[1] and Rajapakse R. L. H. L.[2]

[1]Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa, Sri Lanka
[2] Department of Civil Engineering, University of Moratuwa, Sri Lanka
dnalaka@itum.mrt.ac.lk, lalith@uom.lk

ABSTRACT: Currently, only a limited number of mathematical models have been developed for the Kalu and Gin river basins which predominantly provide water for the water supply schemes, irrigation and mini hydropower schemes in Sri Lanka, due to various reasons. The developed models contain either a large number of parameters which increase the model complexity or a lesser number of parameters which increase the amount of details in a parameter. Therefore, the "abcd" model which is a monthly lump hydrological model that has only four parameters was selected for the present research in order to estimate the local parameters of the model in the Ellagawa and the Thawalama sub catchments of the Kalu and Gin river basins. In the development of the model using Microsoft Excel, 25 years' data was used for the Thawalama sub watershed while 20 years' data was used for the Ellagawa sub watershed. For the model evaluation, a mean ratio of absolute error (MRAE) was used as the objective function while Nash Sutcliff Efficiency coefficient was used for comparison purposes. The optimized a, b, c, and d parameters for Thawalama and Ellagawa watersheds are 0.961, 1066, 0.003, 0.813 and 0.998, 1644, 0.013, 0.741, respectively. The MRAE for the calibration of the Thawalama and Ellagawa watersheds are 0.21 and 0.26, respectively while 0.23 and 0.43 were observed for the validation which show satisfactory results.

Keywords: monthly model, 'abcd' model, objective function, model parameters

1. INTRODUCTION

A considerable amount of uncertainties will be there in the future water demand and the availability of water, which will be a challenge for water management planners. Climate changes and its potential hydrological effects dominantly contribute to this uncertainty (Middelkoop et al., 2001; Xu & Singh, 2004). Further, these climate changes will affect the hydrological cycle and cause changes in precipitation and evapotranspiration (Middelkoop et al., 2001). In addition to the climate change impacts, the land use patterns of the catchments would be changed with urbanization. This can affect the runoff coefficient, evapotranspiration and groundwater recharge. All these changes will in turn affect the water availability and runoff, and thus may affect the flow regimes of rivers. This has alarmed the water managers to establish a systematic method / mathematical model to estimate the basin flow for effective water management.

Currently, Kalu Ganga and Gin Ganga watersheds are vulnerable to intermittent floods and droughts and this situation has aggravated mainly due to land use change, rapid urbanization and climate change impacts which have affected the water supply schemes, mini hydropower plants and agriculture, adversely. Therefore, it is a timely need to manage the water resources of the Kalu Ganga and Gin Ganga watersheds in an efficient manner without leading to any water deficits, for the crucial water requirements mentioned above. Up to now, there are no monthly lump hydrologic models developed for the Gin and Kalu river basins, which incorporate an optimum number of parameters and a model structure to represent the soil moisture and groundwater effectively. Therefore, considering these factors the 'abcd' monthly water balance model, which consists of four parameters was selected for the research to be applied in the Ellagawa and the Thawalama sub watersheds and to estimate it's parameters which match with local hydrological conditions, using appropriate objective functions.

2. METHODOLOGY

According to Thomas (1981), Martinez and Gupta (2010) and Al-Lafta et al., (2013) the model structure of the 'abcd' model is as shown in Figure . In the model, parameter 'a' reflects the propensity of runoff to occur before the soil is fully saturated. Parameter 'b' is the upper limit of the sum of actual evapotranspiration and soil moisture storage in a given month.

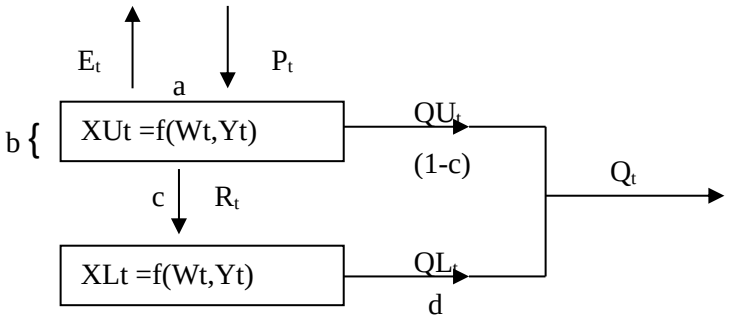


Figure 1. The "abcd" model structure

This parameter reflects the ability of the catchment to hold water within the upper soil horizon. Parameter 'c' controls the water input to the aquifers. The reciprocal of parameter 'd' is equal to the average groundwater residence time (Al-Lafta et al., 2013).

By applying the continuity equation for the upper moisture zone;
$P_t - E_t - R_t - QU_t = \Delta XU = XU_t - XU_{t-1}$

Where; P_t is Monthly precipitation ,E_t - Actual evapotranspiration, R_t - Recharge to groundwater storage, QU_t - Upper zone contribution to runoff, XU_t and XU_{t-1} - Upper soil zone soil moisture storage at the current and previous time steps, the above expression can be rearranged as;
$(P + XU_{t-1}) = (Et + XU_t) + QU_t + R_t$,

Where, $(P + XU_{t-1})$ is the available water (WA_t) and $(E_t + XU_t)$ is the evapotranspiration opportunity (EO_t), EO_t which can be expressed as a nonlinear function of WA_t as in;

$$EOt(WAt) = \frac{WAt+b}{2a} - \sqrt{\left(\frac{WAt+b}{2a}\right)^2 - \frac{WAt.b}{a}}$$

The nonlinear relationship between E_t, EO_t, and PE_t can be written as,

$E_t = EO_t \cdot \{1 - \exp(-PE_t / b)\}$.

The water availability for runoff = $(WA_t - EO_t)$, Upper zone contribution to runoff,
$QUt = (1 - c) \cdot (WA_t - EO_t)$
Ground water recharge; $R_t = c \cdot (WA_t - EO_t)$
Soil moisture storage in ground water compartment after recharging;
$XL_t = (XL_{t-1} + R_t) \cdot (1 + d)^{-1}$
The discharge from ground water compartment can be written as;
$QL_t = d \cdot (XL_t)$, Total stream flow can be written as; $Q_t = QU_t + QL_t$

The above equations were developed in Ms Excel considering the monthly Thiessen average rainfall, stream flow and potential evapotranspiration as input data. For the modelling exercise, (1980-2005) 25 years' and (1980-2000) 20 years' data periods for the Thawalama and Ellagawa sub watersheds

were used, respectively. Subsequently, for calibration, 13 years' data for the Thawalama watershed and 10 years' data for the Ellagawa were used. The balanced data were used for the verification of the model. In the calibration, average values of a,b,c and d parameters in the literature under different studies were used as initial values and calibrated considering the Mean Ratio Absolute Error (MRAE) as the objective function. This is considered to be suitable for medium and low flow regimes when compared with Nash Sutcliff Efficiency (NSE) value which is considered as suitable to calibrate high flows. For the calibration and validation, data sets of the 8th cycle which is the warm up period were used, since by that time, the model would have stabilized in its quasi-steady state. Then the models were further calibrated for the global minimum of MRAE by using Solver along with the Evolutionary option in Microsoft Excel.

3. RESULTS AND DISCUSSION

At the parameter optimization it was clearly observed that MRAE and NSE had reached a very low and a high value respectively, as shown in Table 1. As per the modelling exercises done by Vandewiele et al. (1992), Lafta et al. (2013), Alley (1984) and Martinez and Gupta, (2010), parameter a,b,c and d of the model varies between (0.873-0.999), (14-1900), (0-1) and (0-1) respectively. The optimized parameters of the Ellagawa and the Thawalama watersheds also fall within the ranges given in the above literature.

Table 1. Optimized "abcd" parameters and objective functions

Watershed	Parameter	Initial value	Optimized Parameter value	Objective function			
				Calibration		Validation	
				MRAE	NSE	MRAE	NSE
Thawalama	a	0.936	0.961	0.21	0.81	0.23	0.80
	b	957	1066				
	c	0.5	0.003				
	d	0.5	0.813				
Ellagawa	a	0.936	0.998	0.26	0.77	0.43	0.73
	b	957	1644				
	c	0.5	0.013				
	d	0.5	0.741				

4. CONCLUSION

The "abcd" monthly water balance model can be successfully calibrated and validated with the selected data periods of 25 years (1980~2005) and 20 years (1980~2000) for the Thawalama and the Ellagawa sub watersheds respectively, with the aid of MRAE and NSE as objective functions. The Thawalama watershed shows better performance than the Ellagawa watershed in calibration and validation in the presence of both objective functions. The optimized average a, b, c, d parameter values for the Thawalama and the Ellagawa watersheds are 0.980, 1355, 0.008 and 0.777 with corresponding average MRAE and NSE values of 0.24, 0.79 and 0.33, and 0.77 in calibration and validation, respectively.

5. REFERENCES

Al-Lafta, H. S., Al-Tawash, B. S., & Al-Baldawi, B. A. (2013). Applying the 'abcd' Monthly Water Balance Model for Some Regions in the United States. *Advances in Physics Theories and Applications*, *25*, 36–47.

Alley, W. M. (1984). On the Treatment of Evapotranspiration, Soil Moisture Accounting, and Aquifer Recharge in Monthly Water Balance Models. *WATER RESOURCES RESEARCH*, *20*(8), 1137–1149.

Martinez, G. F., & Gupta, H. V. (2010). Toward improved identification of hydrological models: A diagnostic evaluation of the 'abcd ' monthly water balance model for the conterminous United States: Diagnostic Evaluation Of ' *Abcd* ' monthly. *Water Resources Research*, *46*(8), https://doi.org/10.1029/2009WR008294

Middelkoop, H., Daamen, K., Gellens, D., Grabs, W., Kwadijk, J. C., Lang, H.,Wilke, K. (2001). Impact of climate change on hydrological regimes and water resources management in the Rhine basin. *Climatic Change*, *49*(1), 105–128.

Thomas, H. A. (1981). Improved Methods for National tvater Assessment Water Resources. Retrieved from https://pubs.usgs.gov/unnumbered/70046351/report.pdf

Vandewiele, G.L., Xu, C.-Y., & others. (1992). Methodology and comparative study of monthly water balance models in Belgium, China and Burma. *Journal of Hydrology*, 134(1–4), 315–347.

Xu, C. Y., & Singh, V. P. (2004). Review on regional water resources assessment models under stationary and changing climate. *Water Resources Management*, *18*(6), 591–612.

EFFECT OF INDOOR AIR QUALITY IN CLOSED SPACES FOR HUMAN COMFORT

Weerakoon W.M.D.S.[1], Kumari P.A.C.S.[2] and Suraweera D.D.D. [3]

[1]Department of Civil Engineering, Institute of Engineering Technology, Katunayake.
dininduwmds@gmail.com
[2] Electrical Division, Industrial Engineering Training Institute, Katubedda,, samadara.pa@gmail.com
[3]Department of Electrical & Electronic, University of Vocational Technology, Rathmalana.
dimuthusiri@gmail.com

ABSTRACT: Indoor Air Quality (IAQ) and thermal comfort are important factors in the design of high-quality buildings. Innovations in air-conditioning and other forms of cooling or ventilation, can be viewed as technological solutions to the problem of producing and maintaining energy efficient environmental conditions that are beneficial for human health, comfort and productivity. The aim of this study is to analyze the Carbon dioxide (CO_2) level inside a building space and propose a design to improve the indoor air quality of the building. The evaluation of this study was based on the results of monitoring temperature, humidity and the CO_2 level. The objective of the sturdy is to measure the indoor air quality parameters in selected areas and to find the difference between the actual parameter values and standard values and to propose a design to maintain a comfortable temperature and CO_2 and RH levels in an air-conditioned space. Results show that the CO_2 content gradually increased after closing the door and decreased when the door is opened as fresh air came in, making the CO_2 content come down to the standard values limit of <1000PPM. The relative humidity level was kept unchanged within a satisfactory range of 30-70 %, as suitable for the room. Also, the standard value for the CO_2 content was not achieved as the room was sealed. The information collected from the occupants through the questionnaire supported this finding as they indicated feeling symptoms when exposed to high CO_2 levels when the door was kept closed for long durations. Further, the room temperature did not change according to the set temperature of the Air Conditioner installed in the classroom. The study recommends developing the AC system inside the building to maintain the Indoor Air Quality.

Keywords: Indoor Air Quality, CO_2 level, Thermal comfort

1. INTRODUCTION

Performance of office and school work is affected by indoor environmental Quality (IEQ) and the features of buildings that influence indoor environmental conditions. Work performance inside a building may be improved up to as much as 10% by providing superior IEQ. The economic benefits of work performance improvements will often far outweigh the costs of providing better IEQ, particularly when higher temperatures improve thermal comfort. Also, there is a significant number of studies that have failed to find the impact of temperature on work performance. The impact of temperature or thermal comfort on work performance may depend on the type of work and the level of the workers' motivation.

2. METHODOLOGY

Office spaces and classrooms were selected for this study to get the information of necessary parameters in the University of Vocational Technology (UNIVOTEC) space. Questionnaires were used to collect information from the occupancy of classrooms. The CO_2 meter and Thermal camera were used to measure the room temperature, humidity, CO_2 level and thermal leakage inside the UNIVOTEC building space. The flow chart of this study is illustrated in the Figure -01.

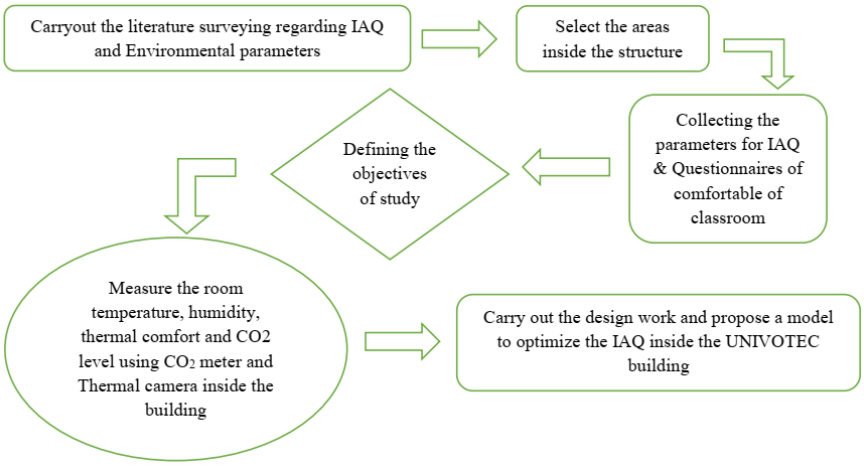


Figure – 01: Flow chart of the study

3. RESULTS AND DISCUSSION

Room temperature, Relative Humidity and CO_2 level in a class room are presented in tables and analysis was done using Microsoft Excel in Figures. Plan layout of the classroom and the points of A, B, C, D, E, F, G, H and I are selected to cover the internal sources of air conditioning inside the classroom as shown in Figure – 02.

Table – 01: Results of CO2 level inside the classroom

Carbon Dioxide									
Time	A	B	C	D	E	F	G	H	I
11.30 am	1465	1415	1368	1286	1312	1397	1432	1440	1477
12.00 pm	1752	1740	1735	1756	1689	1741	1758	1769	1766
12.30 pm	2375	2018	2042	2025	2027	2060	2042	2028	2036
01.00 pm	2169	2180	2190	2358	2173	2211	2151	2130	2131
CLASS INTERVEL									
02.00 pm	1041	1018	1031	1054	1075	1049	1089	1161	1257
02.30 pm	1545	1535	1531	1579	1526	1538	1603	1715	1741
03.00 pm	2017	2012	1998	1925	1937	2078	1982	1979	2004
03.30 pm	2216	2184	2172	2264	2250	2202	2236	2263	2314
04.00 pm	2396	2404	2384	2411	2370	2381	2341	2346	2357
CLASS INTERVEL									
04.30 pm	1318	1265	1154	1148	1146	1238	1328	1273	1281
05.00 pm	1760	1748	1718	1728	1722	1720	1808	1842	1832
05.30 pm	2090	2076	2053	2071	2050	2064	2097	2110	2110

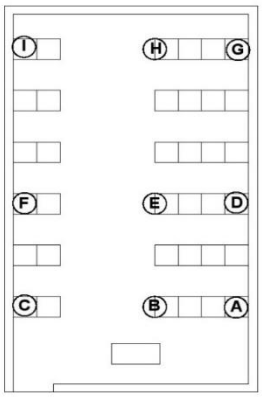


Figure 02: Plan layout of classroom

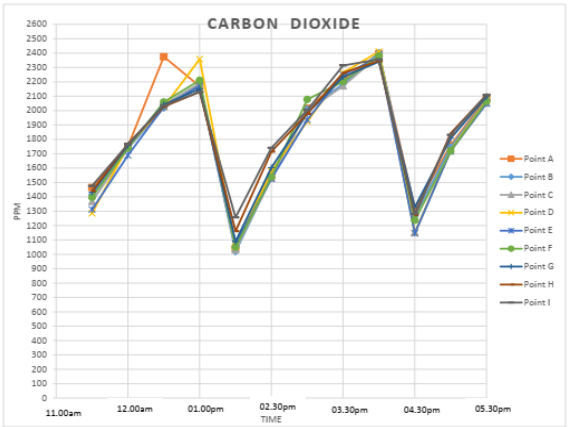


Figure 03: CO2 Variation with time inside the classroom

The observed results of the room temperature, Relative Humidity and the CO_2 level inside the classroom are detailed in Table – 01 in the time period between 11.00 a.m. to 5.30 p.m. Figure – 03 and Table – 01 reveal that the CO2 level was high at 12.30 p.m. and 4.00 p.m. and at 1.30 p.m. the CO2 level was low inside the classroom. Relative humidity with respect to the time period is illustrated in Figure – 04.

Table – 02: Results of RH level inside the classroom

Relative Humidity									
Time	A	B	C	D	E	F	G	H	I
11.30 am	43.5	43.1	42.8	45.6	44	43.7	46.3	46.1	46.5
12.00 pm	42.1	42.8	43	44.4	44.7	43.9	41.9	41.8	41.3
12.30 pm	41.5	42	42.3	44.5	42.1	42.3	41.3	41.4	41.8
01.00 pm	40.1	40.3	40.5	42.1	40.3	41	39.9	40.5	40.9
CLASS INTERVEL									
02.00 pm	45.8	46	46.3	46.9	46.1	46.5	45.2	45	45.4
02.30 pm	42	42.7	43.2	43.7	42.5	44.7	42.1	41.8	41.9
03.00 pm	39.8	40.3	40.1	40	38.8	40	39.3	38.9	39.3
03.30 pm	45.1	46.2	46.7	46.2	46.3	46.7	45	44.5	44.3
04.00 pm	42.6	43	42.6	43.5	42.2	42.5	42.6	42	42.1
CLASS INTERVEL									
04.30 pm	47.4	46.9	46.8	47.4	48.8	48.2	49.7	50.3	49.7
05.00 pm	45.7	46.2	45.8	47.7	46.3	46	46.5	46.7	47
05.30 pm	44.3	44.3	44.3	46.1	26.4	45.5	44.8	44.5	44.4

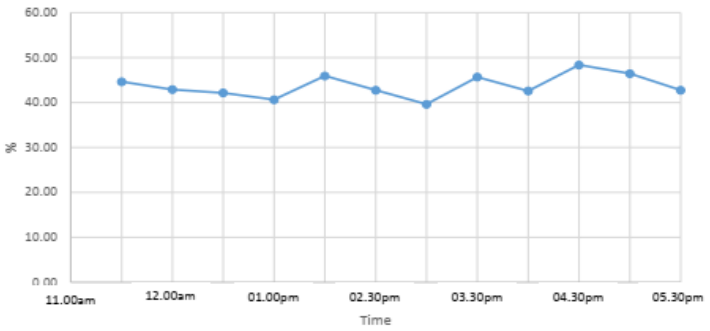


Figure 04: Relative Humidity Variation with time inside the classroom

During the class interval, fresh air comes into the room, but as only the door was open the rate of the incoming fresh air is not enough to reach the required comfort level. Figure – 05 shows the temperature variation with the time period inside the classroom and the highest temperature was observed at 1.30 p.m.

Table – 03: Results of Temperature inside the classroom

Temperature									
Time	A	B	C	D	E	F	G	H	I
11.30 am	28.1	28.2	28.1	27.7	27.8	28	28.5	28.6	28.5
12.00 pm	28.2	28.2	28.2	28.1	28.2	28.2	28.1	28.3	28.4
12.30 pm	28.2	28.1	28.1	28.2	28	28	28.1	28.2	28.2
01.00 pm	28	28	28	28.2	27.8	27.9	27.8	28.2	28.2
CLASS INTERVEL									
02.00 pm	28.7	28.7	28.7	28.8	28.6	28.6	28.6	28.3	28.5
02.30 pm	28.2	28.2	28.2	28.2	28	28	28	28.1	28.2
03.00 pm	27.8	27.6	27.6	28.1	27.8	27.6	27.6	27.2	27.6
03.30 pm	28.2	28.2	28	27.9	27.9	28	28	27.8	27.8
04.00 pm	27.6	27.8	27.8	28	27.7	27.8	27.6	27.4	27.5
CLASS INTERVEL									
04.30 pm	27.7	27.7	27.7	27.7	27.7	27.7	27.8	27.9	27.8
05.00 pm	27.8	27.8	27.7	27.7	27.5	27.6	27.8	27.8	27.9
05.30 pm	27.8	27.8	27.8	27.9	27.7	27.7	27.7	27.7	27.8

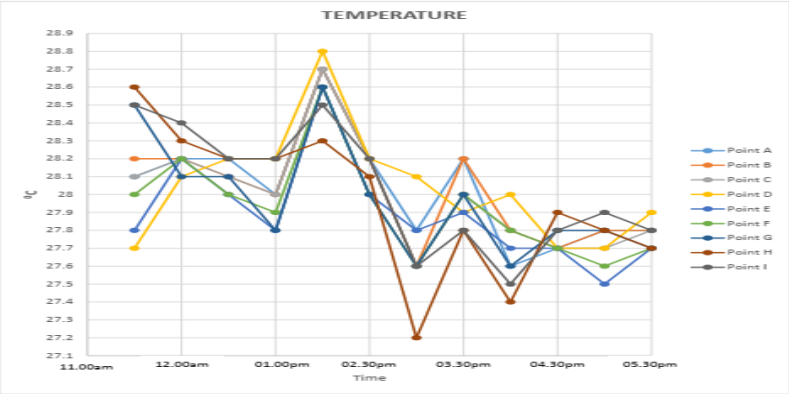


Figure 05: Temperature Variation with time inside the classroom

4. CONCLUSION AND RECOMMENDATION

From the beginning, the standard value (<1000PPM) of the Carbon Dioxide content was not achieved, due to the room being used every day and also because it was sealed. The fresh air cannot enter the room and also in the opposite side of the Air Condition Machine there is a rate increase of Carbon Dioxide, because the air there is unable to be sucked by the Machine. According to figure – 05, the temperature has changed more than expected. If the outside temperature is 30°C and the temperature of the Air Conditioner is 27°C, the room temperature has not changed according to the temperature of the Air Conditioning Machine. This study reveals that the relative humidity of the room is in comfort area and that it is in the limitation of a room. Also, the average humidity readings of the classroom satisfy the comfort range. Further, it is proposed to develop the Air Conditioning systems in the building for controlling the Air quality parameters.

5. REFERENCES

ANSI/ASHRAE Standards 62.1-2007' "*Ventilation for Acceptable Indoor Air Quality*"

ASHRAE, (1997), 1993 ASHRAE handbook – *Fundamentals. American Society of Heating. Refrigerating and Air – Conditioning Engineers, Inc*.

Batagoda, J.H., Jayasinghe, C., (2011) "*Indoor Air Quality Effect for Human Comfort*"

Catalina, T., and Iordache, V., 2011. *IEQ assessment on schools in the design stage. Building and Environment*, 49(1), 129-140.

SEASONAL VARIATIONS OF GROUNDWATER PH VALUE: INTERIM RESULTS OF A CASE STUDY IN GAMPAHA DISTRICT

Bulathsinhala A. U. V. B.[1], Udayangana P. M. B. M.[2] and Thoradeniya W. B. M.[3]

[1,2,3]Institute of Technology, University of Moratuwa, Sri Lanka
udaran22@gmail.com[1*], malithudaya1234@gmail.com[2], b.thoradeniya@gmail.com[3]

ABSTRACT: Among the essential water quality parameters established for drinking water, the pH value is of significant importance. The World Health Organization (WHO) has set the acceptable standard for the pH value of drinking water within a range of 6.5 to 8.5. Waters in the extreme pH ranges below 4.0 and above 10 have been advocated as unsuitable for human consumption due to various adverse effects. In 2013, there was a social upheaval at Rathupaswala, Gampaha District near a latex glove factory after observing the acidity in water samples obtained in the vicinity. The causation was erroneously deduced to factory effluent as the few previous research studies which had indicated the natural acidity of the groundwater in the area, were not known to the larger public. This research attempts to understand the variations of the pH value of groundwater in the area in a series of research work to establish plausible causes and mitigating measures for the issue. The aim of this paper is to present interim results obtained from temporal data collected in two seasons. The methodology employed include filed testing of water samples obtained at the pre-determined locations of a grid and plotting the contours using software ArcGIS and CT-droid. These interim results confirm the seasonal variation of pH values. Further, it was statistically inferred that up to 80% of the wells in the area show pH variations within 1.5 (pH scale) between the two seasons.

Keywords: Drinking water, pH variation of groundwater, pH contours, Rathupaswala, Groundwater quality

1. INTRODUCTION

In the drinking water supply systems, the pH value is an important chemical parameter of water. The World Health Organization (WHO) has set the acceptable standard for the pH value of drinking water within a range of 6.5 to 8.5 to ensure disinfection efficiency and to prevent the water being corrosive. Further, the WHO did not proposed a health based guideline value on their assessment carried out in 1993 citing the reason as the pH levels found in drinking-water is not a health concern (WHO, 2011). Nevertheless, extreme ranges of pH (< 4 and > 10) have been reported to cause adverse impacts to humans including irritations in the eyes, skin and mucous membranes (WHO, 2003).

In the year 2013, a huge social upheaval erupted at Rathupaswala, Gampaha District due to observing acidity in groundwater samples obtained near a Latex Glove factory. Even though a few studies had been carried out prior to this incident (e.g. Wijesekara and Kudahetty 2009), indicating the acidity of the groundwater in the area (Attanagalu Oya river basin), the majority of the people of the area had been unaware of such findings. They believed that the socio-political forces backed propaganda to the effect that the acidic groundwater observed with a low pH is a health hazard and suspected the factory effluent to be the cause of the acidity of the groundwater (Bulathsinhala and Thoradeniya 2018).

In this backdrop, the authors conducted a research study in a neighboring area aiming to understand the community perceptions on their drinking water. The first phase of the research realized the importance of educating the community on the natural pH value of their groundwater, its spatial and temporal variations, the plausible causes and mitigating measures for the areas where the pH value of groundwater is not within acceptable levels for drinking water.

The current phase of the research focuses on spatial and temporal variations of pH values in a sample area selected around the location of the former Glove factory. This paper aims to present the interim results through the following three objectives;

1. Conducting pH tests of groundwater samples at locations on a pre-determined grid during wet and dry seasons.

2. Analyzing the point value variations statistically to establish the percentage variation of the pH, which will be used to educate local communities.
3. Developing seasonal maps of pH variations.

2. METHODOLOGY

An area of 25 Sq.km was selected for the sample study. Groundwater samples were extracted at 121 points in this area. The Google Earth software was used to select the 121 points on a grid consisting of 500 m square (Figure 1).

Figure 1. Grid for water sample collection

Residences with groundwater wells, near the grid points were identified and the Google Navigation mobile application was used to find the location. Water samples extracted from domestic wells of selected locations were checked for the pH value using a portable pH meter.

The exact locations of water sampling points were identified using the CT Droid Software. The data thus collected were processed through Microsoft Excel. Northing and Easting coordinates of the points of water extractions were tabulated and their pH values were arranged as the Zenith Coordinate. Finally, the pH contours were generated using the ArcGIS software. This process was carried out twice a year; one in the rainy season and the other in the dry season.

The variations of pH values between the two seasons were statistically analyzed by testing two null hypotheses at 95% significance level.

H_{01} : Probability of the pH value variation over 1.5 (pH scale) in the wells of the area, between the two seasons is 20%.

H_{02} : Probability of the pH value variation over 1.0 (pH scale) in the wells of the area, between the two seasons is 45%

3. RESULTS AND DISCUSSION

The water sample testing was carried out in two different periods; August 2019 – October 2019 (rainy season) and January 2020 – March 2020 (dry season). The pH contours drawn for the two sets of data are given in Figures 2 and 3.

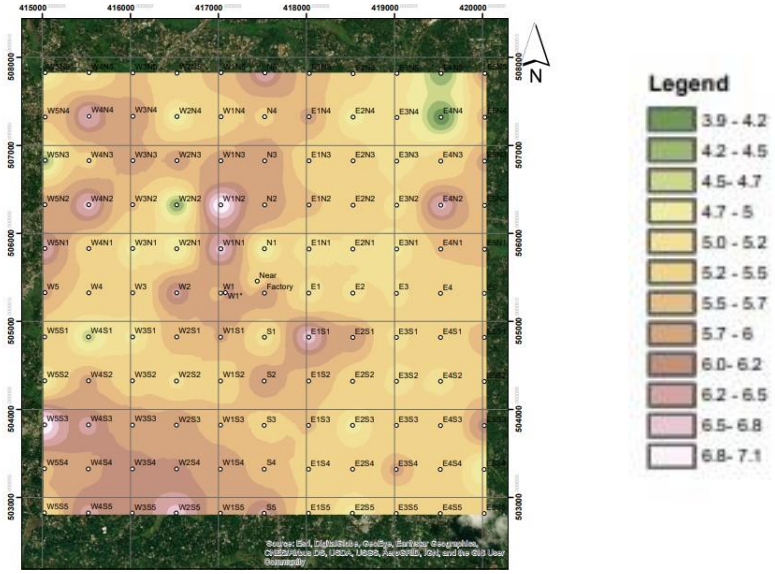


Figure 2. pH contours: Aug. 2019-Oct.2019 (rainy season)

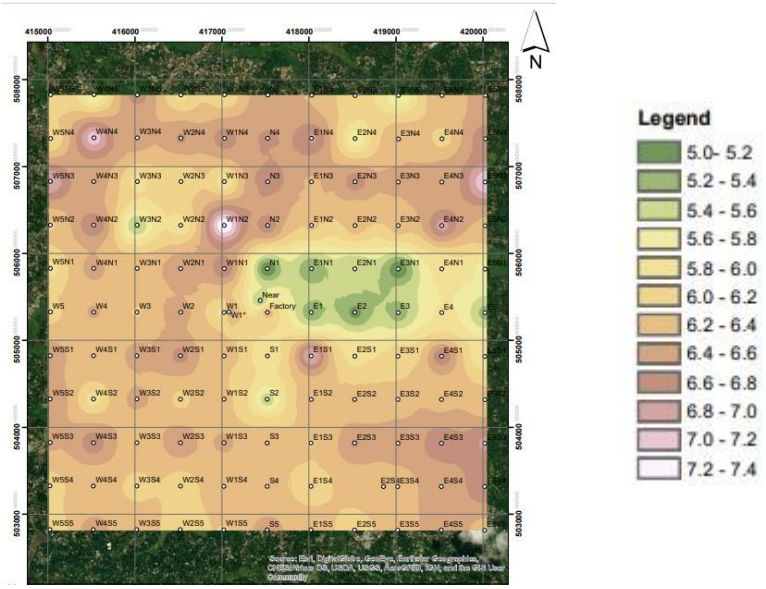


Figure 3. pH contours: Jan. 2020- Mar.2020 (dry season)

The maximum and minimum pH values of the data set 1 obtained during the period, August 2019 - October 2019 are 7.12 and 3.96 while the same for data set 2 during the period January 2020 – March 2020 are 7.41 and 5.02 respectively. The results obtained during the dry season shows that there is an increase in the pH values compared to that of the rainy season, i.e. the acidity of the water had decreased in almost all the locations compared to the rainy season. This increase is an unexpected result which requires further exploration.

The Hypotheses tested allowed the rejection of the two null hypotheses at 95% significant level. Therefore, statistical inference can be drawn that at least 80% wells in the area has pH value variation

less than or equal to 1.5 and at least 55% of the wells have variations up to 1.0. Around 10% of the sample wells had pH variations between 1.5 to 3.0 between the two seasons.

In the next steps it is expected to collect more seasonal data on pH values, data on soils and geological formations and geohydrology etc. to enhance the understanding of the phenomenon in order to educate the local communities and to introduce any mitigating measures including human activities which may aggravate the acidity of the groundwater.

4. CONCLUSION

The studies carried out by government agencies and researchers on pH value of ground water in the Attanagalu Oya river basin at macro level are not easily accessible by the community. Nonetheless, this study further proves that the groundwater is generally acidic within the sample area of 25 sq.km.

The two maps illustrate the fluctuation of the pH values within a short distance. This interim data proves that at 90% of the locations in the sample area, the seasonal variations of the pH value is less than the 1.5 scale point in the pH value range. This further allows to statistically infer that at least 80% of the wells in the area have variations less than or equal to 1.5 at a 5% confidence interval. The continuation of this study will enable developing scientific tools to educate the community on the seasonal variations of pH values of their groundwater at micro level.

5. REFERENCES

Bulathsinhala, A. and Thoradeniya, B. (2018). Post 'Rathupaswala Issue'*:* Neighbouring community perceptions of groundwater, *Engineer*, 85-94

Jayawardana, D. (2015). *Effect of low pH of Groundwater in Rathupaswala Area, Sri Lanka: A Case Study.* Proceedings of the Research Symposium of Uva Wellassa University, *5*,[Online] Available from: https://www.researchgate.Net/publication/272175683_Effect_of_Low_pH_of_Groundwater_in_Rathupaswala_Area_Sri_Lanka_A_Case_Study [Accessed] 01/05/2019

WHO (2003). *pH in drinking water*: Background document for development of WHO Guidelines for Drinking-water Quality, World Health Organization, Geneva.

WHO (2011). *Guidelines for Drinking-water Quality*, 4th Edition, World Health Organization, Geneva. ISBN 978 92 4 154815 1

Wijesekara, R. S. and Kudahetty, C. (2009). *Preliminary Groundwater Assessment & Water Quality study in Aththanagalu Oya Basin*, National Conference on water, food, security & climate change in Sri Lanka, Vol. 2, Water Quality, Environment and Climate Change, pp. 77-86

ATTITUDES TOWARDS THE GREEN SUPPLY CHAIN MANAGEMENT: A CASE STUDY ON MANUFACTURING AND AGRICULTURAL SECTORS IN SRI LANKA

Shisara M.A.K.K.[1*] and Wijewardana Y.N.S.[2]

[1,2] Department of Engineering Technology, Faculty of Technological Studies, Uva Wellassa University of Sri Lanka.

kalindukithmina9@gmail.com[1*], Senani@uwu.ac.lk[2]

ABSTRACT: Green Supply Chain Management Practices (GSCMP) were created by integrating the green concept with traditional Supply Chain Management Practices (SCMP). This is expected to reduce the impact on the environment due to increasing competition, continued growth in international trade and the emerging technology sector. However, certain barriers and drivers directly affect the implementation of GSCMP, internally and externally. The main objective of this study is to evaluate the internal and external barriers and drivers affecting the implementation of GSCMP and the specific objective is to apply stakeholders' recommendations on the implementation of GSCMP in the manufacturing and agricultural sectors in Sri Lanka. An online survey was conducted to determine the major barriers and drivers affecting the implementation of GSCMP internally and externally, as identified by past literature. The survey was conducted on a sample population of 30, working in the manufacturing and agriculture sectors in Sri Lanka, who are well versed in the concept of GSCMP. This sample population was selected using the simple random sampling technique. The overall data were evaluated using descriptive statistics using the Minitab software. The findings of the survey confirmed the lack of knowledge and experience as a major internal barrier and the lack of green professionals as an external barrier. Also, the study confirmed top management support as the main internal driver and green procurement as the main external driver. Furthermore, the comments made by the respondents in this study can be applied for improving the GSCMP and may be of use in moving towards sustainability in the manufacturing and agricultural sectors in Sri Lanka.

Keywords: Green Supply Chain Management, Supply Chain, barriers, drivers, descriptive statistics

1. INTRODUCTION

Today, SCMP play an invaluable role in enhancing and maintaining the competitive advantages of companies. The Supply Chain (SC) is made up of several departments and without a connection to this chain, the desired goods or services cannot be delivered to the desired customers or the desired locations. Therefore, these departments are directly or indirectly related to each other (Kormych et al., 2019).

At present, several major environmental issues are faced by the industry. The main reason for this is the rapidly changing global production scenario. Establishing an eco-friendly system in supply chains is the key to building a strong discourse in the 21st century and can be seen as a major challenge for businesses. As a result, some professionals have found solutions to prevent the negative effects on the environment via SC, resulting in the GSCM (Amemba et al., 2013). The primary purpose of a GSCMP is to conserve energy systems and limit waste in the production process to prevent the accumulation of harmful substances in the environment. GSCMP is an ideal platform for businesses to overcome this challenge and achieve their environmental goals (Baki, 2018).

However, some hinders and motivators influence the implementation of GSCMP internally and externally and these are called barriers and drivers, respectively. Factors that hinder the implementation of GSCMP are defined as barriers. This study examined past literature and identified 15 barriers (7 internal barriers and 8 external barriers) to GSCMP. The factors that motivate GSCMP implementation are defined as drivers. This study examined past literature and identified 13 GSCMP drivers (7 internal drivers and 6 external drivers).

In the recent past, there have been several published studies of barriers and drivers in GSCMP. However, there has been no research conducted on the barriers, drivers, and recommendations for improving GSCMP in the manufacturing and agricultural sectors in Sri Lanka. These are the research questions of this study. This study fills these questions and achieves the objectives. The main objective of this study is therefore, to evaluate the internal and external barriers and drivers affecting the implementation of GSCMP and the specific study is to make stakeholders' recommendations for the implementation of GSCMP in the manufacturing and agricultural sectors in Sri Lanka.

2. RESEARCH DESIGN AND METHODS

2.1. Sample selection

A sample population of thirty-five specialized persons such as engineers, assistant engineers, managers, technicians, and technologists who were well versed in GSCMP applications in the manufacturing and agricultural sectors in Sri Lanka were selected for the study. A simple random sampling technique was used to select the population.

2.2. Questionnaire development

An online questionnaire was prepared and sent to selected professionals to measure the expertise of professionals on the drivers and barriers affecting the implementation of GSCMP identified by past literature sources. An online questionnaire consisting of four main parts; (A) background of the respondents, (B) barriers for introducing GSCMP according to your perception, (C) drivers for introducing GSCMP according to your perception, and (D) recommendations for introducing and implementing GSCMP was developed.

2.3. Data Collection

The online questionnaire with ethical approval was sent to the selected sample population using email and whatsApp technologies. The online survey was conducted from mid-September to mid-October 2020, using the selected sample population. In total, 30 out of 35 of the selected population completed the online questionnaire.

2.4. Data analysis

The data collected from the online questionnaire survey were analyzed by using descriptive statistics. Minitab software version 17.1 was used for analyzing the data.

3. RESULTS AND DISCUSSION

3.1. Background of the Respondents

The findings reveal that the highest number of respondents - 40% (N=12) who participated in the study were from the manufacturing sector and 37% (N=15) were employed as managers. Moreover, the highest number of these respondents, 12% (N=15) had a 1-5 year service period. Further, they all had a knowledge of the concepts of SCMP and of GSCMP in the questionnaire. All the respondents answered ‘yes’ to the two questions ‘‘Do you have an idea about SCMP?’’ (100%, N=30) and ‘‘Do you have an idea about GSCMP?’’(100% , N=30).

3.2. Barriers to introducing GSCMP

Figure 1 shows the mean values at which the barriers were obtained after analyzing the data.

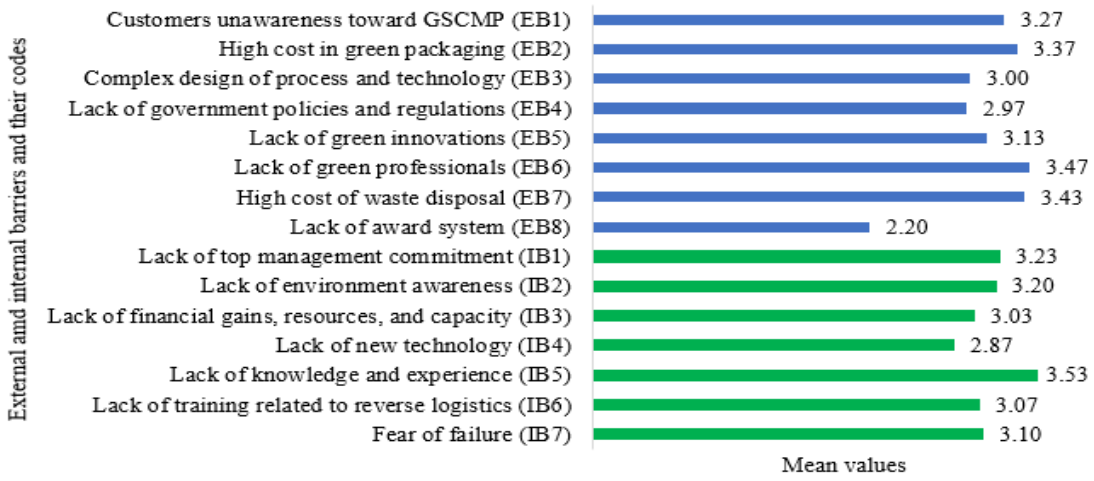


Figure 2. Mean Values Obtained by the External and Internal Barriers

Data analysis revealed the lack of green professionals as the major external barrier to GSCMP implementation. This makes sense of the shortage of green professionals in the manufacturing and agricultural sectors in Sri Lanka and the availability of green professionals has become an essential factor in overcoming this situation.

Moreover, the lack of knowledge and experience was seen as the major barrier to GSCMP implementation internally, therefore all the stakeholders who condemn the implementation of GSCMP should be well aware of this concept. However, it is up to the environmental protection societies to provide a better understanding and experience of this concept.

3.3. Drivers to introducing GSCMP

Figure 3 shows the mean values at which the drivers are obtained after analyzing the data.

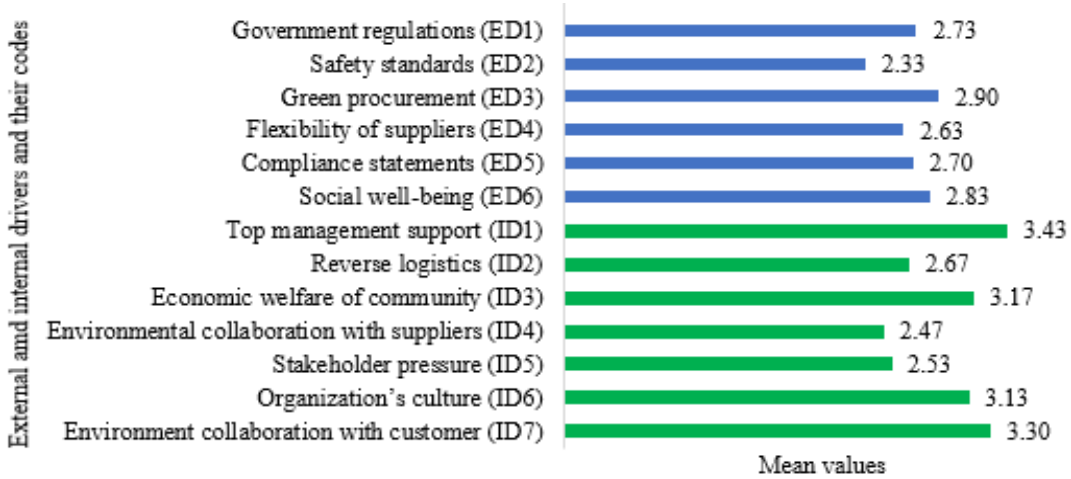


Figure 4. Mean Values Obtained by the External and Internal Drivers

These findings based on the analyzed data revealed green procurement as the major external driver. This means focusing on purchasing only eco-friendly products when purchasing goods or services that an organization needs.

Moreover, top management support has the highest mean value as the main internal driver. This means that the top management needs to make positive decisions about the implementation of GSCMP in their organization. They should invest their finances, human, and other resources in implementing this concept. Zhang et al. (2009) has confirmed this aspect in their study.

3.4 Recommendations for the introduction and implementation of GSCMP

Respondents who participated in the survey had the opportunity to give their views on improving GSCMP in the manufacturing and agricultural sectors in Sri Lanka through the online questionnaire. Recommendations they have made are: incorporating GSCMP in firms with large financial assets, increasing a company's technological assets, increasing a company's reciprocal supply, increasing the efficiency of green packaging systems, encouraging corporate products to be exported to foreign countries, reducing the cost of using energy and purchasing environmentally friendly products. Thus, the application of these recommendations can further streamline the implementation of GSCMP in these sectors in Sri Lanka.

4. CONCLUSION

This study mainly focuses on the barriers and drivers affecting the implementation of GSCMP internally and externally in the manufacturing and agricultural sectors in Sri Lanka. Based on the findings, the lack of knowledge and experience is the main internal barrier and the lack of green professionals is the main external barrier. Further, this study found top management support as the main internal driver and green procurement as the main external driver. In conclusion, the findings of this study can be of great help to Sri Lanka's manufacturing and agricultural sectors in their quest for environmental sustainability, and the views made by respondents can be applied to the development of GSCMP.

5. ACKNOWLEDGMENTS

We gratefully acknowledge all the professionals in the manufacturing and agricultural sectors in Sri Lanka who have given valuable their support to achieve the objectives of this study.

6. REFERENCES

Amemba, C. S., Nyaboke, P. G., Osoro, A., & Mburu, N. (2013). Elements of Green Supply Chain Management. *European Journal of Business and Management*, 5(12), 51–61.

Baki, R. (2018). Literature Review on Green Supply Chain Management Concept and Problems During It's Implementation. *The Journal of International Scientific Researches*, 3(2), 17–25. https://doi.org/10.23834/isrjournal.412121

Kormych, B., Averochkina, T., Savych, O., & Pivtorak, H. (2019). Barriers and drivers of green supply chain management: *A case study of Ukraine. International Journal of Supply Chain Management*, 8(5), 305–313.

Zhang, B., Bi, J., & Liu, B. (2009). Drivers and barriers to engage enterprises in environmental management initiatives in Suzhou Industrial Park, China. *Frontiers of Environmental Science & Engineering in China*, 3(2), 210–220. https://doi.org/10.1007/s11783-009-0014-7

AREAS TO BE INVESTIGATED TO IMPROVE THE RELIABILITY OF THE RESULTS OF THE CROSS-HOLE SONIC LOGGING TEST

Priyankara W.M.D.[1]

Institute of Technology, University of Moratuwa, Sri Lanka
Dinwick92@gmail.com

ABSTRACT: In-situ cast concrete piles have become the solution to foundation constructions where weak soil strata exist. Although quality control measures are most often taken during the installation of piles, it is extremely difficult or impossible to confirm the integrity of a drilled shaft during construction. Therefore, the importance of integrity testing of the cast piles has become a grave concern. The integrity of piles; which is measured with different techniques, which include the Cross-hole Sonic Logging (CSL) test has become one of the most reliable and widely used techniques among them, especially in the Sri Lankan construction industry. Although it has developed up to a certain standard, there are areas that need to be investigated in order to improve the reliability of the results obtained by the CSL test. This study is therefore focused on identifying the drawbacks and lapses of the CSL method and to propose potential research gaps for future studies.

Keywords: Piling, Cross-Hole Sonic Logging, Integrity of piles, Non-Destructive testing, Ultrasonic wave

1. INTRODUCTION

Cast in place concrete piles are widely chosen as a deep foundation solution for places in which challenging soil conditions exist. Due to errors in construction; during boring and toe flushing, in reinforcement cage insertions and in concreting and other processes, minor and major anomalies can take place in the piles. An anomaly is any irregular feature that is encountered in non-destructive testing results. If an anomaly, because of either size or location, can affect pile shaft performance, then the anomaly is considered as a defect (Amir 2002). Some examples of defects are voids, honeycombs, cracks, necking, soil inclusions, and corroded rebar. The presence of these defects can affect the structural soundness of piles significantly. Therefore, it is important to identify these defects and treat them with great care before the completion of the foundation works. The non-destructive testing (NDT) methods such as the Low Strain Integrity Test (PIT) and Cross-Hole Sonic Logging (CSL) test are widely used in the industry to identify these defects in piles. Among them, the CSL offers the most reliable data for assessing in-situ constructed deep foundation elements. Although this technology has developed more with the development of computer technology during the recent past, many practitioners still have difficulties in interpreting CSL results with an anomalous response. The main objective of this paper is therefore, to identify possible improvements that could be made to enhance the interpretation ability of the persons involved and to find research gaps in the CSL method for future studies.

2. LITERATURE REVIEW

The Literature review mainly focussed on two aspects; firstly, to identify the drawbacks of the CSL method with currently available instruments and the methodology and secondly, to find the potential research areas of this method that could improve the reliability of the results.

The Cross-hole Sonic Logging Test detects pile integrity by transmitting ultrasonic signals through pile shafts from one water filled access tube that is tied to a reinforcement cage to another. Initially, both wave transmitting and receiving probes are lowered to the bottom of the pile and then simultaneously lifted-up while measuring the transmitted signal. Such a set of measurements are called a 'profile' and all possible profiles are collected to cover the pile shaft. Then the testing instrument

plots the Depth versus the First Arrival Time (FAT) and the Depth versus the Relative Pulse Energy received. Those two data are used to investigate the quality of the concrete of the pile.

2.1 Drawbacks in CSL method

According to FHWA (2015), there are two major concerns in the CSL method; the frequent ‘‘false positives’’, anomalies that are not confirmed as being significant defects on coring and the lack of integrity evaluation outside the reinforcing cage. The first concern often leads to coring of sound shafts, which unnecessarily consumes agency time and resources. The second concern acknowledges a significant limitation of CSL testing. Concrete outside the reinforcing cage is critical for side resistance and shaft durability, but is not directly assessed with CSL testing. Boeckmann et al. (2019) constructed 4 feet diameter concrete piles with intentional defects and their results showed that defects due to weak concretes couldn’t be identify with the CSL test. Another possible drawback in the CSL method is the blockage of access tubes due to leakage of concrete grout. This often leads to coring; which affects costs and time waste. This can be eliminated through proper workmanship during pile casting. According to Zhussupbekov et al. (2019), detectability of the CSL method highly depends on the number of access tubes and on the other hand the increment of access tubes can reduce the effective area of the pile shaft. Therefore, an optimum number of access tubes needs to be installed during construction. The same study showed that major diagonal defects are more difficult to find with the CSL method. White B. et al. (2008) have also stated that diameter variations or bulging couldn’t be detected with this technique. Evaluation often requires experience and engineering judgment when results are complicated or not outwardly conclusive which leads to more consultancy costs. Even though this method has the above drawbacks, it is still widely used due to its ability to detect defects with higher precision compared to other available techniques.

2.2 Potential research gaps in CSL methods

Though many concerns were raised in the above sections, not all can be addressed practically. Therefore, the writer prioritized a few concerns, depending on their vitality and practicality which are listed below:

- Evaluating the integrity of concrete outside of the rebar cage
- Identify anomaly “signatures” associated with weak concrete which can be used as a reference in data interpretation
- Determining the optimum number of access tubes for different pile sizes
- Identifying a more suitable wave which provides more details on defects found in piles
- Determining a relationship between concrete grade and minimum detectable defect size

3. METHODOLOGY

Comprehensive study will be carried out to design series of CSL tests to fulfil the aforementioned knowledge gaps. Then reinforced concrete structures will be casted with the aid of wooden moulds with artificial defects in specific locations and sizes. These will be tested with CSL apparatus and based on the results, in-situ concrete piles will be designed and constructed to conduct CSL tests in wet conditions. The obtained results will be analysed to derive a conclusion.

4. CONCLUSION

According to the literature reviewed, the CSL method is one of the widely used techniques to evaluate the integrity of piles in the construction industry. Even though it has a higher capability of detecting defects in piles, yet there are some vital concerns to be addressed to

improve the reliability of the results obtained by this technique. Therefore, detailed studies on these aspects, would be beneficial for the entire deep foundation construction industry.

5. REFERENCES

Amir,J.M. (2002). Discussion of *'Reliability Evaluation of Cross-Hole Sonic Logging for Bored Pile Integrity" by D. Q. Li, L. M. Zhang, and W. H. Tang', Journal of Geotechnical and Geo Environmental Engineering © Asce / March 2007 / 347*

ASTM Standard D6760. Standard Test Method for Integrity Testing of Concrete Deep Foundations by Ultrasonic Crosshole Testing. ASTM International, West Conshohocken, PA, 2016.

Boeckmann,A.Z. & Loher,E.J. (2019) 'Evaluation of Thermal Integrity Profiling and Cross-hole Sonic Logging for Drilled Shafts with Concrete Defects', *Transportation Research Record 2019,* Vol. 2673(8) 86–98

Fiona,W.Y Chan & Steven,W.F (2005). Effects of Different Sonic Access Tube Materials on the Signal Strength of Ultrasonic Waves in the Cross-hole Sonic Logging Technique, *HKIE Transactions,* 12:2, 1-7

White,B. Nagy, M. & Allin, R. (2008) 'Comparing cross-hole sonic logging and low-strain integrity testing results', *International conference on the application of stress wave theory to piles,* 472-476

Session 03

ENHANCEMENT OF THERMAL CONDUCTIVITY OF GRAPHITE FILLED NATURAL RUBBER LATEX DIPPED COMPOSITES

Gamlath G.R.V.S. [1], Etampawala T.N.B.[1,2*]

[1]Centre for Advanced Material Research, University of Sri Jayewardenepura, Sri Lanka
[2]Department of Polymer Science, Faculty of Applied Sciences, University of Sri Jayewardenepura, Sri Lanka
tetampa@sjp.ac.lk[1,2*]

ABSTRACT: Latex dipping is widely used in the manufacture of gloves, condoms, balloons, etc. In some applications enhancement of the thermal conductivity of the end product is of utmost importance. In general, latex condoms reduce heat transfer, which may contribute to a reduction of sexual pleasure. Incorporation of fillers to enhance thermal conductivity without compromising the physio-mechanical properties of micrometre thin-films is challenging. In this work, jet-milled graphite powder of about 4 µm in size was incorporated to the centrifuged natural rubber latex and dipped films were prepared using a glass former. The thermal conductivity of the latex films was determined using Lee's disc method and compared with the reference sample that was prepared using the same formulation but without the graphite additive. Jet-milled-pristine-Graphite incorporated natural rubber latex samples showed thermal conductivity of 0.094 $Wm^{-1}K^{-1}$, which is approximately a five-fold enhancement with respect to the control sample. The preliminary results of the Jet-milled graphite incorporated films showed further enhancement of thermal conductivity.

Keywords: Natural rubber centrifuged latex, Latex dipping, Graphite powder, Thermal conductivity

1. INTRODUCTION

Natural rubber latex is a thixotropic, neutral milky fluid having density around 0.98 gcm^{-3} (Tillekeratne et al., 2003). Fresh latex contains about 30 – 35% of Dry Rubber Content (DRC). Since its DRC is low it is difficult to use in the manufacturing of dipped products. Once it is centrifuged, the DRC could be increased up to 60%. Centrifuged natural rubber latex, when compounded with other chemical ingredients can be used in the manufacture of commercially valuable articles such as gloves, condoms and balloons.

Efficient thermal dissipation in rubber-based products is a beneficial property as it enhances the durability and the lifetime of the product. For a product like a condom, efficient heat dissipation could minimize sweating and could improve the comfort levels of the product (George et al., 2017).
Presently, most of the male condoms are prepared using natural rubber latex: they are easy to use and serve as a good physical barrier. However, the reduction of strength at maximum stretch, poor heat transfer properties, low lubricity, harmful effects of oil-based lubricants and oxidation are some of the shortcomings associated with natural rubber (NR) latex condoms (Agbakoba, 2018). Hence, the usage of carbon-based materials to enhance the flexibility, thermal conductivity and modulus of natural rubber latex thin films came into play. Further, the incorporation of nanoscale fillers could improve the elastic properties of latex films such as ultimate tensile strength and maximum strength at failure (Iliut et al., 2016).

Graphene, a two – dimensional sp^2 hybridized nanomaterial has been studied extensively for a number of biomedical applications including drug delivery, bio sensing, bioimaging etc. (Sukumar et al., 2020). Graphene and its precursor graphene oxide have received tremendous attention recently, due to their versatility and larger surface area (Dong et al., 2015).

Graphene could be incorporated into polymer nanocomposites for several applications such as in the manufacture of condoms, gloves, etc. (Sukumar et al.., 2020). Carbon nanotubes can be used as a potential reinforcing nanofiller to enhance the thermal conductivity of the NR latex condoms

(Agbakoba, 2018). Exfoliated graphene could be incorporated to the natural rubber latex in order to enhance the thermal conductivity of the latex condoms (George *et al*., 2017). Further, the reduced graphene oxide has been successfully incorporated to the NR latex (Lim et al., 2019) and significant improvement in thermal conductivity has been observed.

However, there has been very little technological improvement in the condom industry, despite the role they play. None of the researchers had focused on the incorporation of jet-milled graphite powder to natural rubber latex in order to be used in condom manufacturing. Therefore, the main aim of the study is to investigate the thermal conductivity and the mechanical property enhancement of the jet-milled graphite incorporated latex films.

2. METHODOLOGY

Centrifuged natural rubber latex was obtained from the Industrial Development Board, Peliyagoda. Graphite powder was obtained from the Bogala Graphite Lanka PLC. The jet-milled graphite incorporated latex films were prepared based on the following formulation.

Table 1. Compounding formulation for Graphite incorporated NR latex films

Compounding ingredients	Dry weight (phr)	Wet weight (phr)
60% Centrifuged natural rubber latex	100	167
50% ZnO dispersion	0.9	1.8
10% KOH solution	0.1	1
50% Sulphur dispersion	1.5	3
50% ZDC dispersion	0.7	1.4
50% Graphite dispersion	1.5	3

Note: derived formulation from George *et al*., (2017)

1% $Ca(NO_3)_2$ was used as the pre-coagulant and the post-coagulant.

Table 2. Pre-coagulant and post-coagulant formulation

Chemical ingredient	Amount
$Ca(NO_3)_2$	1 g
Methanol	99 ml

Latex compounding was done with continuous stirring. Well cleaned and dried glass formers were used. Glass formers were first dipped in pre-coagulant, then in latex compound and lastly in post-coagulant. 1.5 phr and 3 phr graphite latex films were prepared along with the control samples. Control samples were prepared using the same formula, but without a graphite additive. The prepared samples were oven dried at 80 ± 5ºC for about 1 ½ hours to cure.

The oven cured samples were kept at room temperature for about 4 hours to mature. Silica powder was used to remove the tackiness of the samples. The thermal conductivity and the tensile properties of the latex films were measured. Lee's disc method was used in measuring the thermal conductivity of the samples.

3. RESULTS AND DISCUSSION

The preliminary results obtained are shown below:

Tensile property values of jet-milled graphite incorporated latex films along with the control samples:

Table 3. Tensile property values of the latex films

Sample	Tensile strength (MPa)	Tensile modulus (MPa)	Elongation at Break (%)
NR latex films	25 ± 1.5	1.5 ± 0.03	867
1.5 phr jet-milled graphite incorporated NR latex films	32 ± 1.6	1.9 ± 0.04	820
3 phr jet-milled graphite incorporated NR latex films	27 ± 2.0	1.8 ± 0.03	845

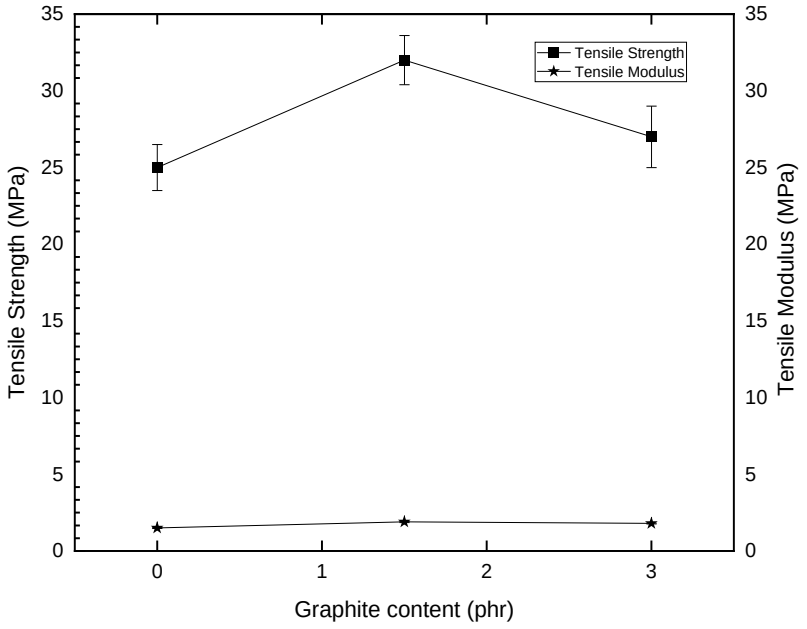


Figure 1. Tensile property values of the latex films

Thermal conductivity values in jet-milled graphite incorporated natural rubber latex films:

Table 4. Thermal conductivity values of latex films

	Thermal conductivity in $Wm^{-1}K^{-1}$ at 37°C
NR latex film	0.019
1.5 phr jet-milled graphite incorporated NR latex film	0.094
% increment	395

4. CONCLUSION

The jet-milled graphite incorporated NR latex films showed an enhanced thermal conductivity (five-fold increment) along with a 28% increase in tensile strength. Further, jet-milled graphite incorporated NR latex films could be used as a precursor for the preparation of new generation latex-graphite dipped composites for future applications.

5. ACKNOWLDGEMENT

The research was supported by the Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher Education funded by the World Bank.

6. REFERENCES

Agbakoba, V. C. (2018). *Potential Use of Carbon Nanotubes as a Nanofiller for Natural Rubber Latex Condoms*. Degree of Magister Scientae, Nelson Mandela University of Science, Port Elizebath, South Africa.

Dong, B., Liu, C., Zhang, L., & Wu, Y. (2015). Preparation, fracture, and fatigue of exfoliated graphene oxide/natural rubber composites. *RSC Advances*, 5(22), 17140–17148. https://doi.org/10.1039/c4ra17051b

George, G., Sisupal, S. B., Tomy, T., Pottammal, B. A., Kumaran, A., Suvekbala, V., Gopimohan, R., Sivaram, S., & Ragupathy, L. (2017). Thermally conductive thin films derived from defect free graphene-natural rubber latex nanocomposite: Preparation and properties. *Carbon*, *119*, 527–534. https://doi.org/10.1016/j.carbon.2017.04.068

Lim, L. P., Juan, J. C., Huang, N. M., Goh, L. K., Leng, F. P., & Loh, Y. Y. (2019). Enhanced tensile strength and thermal conductivity of natural rubber graphene composite properties via rubber-graphene interaction. *Materials Science and Engineering B*: *Solid-State Materials for Advanced Technology*, 246 , 112–119. https://doi.org/10.1016/j.mseb.2019.06.004

Sukumar, T., Varghese, J., Kiran, S., Bhargavan, S., Jayasree, P., Suvekbala, V., Alaganandam, K., & Ragupathy, L. (2020). *Cytotoxicity of Formulated Graphene and Its Natural Rubber Nanocomposite Thin Film in Human Vaginal Epithelial Cells: An Influence of Noncovalent Interaction ACS Biomaterials Science and Engineering*, *6*(4), 2007–2019. https://doi.org/10.1021/acsbiomaterials.9b01897

Tillekeratne, L. M. K., Nugawela, A., & Seneviratne, W. M. G. (2003). Hand Book of Rubber | *Volume 2* | Processing Technology (L. M. K. Tillekeratne, A. Nugawela, & W. M. G. Seneviratne (eds.); 1st ed.). Rubber Research Institute of Sri Lanka Agalawatta.

INVESTIGATION OF OPTIMUM DICYMUL PEROXIDE LOADING FOR THERMOPLASTIC VULCANIZATE FROM NATURAL RUBBER/HIGH DENSITY POLYETHYLENE FOR ROOFING APPLICATION

Wickramaarachchi W.V.W.H.[1], Walpalage S., Egodage S.M. [3]

[1]Institute of Technology, University of Moratuwa, Sri Lanka
[2,3]University of Moratuwa, Sri Lanka
wathsalav@itum.mrt.ac.lk[1*], shanthaw@uom.lk[2] , segodage@uom.lk[3]

ABSTRACT: In Sri Lanka, different types of roofing material, either locally manufactured or imported, are used extensively with their inherent drawbacks. Asbestos is the widely used roofing material due to economic advantage; however, it is associated with scientifically proven health risks. Therefore, there is a timely need for introducing economically advantageous and health hazard free roofing material to the market. Thermoplastic vulcanizate (TPV), prepared using dynamic vulcanization, is a type of rubber-thermoplastic blend which has enhanced properties compared to their parent materials. This study focused on finding the optimum dicymul peroxide (DCP) loading as the vulcanizing agent for the development of TPV from natural rubber (NR) and high-density polyethylene (HDPE) for a roofing material. Polyethylene roofing materials are currently used with some drawbacks such as lightweight and transparency. Incorporation of natural rubber can minimize these issues and it will be a good opportunity to give a value addition to the raw natural rubber export in Sri Lanka. In this work, a series of NR/HDPE TPVs were prepared using 20 phr of $BaSO_4$ as a functional filler and by varying the DCP loading from 0.5-2.5phr at 0.5 intervals using a twin-screw extruder. Mechanical properties such as tensile strength, elongation at break, tear strength and impact strength of the TPVs were investigated. It was identified that 1 phr of DCP loading gives the best mechanical properties for the TPV from NR and HDPE as a roofing material.

Keywords: Natural Rubber, High Density Polyethylene, Thermoplastic Vulcanizate, Dicymul peroxide, Roofing Material.

1. INTRODUCTION

Clay roofing is believed to be the safest and the most durable roofing material among the common roofing materials, namely asbestos, plastic and metal in Sri Lanka (Ariyadasa et al., 2015). Despite this, most Sri Lankans continues to use asbestos due to its economic advantage, although numerous scientifically proven health risks are associated with it. In 2016, the Sri Lankan government decided to limit the import of asbestos products and raw material needed to manufacture asbestos with effect from January 2018 and also to ban the production of asbestos from January 2024 ("Sri Lanka Government to Stop Asbestos Importation and Manufacturing," 2016). Therefore, it is necessary to develop a new substitute as a solution to replace asbestos roofing.

Polymer blends, including rubber-thermoplastic blends, are widely used in commercial applications due to their wide range of benefits over synthesizing of new polymers (De & Bhowmick, 1990). Dynamic vulcanization is a widely accepted technique to prepare a kind of rubber-thermoplastic blend named thermoplastic vulcanizate (TPV). In TPV, the vulcanized rubber phase is dispersed in the continuous thermoplastic phase (Naskar & Babu, 2014), and hence TPV can be recycled as thermoplastics. TPV is believed to be stronger than most of the commodity thermoplastics, and the elastomers, in view of physicochemical properties (Abdou-Sabet et al., 1996). TPVs have been developed with different types of vulcanizing agents, and with/without other property enhancing additives (Ning et al., 2018). The properties of the resultant TPV depend on their composition and the structure developed during melt blending (Abdou-Sabet et al., 1996). The addition of functional fillers to the TPVs would reduce the cost and also enhance the properties of the final product (Rothon, 2002). It was previously identified that 20/80 NR/HDPE as the optimum blend composition and $BaSO_4$ as the most suitable functional filler for NR/HDPE TPVs for roofing applications (Wickramaarachchi et al., 2019), (Wickramaarachchi et al., 2020).

The selection of a vulcanizing agent, and furthering its loading, are important, and it depends on the types of the component polymers of a TPV. Peroxide is the most suitable vulcanizing agent for NR and HDPE as it causes to crosslink both polymers, and offers improved mechanical properties (Utara & Booahthum, 2011). Higher peroxide loadings may generate more crosslinks within individual phases and may reduce adhesion between the phases, while lower loadings may generate lesser crosslinks which may provide inferior properties to the TPV. Therefore, investigating an optimum peroxide loading for TPV is highly important. This paper presents the effect of dicymul peroxide (DCP) loading on the mechanical properties of the TPV from NR and HDPE.

2. METHODOLOGY

20/80 NR/HDPE TPVs were prepared by melt blending in a co-rotating twin screw extruder (KTE 20) using 20 phr of $BaSO_4$ and varied DCP loadings from 0.5-2.5 phr at a 0.5 phr intervals. NR and HDPE were first melt blended in the extruder at 150-175 °C from feeder to die and taken away as pellets. $BaSO_4$ was then mixed with the pellets prepared using the extruder. The $BaSO_4$ filled pellets were mixed with DCP in the extruder at two additional times to obtain homogenously mixed blend and pelletized. Test specimens for mechanical tests were prepared from the blends according to the ASTM standard, D3182-85. Tensile properties and tear strength of the TPVs were determined, using a Hounsfield H10KT Universal tester, as per ASTM D638 and ASTM D1004, respectively. The impact strength was determined using Charpy impact tester according to ASTM D6110.

3. RESULTS AND DISCUSSION

3.1. Tensile Properties

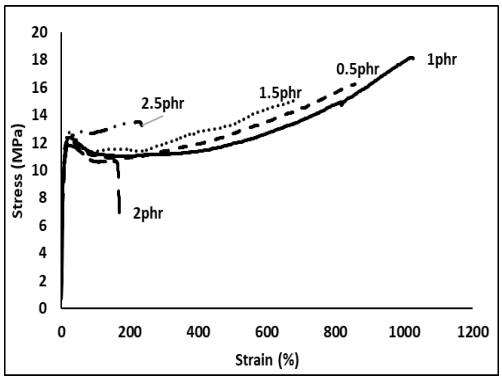


Figure 1: Stress-strain curves of NR/HDPE TPVs at different DCP loadings

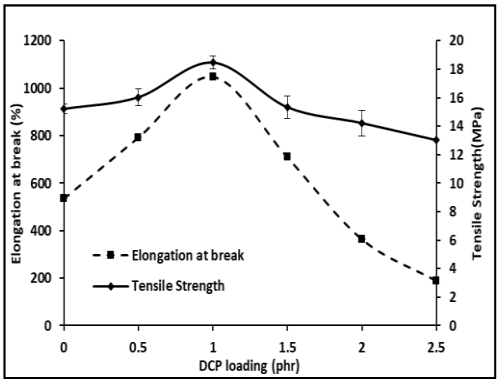


Figure 2: Variation of tensile strength and elongation at break of TPV with DCP

Stress-strain curves are a vital graphical measure of a material's mechanical properties and help to calculate young's modulus and explain material behaviour. Stress-strain curves for all the NR/HDPE TPVs (Figure 1) exhibited a behaviour of a thermoplastic, suggesting that the continuous phase of the TPV is HDPE. TPVs at 0.5, 1 and 1.5 phr DCP loadings exhibit a hard and tough thermoplastic behaviour, while higher DCP loadings (2 and 2.5 phr) exhibit a hard and brittle thermoplastic behaviour.

Figure 2 illustrates the variation of tensile strength and elongation at break of TPVs at different DCP loadings. It shows that tensile strength and elongation at break increased up to DCP loading of 1 phr and then decreased. DCP will form crosslinks in both NR and HDPE phases, and enhance the tensile properties at lower DCP loadings.

3.2. Impact Strength

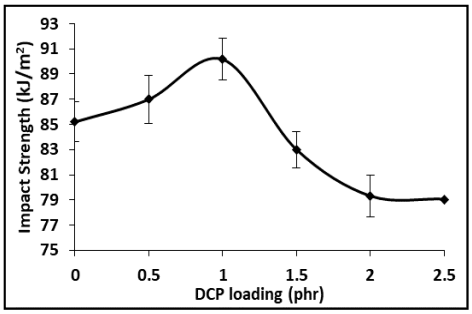


Figure 3: Variation of impact strength of the TPVs with DCP loading

Impact strength is the ability of absorbing energy which is the most important property for the roofing application. Figure 3 shows the variation of impact strength of the TPVs at different DCP loadings. Maximum impact strength is shown at DCP loading of 1 phr. After 1 phr loading, impact strength drastically drops due to formation of a brittle structure as observed by stress-strain curves.

3.3 Tear Strength

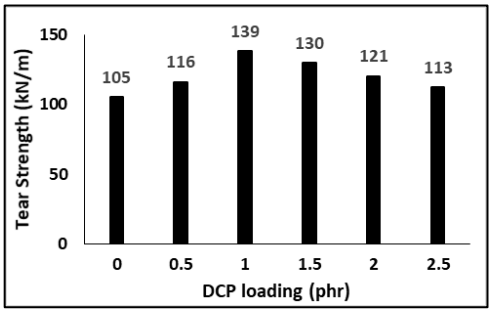


Figure 4: Variation of tear strength with DCP loadings

Tear strength is a valuable property that contributes to crack growth resistance of a roofing material. Tear strength also initially increases and then decreases with the DCP loading, passing through a maximum at 1 phr (Figure 4). The maximum mechanical property enhancement obtained at DCP loading of 1 phr suggests that it is the optimum DCP loading for the 20/80 NR/HDPE TPV filled with 20 phr of $BaSO_4$.

With the addition of 0.5 phr loading of DCP, crosslinks will be formed in both phases. However, NR phase of the TPV might be first crosslinked since NR, compared to HDPE, has a highly amorphous and unsaturated structure. The crosslinked NR will form a finely dispersed NR phase in the continuous HDPE phase. With the addition of DCP up to 1 phr loading, more crosslinks form within individual phases and between the two phases, and thereby the mechanical properties are enhanced. The highest tear strength exhibited at DCP loading of 1 phr is a result of an improvement of interfacial adhesions between the two phases, which could reduce crack propagation during tearing. The degree of crystallinity of the HDPE phase would be the highest at DCP loading of 1 phr. Further addition of DCP causes to increase crosslinking in the HDPE phase, leading to a reduction of crystallinity in the HDPE phase of the TPV. The highly crosslinked HDPE phase developed at higher DCP loadings also causes the formation of a brittle structure as observed in the stress-strain curves and to prevent formation of adhesions between the two phases. The brittle structure of TPV and the poor interfacial adhesions developed at higher DCP loadings will reduce tensile, impact and tear properties drastically. Formation of a brittle structure at higher DCP loadings was reported for TPVs from NR and low

density polyethylene (Sampath et al., 2019). In this study, images of scanning electron microscopy of tensile facture surfaces exhibited a rough fracture surface at DCP loading of 0.3 phpp (parts per hundred parts of polymer) and a smooth fracture surface at DCP loading of 0.9 phpp.

4. CONCLUSION

Tensile properties, impact strength and tear strength of the TPVs increased with the addition of DCP up to 1 phr loading, and then decreased with the increase of DCP loading, identifying DCP loading of 1 phr as the optimum loading for the 20/80 NR/HDPE TPV filled with 20 phr of $BaSO_4$. The mechanical properties, which are on par with the properties of a roofing material, recommends the use of the TPVs developed in roofing applications. However, further investigations on the phase morphology and the crystallinity of the TPVs are required to explain the mechanical property variation with the DCP loading and it is suggested that the use of a coupling agent like titanate or zirconate can be used to improve the compatibility of developed TPV.

5. ACKNOWLEDGMENT

This research project is supported by the National Research Council under the Public Private Partnership grant scheme (Grant Number PPP 14-08); the partners of Chemical and Process Engineering Department of the University of Moratuwa and Samson Compounds (pvt) Ltd.

6. REFERENCES

Abdou-Sabet, S., Puydak, R. C., & Rader, C. P. (1996). Dynamically Vulcanized Thermoplastic Elastomers. *Rubber Chemistry and Technology*, *69*(3), 476–494. https://doi.org/10.5254/1.3538382

Ariyadasa, M., Adikary, U., & Muthuratne, S. (2015, December 1). *Investigating the Physical, Mechanical and Thermal Properties of Common Roofing Materials in Sri Lanka*. *Innovations for Resilient Environment.* NBRO Symposium, Colombo, Sri Lanka.

De, S. K., & Bhowmick, A. K. (1990). *Thermoplastic elastomers from rubber-plastic blends*. Ellis Horwood.

Naskar, K., & Babu, R. R. (2014). *Thermoplastic Elastomers (TPEs) and Thermoplastic Vulcanizates (TPVs*). In S. Kobayashi & K. Müllen (Eds.), Encyclopedia of Polymeric Nanomaterials, . Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36199-9_310-1

Ning, N., Li, S., Wu, H., Tian, H., Yao, P., Guo-Hua, H. U., Tian, M., & Zhang, L. (2018). Preparation, microstructure, and microstructure-properties relationship of thermoplastic vulcanizates (TPVs): A review. *Progress in Polymer Science*, *79*, 61–97.

Rothon, R. N. (2002). *Particulate Fillers for Polymers*. Rapra Technology Ltd. , Shewsbury, Shropshire, UK.

Sampath, W. D. M., Egodage, S. M., & Edirisinghe, D. G. (2019). Effect of Peroxide Loading on Properties of Natural Rubber and Low-density Polyethylene Composites. *Journal of Physical Science*, *30*(3).

DuBose, B. (2016, September 21). Sri Lanka Government to Stop Asbestos Importation and Manufacturing. . *DuBose Law Firm*, PLLC. https://www.duboselawfirm.com/2016/09/21/sri-lanka-government-stop-asbestos-importation-manufacturing/

Utara, S., & Booahthum, P. (2011). Novel Dynamic Vulcanization of Polyethylene and Ozonolysed Natural Rubber Blends: Effect of Curing System and Blending Ratio. J*ournal of Applied Polymer Science*, 120. https://doi.org/10.1002/app.33466

Wickramaarachchi, W. V. W. H., Walpalage, S., & Egodage, S. M. (2019). Identification of the Best Blend Composition of Natural Rubber-High Density Polyethylene Blends for Roofing Applications. *International Journal of Chemical and Materials Engineering*, *13*(4), 195–199.

Wickramaarachchi, W., Walpalage, S., & Egodage, S. M. (2020). *Effect of particulate fillers on natural rubber/high-density polyethylene blends for roofing application.* Polymers and Polymer Composites, 29(6), 763-769. .https://doi.org/10.1177/0967391120934615

STUDY OF THE DETERIORATION OF MECHANICAL PROPERTIES OF POLYPROPYLENE SHEETS UNDER SRI LANKAN OUTDOOR ENVIRONMENTAL CONDITIONS

Alahapperuma KG[1*]

[1*]Department of Mechanical and Manufacturing Technology
University of Vocational Technology, Sri Lanka
gayanthi111@yahoo.com

ABSTRACT: Polymeric materials are made up of many repeating units. Nowadays they are widely used in major areas of human lives. Polypropylene (PP) is one of the highly consumed polymers, and is regarded as a multi-purpose and an exceedingly durable material. Among the areas of applications of PP are major sectors such as construction, packaging, health care and household utensils. One major drawback of PP based material is its high sensitivity to ultraviolet (UV) environments and therefore, it is a lifetime determining factor for some outdoor uses. The objective of this study is to investigate the environmental degradation behaviour of PP based products by varying the exposed time to an outdoor environment in the hot sun. Commercially available thin sheets of PP (with thickness<5mm) were selected for this research. Initially, tensile properties, hardness and water absorption properties were tested. The prepared samples were exposed to the outdoor environment to examine the environmental degradation behavior according to different outdoor exposure time periods. Tensile properties, hardness, and water absorption characteristics were tested after the outdoor exposure test. According to the results, a 20.12% reduction in tensile strength, a large reduction of 72.22 % in elongation and a 22.22% increase in hardness of the samples were perceived. However, only a 0.01% increase in water absorption was detected with outdoor exposure. Therefore, more comprehensive tests need to be conducted to predict the stability of commercial PP products in outdoor environmental uses.

Keywords: Environmental degradation; Hardness; PP; UV;

1. INTRODUCTION

Polymeric materials are composed of large molecules and made of many repeating units. Polymers are widely used in many areas of application, today. Polymer materials display many enhanced processing and serviceable properties that make them useful for manufacturing different item. (Alahapperuma and Samarasekera, 2018a; 2018b; 2019; Ashter, 2016; Egodage, 2017; Rajapakshe et al., 2017; Samarasekera *et al.*, 2014).

Polypropylene (PP) is the second-most widely consumed synthetic polymer, throughout the world, after polyethylene. PP is a thermoplastic polymer which is also called a polypropylene. It is a simple chain polymer with excellent chemical resistance, low density, relatively high tensile strength, durability, resistance to dirt, has a high melting point and comes in a wide range of colours. Polypropylene is also a reasonably economical material. These features make PP one of the most widely used polymers in a large range of applications. Additives such as lubricants, heat stabilizers, impact modifiers, fillers and UV stabilizers enhance PP's usable duration and improve its characteristics to be compatible with very many applications (Greco *et al.*, 2017; Alahapperuma and Samarasekera, 2018a; 2019; Ashter, 2016; Karian, 2003).

Due to exposure to the environment and factors such as water, UV light rays and heat can change the inherent properties of polymers. Exposure to alkalis, certain salts and acids also affect the properties considerably. These effects can be unfavourable for the intended uses of PP. The aforementioned changes due to degradation leads to a reduction of the polymer molecular length and may also cause fracture and failure of products (Alahapperuma and Samarasekera 2018a; 2018b; Ashter, 2016; Sullalti et al., 2016). Since degradation of some plastics in natural outdoor environments is a major factor to be considered, studies have been conducted to analyze and compare degradation characteristics of UV treated PP, and other plastics and their composites with different comparable

structures. In one such comparative study done in the University of Patras, Greece, to compare degradation characteristics of different plastics in the environment, it had been observed that PP based products show a higher environmental degradation rate than polyethylene (PE) and polyethylene terephthalate (PET) based products. Findings further reveal that fragmentation of plastic sheets can occur by solar radiation within a month to a couple of years (Fotopoulon et al., 2017).

A study that summarizes the available literature indicates huge differences of degradation rates among different types of thermoplastic polymers (Chamas et al., 2020).

In another joint study done in Japan (from 2010-2012), to check weatherability of PP by accelerated weathering and outdoor weathering, the flexural strength of PP was observed to decrease under accelerated weathering than in outdoor weathering (Shimizu et al., 2016).

Under the influence of incidents of UV radiation from sun rays, photo-chemical processes such as chain scissions occurred, and either moisture or chemical contaminants may accelerate these natural reactions. The changes due to these reactions can weaken the natural functioning of PP based products and may lead to final failure of products, at a faster rate. So, analysis of the degradation behaviour of PP under a natural outdoor environment in the hot sun is necessary to control the lifetime of the product, as a service requirement (Greco et al., 2017; Kadhim et al., 2017; Sheikh et al 2006; Shimizu et al., 2017). Therefore, the main objective of this research is to study the degradation characteristics of commercial PP sheets exposed to outdoor environments.

2. METHODOLOGY

Commercially available PP sheets (with thickness<5mm) were selected for the analysis. Altogether, nine sets of test pieces were prepared for each and every test, from the selected PP sheets. First, original tensile properties, Shore–D hardness and water absorption properties of the selected materials were tested, under standard conditions as reference samples. After that, outdoor exposure tests were done for other remaining eight sets of test pieces. Accordingly, eight sets of test pieces were removed from the outdoor environment after different time durations of 30, 60, 90, 120, 150, 180, 210 and 240 days, respectively. Next, tensile properties, hardness and water absorption properties were measured for these outdoor exposed test pieces under standard conditions as before. Tensile, hardness and water absorption tests were done under ASTM D 638, ASTM D 2240 and ISO 62 standards, respectively. Obtained results and properties were compared with that of the original (reference) samples.

3. RESULTS AND DISCUSSION

Hardness Test

Test results show that hardness increased with the increase of the outdoor exposure time duration. Samples that were not exposed to an outdoor environment (reference sample) indicated 45 Shore-D average hardness with zero standard deviation. The hardness value after outdoor exposure had increased up to 55 Shore-D hardness with 0.52 standard deviation, indicating a 22.22% increase after 240 days. The samples with outdoor exposure of 150 days were detected to be somewhat fragile while handling them. The samples with outdoor exposure for 240 days were observed to be highly fragile, indicating an increase of brittleness of the samples with outdoor exposure time duration. These changes in the properties may be due to decreased structural stiffness, caused by degradation of polymer molecules.

Water Absorption Test

The percentage of water absorption showed a very small increase in value, with the increase of exposed time to the outdoor environment. Samples that were not exposed outdoors (reference set of samples) showed 0.03% of water absorption and this value increased only up to 0.04 %, after an outdoor exposure of 240 days. This small increase of water absorption may be due to the formation of surface cavities resulting from a photo-degradation process. Formation of a loose surface layer or molecular-chain scissioning taking place during photo-degradation may be the reason for these surface cavities.

Tensile Strength

According to the test results of tensile strength, there was a gradual reduction of tensile strength with the increase of outdoor exposure time. Reference samples' average tensile strength was 38.5 N/mm^2 with a 0.91 standard deviation, and that value was reduced to 30.75 N/mm^2 with a 1.11 standard deviation after being exposed to the outdoor environment for 240 days. The decrease in the stiffness of chain molecules, caused by initiation of scissioning of molecular chains and its advancement due to photo-degradation may be the reasons for the gradual reduction of tensile strength of these samples.

Percentage Elongation

With the extension of the time exposed to the outdoor environment, percentage elongation was reduced drastically. Samples that were not exposed to the outdoor environment showed a percentage elongation of 73.95% with 0.76 standard deviation. This value had decreased to 20.54% with 1.58 standard deviation after exposure to UV for 240 days. The reason for this drastic decrease of percent elongation of the samples might be the same as for the decrease of tensile strength of the samples.

4. CONCLUSION

Experimental results indicate somewhat significant mechanical and physical property variations, except for water absorption properties, in the tested PP samples. Therefore, it can be concluded that further tests need to be conducted to predict the stability of PP based products in outdoor environmental conditions.

5. REFERENCES

Alahapperuma, K. G., & Samarasekara, A. M. P. B. (2018). Analysis of photo-degradation behaviour of poly vinyl chloride based products. *Annual Journal, Faculty of Graduate Studies, University of Kelaniya, Sri Lanka, Vol. 6.* 94-106.

Alahapperuma, K. G., & Samarasekara, A. M. P. B. (2018). Analysis of degradation characteristics of polymer products during engineering applications. *Annual Sessions -2018, IESL,(Transactions 2018, Part B),* 679-685.

Alahapperuma, K. G., & Samarasekara, A. M. P. B. (2019). Degradation of unplasticised poly vinyl chloride based engineering products upon exposure to ultra violet radiation. *Tropical Agricultural Research 30(4): 117,* Retrieved from DOI: 10.4038/tar.v3014.8333

Ashter, S. A. (2016). *Introduction to bioplastics engineering.* William Andrew, A Volume of Plastics Design Library.

Chamas, A., Moon, H., Zheng, J., Yang, Q., Tabassum, T., Jang., J. H., & Sangwan, S. (2020). Degradation rates of plastics in the environment, *Sustainable Chemistry and Environment, Vol.08,* 3494-3511.

Egodage, D. P., Jayalath, H. T. S., Samarasekara, A. M. P. B., & Amarasinghe, D. A. S. (2017). Fabrication of antimicrobial material for food packaging applications. *International Forestry and Environment Symposium, Vol.21.*

Fotopoulou, K. N., & Karapanagioti, H. K. (2017). Degradation of various plastics in the environment. *Hazardous Chemicals Associated with Plastics in the Marine Environment, Springer, Cham,* 71-92.

Greco, A., Ferrari, F., & Maffezzoli, A.(2017). UV and thermal stability of soft PVC plasticized with cardanol derivatives. *Journal of Cleaner Production, 164,* 757-764.

Kadhim, L. F. (2017). Mechanical properties of high density polyethylene/chromium trioxide under ultraviolet rays. *International Journal of Applied Engineering Research, 12(10),* 2517-2526.

Karian, H. ed., (2003). *Handbook of polypropylene and polypropylene composites,* revised and expanded. CRC Press.

Rajapaksha, L. D., Saumyadi, H. A. D., Samarasekara, A. M. P. B., Amarasinghe, D. A. S., & Karunanayake, L. (2017). Development of cellulose based light weight polymer composites. *In 2017 Moratuwa Engineering Research Conference (MERCon).*

Samarasekara, A. M. P. B., Wimalananda, M. D. S. L., & Muthugala, N. (2014). Utilisation of Photo Activators to Produce of Low Density Polyethylene Based Photodegradable Composite Materials. In Proceedings of International Forestry and Environment Symposium (Vol. 18).

Sheikh, N., Akhavan, A., Naimian, F., Khoylou, F., Hassanpour, S., & Sohrabpour, M. (2006).Formulation of a photosensitised polyethylene film; Its structure and property variation under the weathering conditions of Tehran. *Journal of Polymers and the Environment, 14(1),* 103-109.

Shimizu, K., Tokuta, Y., Oishi, A., Kuriyama, T., & Kunioka, M. (2016). Weatherability of polypropylene by accelerated weathering tests and outdoor exposure tests in Japan. *Journal of Polymers*. Retrieved from http://dx.doi.org/10.1155/2016/6539567.

Sullalti, S., Totaro, G., Askanian, H., Celli, A., Marchese, P., Verney, V., & Commereuc, S. (2016). Photodegradation of TiO_2 composites based on polyesters. *Journal of Photochemistry and Photobiology A: Chemistry,* 321, 275-283.

IMPLEMENTATION OF A NOVEL PROCESSING METHOD TO REDUCE CLAY AGGEGATION OF NATURAL RUBBER-CLAY NANOCOMPOSITE TO IMPROVE MECHANICAL PROPERTIES

Perera Sudarshana[1], Egodage S.[2], Walpalage S.[3]

[1] Institute of Technology University of Moratuwa, Sri Lanka
[2,3] University of Moratuwa, Sri Lanka
sudarshanap@itum.mrt.lk[1*], segodage@uom.lk[2], shanthaw@uom.lk[3]

ABSTRACT: Two types of natural rubber clay nanocomposites, were prepared (2 and 5 phr modified organoclay loadings) by acid free co-coagulation (AFCC) and common industrial mechanical mixing (IMM) methods. Bis(triethoxysilylpropyl) tetrasulfide modified organoclay showed better dispersion with minimum aggregation in the nanocomposite prepared from the AFCC method compared to the IMM method. Tensile strength, hardness, tear strength and crosslink density of nanocomposites prepared by the AFCC method are greater than nanocomposites prepared from the IMM method at all clay loadings. The study of scanning electron microscopic images further confirmed that modified organoclay layers are better dispersed as separated clay structures in the nanocomposite prepared by the AFCC method rather than that prepared using the IMM method. The anionic (sodium dodysyl sulphate) and cationic (Cetyl tri methyl ammonium bromide) surfactants used in both nanocomposites have influenced the co-coagulation and separation of clay layers, especially in the nanocomposites prepared by the AFCC method.

Keywords – Natural rubber, Nanocomposite, Coagulation, Organoclay, Bis(triethoxysilylpropyl) tetrasulfide

1. INTRODUCTION

The concept of nanocomposite is widely used in rubber manufacturing products specially to enhance the mechanical properties of vulcanized rubber products for longer service life. Most of the nanocomposite studies are limited to research only but expansion of such knowledge for industrial application is very important. Among various fillers, nanoclay is the most frequently used filler for the preparation of nanocomposite in which rubber chains penetrate inter layer gallery space of clay forming intercalated and exfoliated clay structures (Ray & Okamato., 2003). In exfoliated clay structures, individual clay layers are randomly separated by rubber chains, but intercalated clay structures are formed with one or more rubber chain(s) inserted into interlayer gallery spaces. However, neither of the structures were obtained easily in many studies. However, penetration of rubber chains into inter layer gallery spaces is difficult by the latex emulsion blending process followed by acid co-coagulation (Wang et al., 2005). The formed aggregated clay structures encapsulated by rubber chains without intercalation is called separated clay structures (Wu et al., 2005) and clay layers found as a large stack with multiple clay layers are called aggregated clay structures. However, it is believed that more intercalated clay structures are formed during the preparation of nanocomposites using high shear force by the widely used IMM method, but formation of a large number of aggregated clay structures together with clay structures with limited separation is the drawback. Aggregated clay structures are considered as weak sites and resulted poor mechanical properties. The organoclay modified by Bis(triethoxysilylpropyl) tetrasulfide coupling agent by AFCC method gave minimum aggregation even at 2 phr clay loading in our previous study (Perera et al.,2020) but such a method was not compared with the IMM method in which clay was directly incorporated into dry rubber using mechanical mixing. It is essential to find a new pathway to replace the widely used IMM method for obtaining superior mechanical properties by the reduction of aggregated clay structures using minimum clay loading which is the aim of the current study. The present study was carried out selecting 2 and 5 phr modified organoclay clay loadings because

mechanical properties showed significant change at this level in our previous study (Jayaraj et al., 2018).

2. METHODOLOGY

The organoclay was prepared by intercalation of cetyl tri methyl ammonium bromide (CTAB) into montmorillonite clay (MMT) according to the method described in our previous study (Jayaraj et al., 2018). The organoclay was further modified by Bis(triethoxysilylpropyl) tetrasulfide according to the procedure described in another previous our study (Perera et al., 2020). Centrifuge natural rubber (NR) latex was mixed with 2 and 5 phr modified clay suspension separately in the presence of 1 phr loading of sodium dodysyl sulphate (SDS) in the form of dispersion and mixed using the mechanical stirrer at a speed of 60 rpm for 24 hours. After that 2 phr loading of CTAB in the form of dispersion was mixed and allowed to co-coagulation. The coagulum was dried in an air circulated oven for 2 days at 50 ˚C. The dried rubber was milled to obtain sheets having even thickness and the milled sheets were dried again for another day in the oven under the same drying conditions. It was then processed in brabender plasticorder of model ME made in Toyo Seiki Seisaku-Sho, Japan, operated at a speed of 60 rpm for 5 minutes. The prepared nanocomposites by the new route using the AFCC method are called NC-A2 (2 phr modified organoclay) and NC-A5 (5 phr modified organoclay). The modified organoclay loadings, 2 and 5 phr in powder form were mixed with NR pale crepe together with 1 phr of SDS and 2 phr of CTAB in the brabender plasticorder operated at a speed of 60 rpm for 5 minutes. The prepared nanocomposites from IMM method are called NC-C2 (2 phr modified organoclay) and NC-C5 (5 phr modified organoclay) nanocomposites. Scan electron microscopic (SEM) images were taken for these nanocomposites. The prepared nanocomposites were vulcanized using a hydraulic press and crosslink density and mechanical properties were determined according to ISO standards.

3. RESULTS AND DISCUSION

SEM images of NC-C2 and NC-C5 nanocomposites show higher aggregation of modified organoclay compared to NC-A2 and NC-A5 nanocomposites in Figure 1. It confirms that incorporation of modified organoclay only by mechanical mixing in dry rubber route causes higher aggregation, and separation of clay from the rubber phase is also visible. It reveals that surfactants distributed by the effect of emulsion blending using the AFCC method causes better dispersion of modified organoclay in NC-A nanocomposites compared to NC-C nanocomposites. It may be also be due to modified clay with lower surface energy driven by the grafted siloxane network which is better dispersed in rubber latex rather than in dry rubber (Perera et al., 2020). It is evident that the crosslink density of NC-A2 and NC-A5 nanocomposites are higher than that of NC-C2 and NC-C5 nanocomposites due to better dispersion of modified organoclay layers (Figure 2). The aggregated clay structures are minimum in NC-A nanocomposites due to separation of negatively charged clay layers by negatively charge SDS surfactants at latex stage. Separation of clay layers from clay stack is the most difficult process in the preparation of NR clay nanocomposites. It is achieved in NC-A nanocomposite by ionic repulsion forces creating between clay layers and SDS. The positively charged CTAB surfactants cause ionic interaction towards the negatively charged rubber particle, clay and SDS and thereby coagulating the rubber clay mix. Aggregation of clay is prevented by formation of separated clay structures encapsulated by rubber under latex environment in which well-balanced ionic interaction and repulsion forces occur between rubber, clay, and surfactants. As a result the tensile strength (Figure 3), the tear strength, and the hardness (Figure 4) of NC-A nanocomposites improved more than in NC-C nanocomposites.

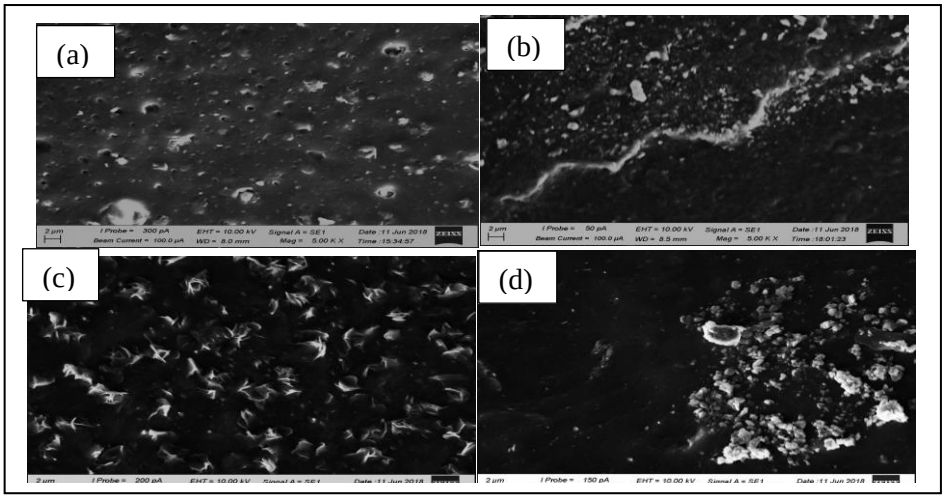


Figure 1 SEM image (a) NC-A2 (b) NC-C2 (c) NC-A5 and (d) NC-C5 nanocomposites

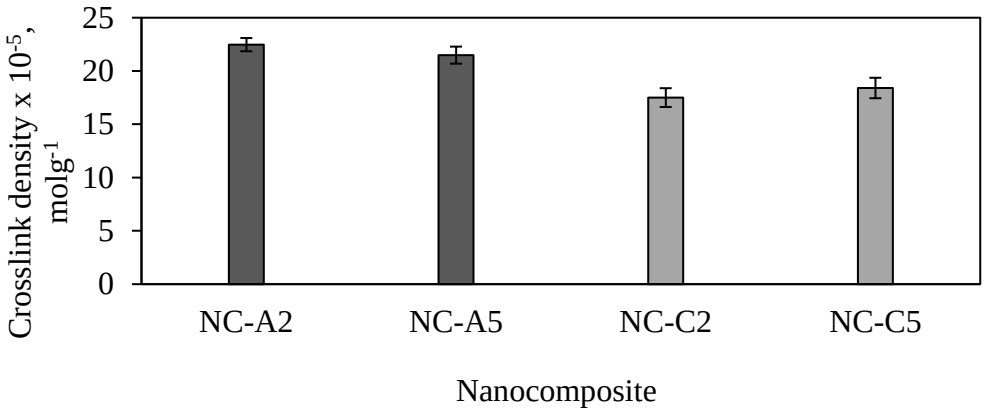


Figure 2 Crosslink density of NC-A and NC-C nanocomposites

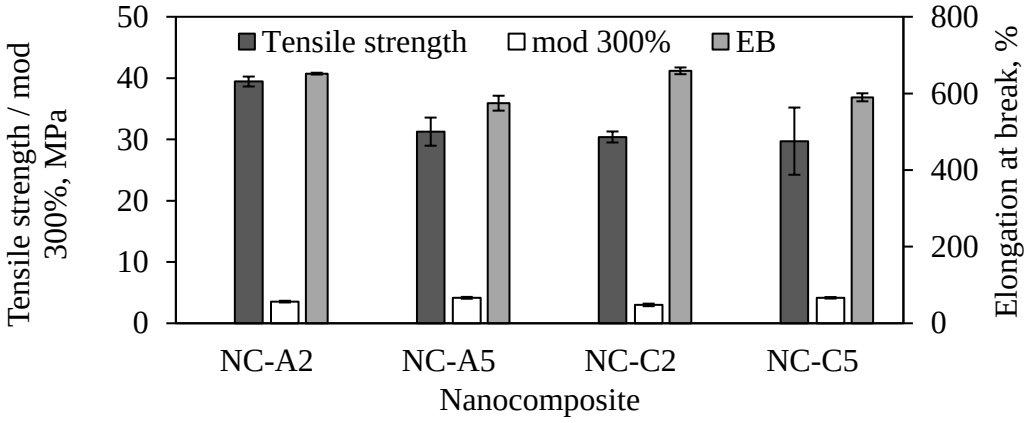


Figure 3 Tensile strength, modulus 300% and elongation at break of NC-A and NC-C nanocomposites

However, elongation at break of those nanocomposites (Figure 3) do not change according to the process, whereas it is reduced with loading of modified organoclay. It is interesting to note that mod 300% does not change significantly in the nanocomposites (Figure 4) which may be due to the use of very small modified organoclay in the study and it does not influence on mod 300%.

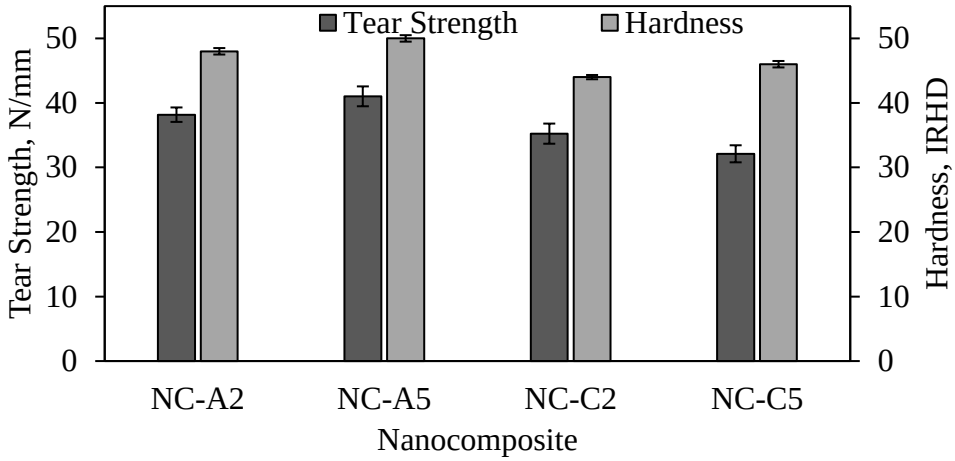


Figure 4 Tear strength and hardness of NC-A and NC-C nanocomposites 5

4. CONCLUSION

Modified organoclay can be dispersed more effectively in the nanocomposite prepared by the AFCC method having more separated clay structures with minimum aggregation than in the nanocomposite prepared by the IMM method. Better dispersion of separated clay structures causes improved mechanical properties and higher crosslink density. The current study showed that the effect of surfactants on the separation of clay layers is more prominent in the NR latex rather than in NR dry rubber. The combination of CTAB and SDS used as a novel co-coagulation agent for preparation of NR clay nanocomposite by the AFCC method is successful but such a combination is not effective for the IMM method. This study also recommends that the IMM method should be replaced by the AFCC method to get the maximum benefit of nano level dispersion of clay, otherwise nanoclay may also aggregate and the real outcome of nano particles will not be achieved.

5. REFERENCE

Jayaraj, S., Egodage, S., & Walpalage, S., (2018). New approach for preparation of dry rubber nanocomposites through acid-free co-coagulation: Effect of organoclay content. *Journal of Applied Polymer Science*, 135(28), 46502.

Perera, S., Egodage, S., & Walpalage, S., (2020). Enhancement of mechanical properties of natural rubber-clay nanocomposites through incorporation of silanated organoclay into natural rubber latex. *E-polymer*, 20*(*1), 144-153.

Ray, S.S., & Okamoto, M., (2003). Polymer/ layered silicates nanocomposites: a review from preparation to processing, *Progress in Polymer Science*, 28(11), pp. 1539-1641.

Subramani, S., Choi. S.W., Lee, J.Y., & Kim, J.H., (2007). Aqueous dispersion of novel silylated (polyurethane-acrylic hybrid/ clay) nanocomposite, *Polymer*, 48(16), pp. 4671-4703.

Wang, Y., Zhang, H., Wu, Y., Yang, J., & Zhang, L., (2005). Preparation and properties of natural rubber/ rectorite nanocomposites, *European Polymer Journal*, 41(11), pp. 2776-2783.

Wu Y.P., Wang Y.Q., Zhang H.F., Wang Y.Z., Yu D.S., Zhang L.Q & Yang, J. (2005). Rubber-pristine clay nanocomposites prepared by co-coagulating rubber latex and clay aqueous suspension. *Composites Science and Technology*, 65(7), pp.1195–1202

MODIFIED SILICA AND MULTI WALLED CARBON NANOTUBES AS ADDITIVES FOR ENHANCEMENT OF THERMAL CONDUCTIVITY OF NON-MARKING TYRE COMPOUNDS

Jayawardane Y. W.[1] and Etampawala T.N.B [1,2]*

[1]Department of Polymer Science, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

[2]Center for Advanced Material Research, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

yashmijaya2@gmail.com [1],tetampa@sjp.ac.lk [2*]

ABSTRACT: Non-marking tyres are widely used to avoid black driving marks on the floor. They are manufactured by adding silica instead of carbon black to rubber lattices. Incorporation of silica has resulted some crucial issues. The main problems are having a considerable long curing process which cause heat buildup and unfinished crosslinking. This study mainly focused on addressing these limitations by the novel technology of incorporating modified silica and modified multi-walled carbon nanotubes (MWCNTs). Sample tyre compounds were prepared using different loadings of modified silica and modified MWCNTs and were evaluated their thermal and mechanical properties accordingly. Surface modification of silica was confirmed by FTIR analysis and that of multi-walled carbon nanotubes was done by Raman spectroscopic analysis. Tensile and tearing tests were carried out for each sample and thermal conductivity was measured using TPS 3500 Hot Disk Series – Thermal constants analyzer. The properties were analyzed with respect to the reference sample containing 45 phr of unmodified silica. Significantly, this study showed lowering of tensile and tearing properties with the increase of the modified silica content and low mechanical properties in modified silica compounds compared unmodified silica compounds with same filler content. The results showed that modified MWCNTs could significantly enhance the thermal properties of the composites than pristine MWCNTs. This has been achieved by better dispersity and suppressing the thermal resistance barrier by formation of effective thermal conductive channels by modified MWCNTs. Thermal conductivity of the non-marking tyre compound was able to enhance by maintaining the mechanical properties and non-marking characteristics.

Keywords: Non-marking tyre, Multi-walled carbon nanotubes, Silica, Thermal conductivity

1. INTRODUCTION

Non-marking tyres are made from a mixture of synthetic rubber and silica or resin instead of carbon black. One of the main drawbacks of using the silica and natural rubber (NR) compound is that it has low thermal conductivity. Mostly, non-marking tyre compounds contain silica as the filler in its composition. Thermal conductivity of natural rubber, silica and carbon black are 0.293 Wm-1K at 25 °C, 0.078 Wm-1K at 25 °C (Vangala, Sharma, Pinnelli, & Ramana murthy, 2013) and 6-174 Wm-1 K(Ngo & Byon, 2016) respectively. The thermal conductivities of compounds of NR/carbon black and NR/silica are 0.45 Wm-1K (Song & Ma, 2013) and 0.198 Wm-1 K (Sharafian, Fayazmanesh, mccague, Bahrami, & Transfer, 2014), respectively. In the curing process, heat should flow through the compound. If there is a thermally conductive material inside, it would take less time to get cured and less energy is required eventually, which would reduce the production cost. Due to the low thermal conductivity of silica, it takes comparatively a higher processing time to get cured and also may end up with unfinished crosslinked compound within the cure time. This will consume high energy and result in high cost in the end. This situation can be overcome by improving thermal conductivity which eventually would save energy and increase the production in a given time.

In a rubber compound, there are three main interactions to be found. They are rubber-filler interactions, rubber- rubber interactions and filler- filler interactions. Rubber-rubber and rubber-filler interactions do mainly affect the mechanical properties of a rubber compound. In this study, the effect of rubber –filler interactions are considered. The tensile and tearing strengths are proportional to the strength of rubber-filler interactions. If filler-filler interactions get prioritized, that would definitely make a negative impact on mechanical properties (Huabcharoen, Wimolmala, Markpin, &

Sombatsompop, 2017). Considering that, modified silica series were formed with the reference sample having 45 phr unmodified silica for the evaluation of the effect of silica modification on the mechanical properties of a non-marking tyre compound.

MWCNTs have been widely used due to its high thermal conductivity (~ 3000–3500 W m^{-1} K^{-1} at RT)(Yang et al., 2002). In this study, modified MWCNTs were used to enhance thermal and mechanical properties. MWCNTs are being modified through oxidative treatment in order to increase the interfacial adhesion between MWCNTs and rubber matrix via silane linkages. The reason for functionalization is due to agglomeration by pristine MWCNTs due to its hydrophobic nature. Incorporation of modified MWCNTs act as a secondary filler and enhances the mechanical properties as well. (Liu, Hua, Liu, & Wang, 2018). Here, it was expected to form covalent bonds by modified MWCNTs with modified silica and rubber molecules. Through this novel approach, a non-marking compound which is not in white colour was compounded.

2. METHODOLOGY

2.1 Modification of silica: Acid treatment for 20g of finely grounded silica was done by thoroughly stirring with 1M HCl at 70 ^{o}C for 1h. Then the solution was filtered and washed several times until it becomes neutralized by deionized water. Later, the sample was oven dried at 120 ^{o}C for 6h (Huabcharoen et al., 2017)

2.2 Modification of MWCNTs: 1g of NANOCYL®NC7000TM series thin Multi-Walled Carbon Nanotubes (MWCNT) was dispersed in a mixture of concentrated sulfuric acid 95% (H_2SO_4) and nitric acid 65% (HNO_3) in 3:1 ratio by ultrasonication at 50 ^{o}C for 1h. Then it was washed until it becomes neutralized (pH 7) using deionized water. Later the sample was oven dried at 120^{o}C for 6h (Haider, Mohammed, Ahmed, & Research, 2014).

2.3 Raman and FTIR analysis: Modified MWCNTs were characterized using Raman analysis (DXR2 SMART RAMAN-wavelength 785nm) and modified silica was characterized by FTIR analysis (Thermo Scientific Nicolet S10 FT-IR spectrometer).

2.4 Sample preparation: Rubber compounds were prepared with different loadings of modified silica and modified MWCNTs. An internal mixture and two roll mixture were used for compounding process. Curing curves were measured by Moving Die Rheometer (MDR). Samples were tested for tensile strength and tearing strength.

2.5 Thermal conductivity measurement: TPS 3500 Hot Disk Series – Thermal constants analyzer was used to measure the thermal conductivity. The values of thermal conductivity, thermal diffusivity and specific heat were recorded.

3. RESULTS AND DISCUSSION

The Raman analysis was conducted for both pristine and modified MWCNTs. Here, the I_D/I_G ratio was considered. The G band is due to the stretching vibrations of sp^2 hybridized carbon and D band is due to the sp^3 hybridized carbon (Szybowicz, Nowicka, & Dychalska, 2018). With modification of MWCNTs the above ratio should be increased. The reason is due to the dissociation of sp^2 c-c bond due to formation of -COOH groups on the surface of the wall of the MWCNTs through chemical modification (Figure 1).

The FTIR spectroscopy, was used to characterize the modification of silica. With the acid treatment, the number of –OH groups on silica surfaces get increase with the dissociation of Si-O-Si bonds in silica resulting in an increase in the intensity of the –OH peak and decrease in the intensity of the Si-O-Si bond (Figure 2). Higher filler-filler interactions which increase silica aggregation due strong H-bond formation between excess –OH groups with modification would decrease mechanical properties. When the modified silica content gets decrease the filler-filler interaction get decrease and make a positive impact on mechanical properties. This is shown by the results in Table 1. (Huabcharoen et al., 2017). The sample with 45 phr modified silica content was used to compound sample series 2 because MWCNTs could increase the mechanical properties since it acts as secondary filler.

Thermal conductivity was enhanced by modified MWCNTs than pristine MWCNTs. The reason is due to creating an effective thermal conductive channel by modified MWCNTs. (Liu et al., 2018). The values of thermal conductivity, thermal diffusivity and specific heat is in Table 2.

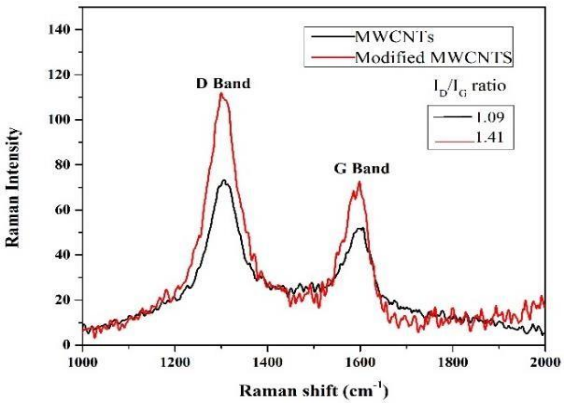


Figure 6 Raman Analysis of pristine MWCNTs and modified MWCNTs

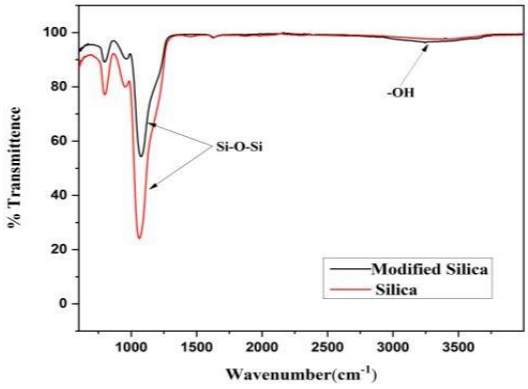


Figure 2 FTIR Analysis of unmodified and modified silica

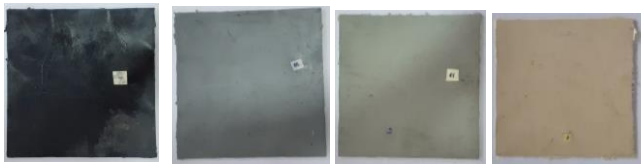
Mechanical Properties	Sample series 1				Sample series 2		
	Unmodified silica	Modified silica			Pristine MWCNTs	Modified MWCNTs	
	45 phr	45 phr	35 phr	15 phr	10 phr	10 phr	1 phr
Tensile Strength(MPa)	28.557	18.877	22.809	24.207	24.005	26.15	13.86
Tear Strength(N/m)	59.816	36.419	39.791	40.29	62.92	73.852	70.754

Table 1. Tensile strength and tearing strength of all the compounded samples

Sample name	Thermal Conductivity(W/mK)	Thermal Diffusivity(mm^2/s)	Specific Heat Capacity(MJ/m^3K)
10 phr pristine MWCNTs	0.2632 ± 0.0012	0.2104 ± 0.0029	1.251 ± 0.011
10 phr modified MWCNTs	0.3062 ± 0.0005	0.2649 ± 0.0006	1.156 ± 0.003
1 phr modified MWCNTs	0.2394 ± 0.0005	0.1863 ± 0.0011	1.285 ± 0.006

Table 2. Thermal Conductivity, thermal diffusivity and specific heat values of sample series 2.

This novel approach, has been able maintain the non-marking quality. Incorporation of 10 phr modified MWCNTs has maintained the non-marking quality (Figure 3).



10 phr of MWCNTs | *10 phr modified MWCNTs* | *1phr modified MWCNTs* | *Reference (45phr unmodified silica)*

Figure 3. Pristine and modified MWCNTs incorporated vulcanized sheets and vulcanized reference sheet.

4. CONCLUSION

This novel concept was able to enhance the thermal conductivity while maintaining the mechanical properties. Incorporation of modified silica to a rubber matrix cause strong filler-filler interactions which cause a negative impact on tensile and tearing properties. Better dispersity of MWCNTs can be obtained by modification. Formation of effective thermal conductive channels have reduced the thermal resistance in modified MWCNTs than pristine MWCNTs. The compound formed by this novel concept had low specific heat capacity which confirmed it can be used as a solution for the high heat buildup in non-marking tyres. Currently, further development of this novel formulations is in progress to enhance the electrical conductivity.

5. ACKNOWLEDGEMENT

This research was supported by the Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher education funded by the World Bank.

The research used resources at the Instrument Center operated by the Faculty of Applied Sciences of the University of Sri Jayewardenepura, the Center for Advanced Material Research and the Instrument Center of the Faculty of Applied Sciences of the University of Sri Jayewardenepura, the Rubber Research Institute of Sri Lanka and the Institute of Technology, University of Moratuwa.

6. REFERENCES

Haider, A. J., Mohammed, M.R, Ahmed, D. S. (2014). Preparation and characterization of multi walled carbon nanotubes/Ag nanoparticles hybrid materials. International Journal of Scientific & Engineering Research,5(3). https://www.researchgate.net/journal/International-Journal-of-Scientific-and-Engineering-Research-2229-5518.

Huabcharoen, P., Wimolmala, E., Markpin, T., & Sombatsompop, N. J. B. (2017). Purification and characterization of silica from sugarcane bagasse ash as a reinforcing filler in natural rubber composites. BioResources, 12(1), 1228-1245.

Liu, K., Hua, J., Liu, J., & Wang, Z. (2018). Study on Preparation and Properties of HVBR Reinforced with Si69-modified Carbon Nanotubes. *Polymer-Plastics Technology and Engineering*, 57(18), 1953-1962. doi:10.1080/03602559.2018.1447130

Szybowicz, M., Nowicka, A. B., & Dychalska, A. (2018). *Chapter 1 - Characterization of Carbon Nanomaterials by Raman Spectroscopy*. In S. Mohan Bhagyaraj, O. S. Oluwafemi, N. Kalarikkal, & S. Thomas (Eds.), Characterization of Nanomaterials (pp. 1-36): Woodhead Publishing.

Vangala, D., Sharma, D., Pinnelli, S. P., & Ramana murthy, S. (2013). Dependence of thermal conductivity in micro to nano silica. *Bulletin of Materials Science*, 36, 517-520. doi:10.1007/s12034-013-0519-3

Yang, D., Zhang, Q., Chen, G., Yoon, S., Ahn, J., Wang, S., and Li, J. (2002). Thermal Conductivity of Multiwalled Carbon Nanotubes. Physical ReviewB, 66(16). doi:10.1103/PhysRevB.66.165440

3D FINITE ELEMENT SIMULATION OF A SOLID RESILIENT TIRE FOR IMPACT ANALYSIS

Premarathna W.A.A.S.[1], Jayasinghe J.A.S.C.[2], Gamage P.[3] and Ranatunga R.R.M.S.K.[4]

[1, 2 ,3] University of Peradeniya, Peradeniya, Sri Lanka
[4] Elastomeric Engineering (Co) Ltd, Horana, Sri Lanka
asaranga225@gmail.com[1], supunj@eng.pdn.ac.lk[2], pramilag@eng.pdn.ac.lk[3], ranatunga@stellana.com[4]

ABSTRACT: Solid resilient tires are commonly utilized in the fields of construction and transportation sectors to lift and move heavy loads. In such environmental conditions, solid resilient tires frequently travel on uneven surfaces and impact on folds or curbs. These sudden impacts generate high stresses and thereof failures of the solid tires. The factors which cause such failures are not easy to capture experimentally due to their complexity and high cost. Hence, this study is focused on stress generation and thereof identify the failure regions in the solid resilient tires by using Finite Element (FE) numerical method when the tire travels on a fold surface. Initially a tire static model was developed and validated using experimental data to develop the tire impact numerical model. The validation results clearly showed, that the numerical data agreed well with the experimental data. Moreover, the impact analyses results show that high stresses occur in the side walls and the tread layer of the solid tire. Hence, the study identifies a high tendency of tire failures due to side wall cracks at the base layer and layer separations between tread and cushion layers in solid resilient tires.

Keywords: Fold Surface, Hyper-elastic Models, Impact Analysis, Solid Resilient Tires, Tire Numerical Model

1. INTRODUCTION

Solid resilient tires are mainly utilized in forklift vehicles to transport heavy loads. Figure 1 shows the main components of solid resilient tires. The base layer in the tire and embedded bead bundles make good gripping contact with the rim. A high amount of heat generation and traction mainly occur in the cushion layer and the tread layers of the tire, respectively.

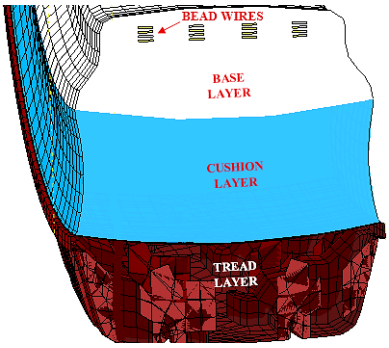


Figure 1. Components of the Solid Resilient Tire

According to the literature review, there were few or no studies conducted to numerically analyze the impact conditions of solid resilient tires on a fold surface. Instead, a few numerical analyses have been carried out to analyse the static behaviours of solid resilient tires (Suripa & Chaikittiratana, 2008; Dechwayukul et al. 2010; Phromjan & Suvanjumrat, 2020). However, Wei & Olatunbosun (2014) have studied the impact analysis of a pneumatic tire and its findings show that the height of rectangular obstacles increases the amplitude of the tire, the vertical force, the longitudinal force and the tire deformation. Moreover, impact forces on the axel of a pneumatic tire on a curb was analysed by including a suspension system with a full car model (Shiraishi et. al., 2000). In addition, pneumatic truck tire impact on a curb, when moving over rock and on a culvert grate were observed using a detailed truck numerical model (Reida et. al., 2007). Furthermore, Azizi (2020) experimentally studied the cleat impact of a pneumatic tire using a test drum. In this study, the frequency spectrum of the cleat impact was obtained as a function of the tire contact patch length, cleat size and the rolling

speed. According to the literature reviewed, it is found that there is a lack of impact analyses performed on solid tires. Hence, this study is conducted to investigate stress generation and to identify the failure regions in a solid resilient tire by using 3D numerical methods when the tire impacts on a fold surface.

2. METHODOLOGY

In this study, FE numerical analyses were performed on solid resilient tires under impact conditions. Figure 2 illustrates the numerical model of the tire under impact conditions. Initially, the tire static numerical FE model was developed on *ABAQUS* (Standard) and, the curve fitting approach was utilized to obtain suitable hyper-elastic material models which are used to express mechanical behaviour of each rubber layer in the tire. Mooney-Rivlin, Ogden and Yeoh hyper-elastic material models were obtained as the best fitted material models of the base layer, the cushion layer and the tread layer, respectively. The mesh of the complete tire model was generated using eight node-hexahedral elements and the model contains a total number of 71685 solid elements. Moreover, static analysis was performed using the flat region as shown in Figure 2. A load 19614 N was applied to the centre of the tire and the inner surface of the base layer was assigned as a rigid body to represent the rim of the tire. The developed static model was validated using experimental data which were obtained from actual tire vertical deformation. The accuracy of the developed model was presented as three measures of accuracy and corresponding errors were Mean Absolute Percentage Error (MAPE) 2.91%, Mean Absolute Deviation (MAD) 0.66 and Mean Squared Deviation (MSD) 0.46. Since the errors were very small and less than 5%, it is confirmed that the developed model compares well with the actual behaviour of the tire.

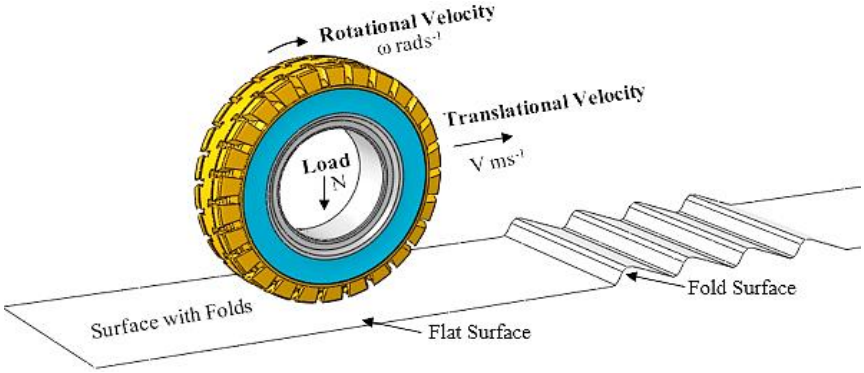


Figure 2. The FE Numerical Model of the Solid Resilient Tire

After that, the transient dynamic model of the solid tire was developed using the validated static FE model. To conduct the tire impact analysis on the fold surface, explicit solver was utilized and static results were imported into the *ABAQUS* explicit interface. To avoid convergence issues the simplified tread pattern was considered. The rubber material relaxation properties were obtained using the frequency sweep test. The viscous part in the rubber layers was well enough to capture the damping effect during the impact. As the solid tires were moved along short distances with very low velocities, the 5 kmh^{-1} moving speed was adopted in this study. Thereafter, stress generation in the rubber layers and the tire side walls were determined.

3. RESULTS AND DISCUSSION

Figure 4 graphically illustrates the stress history of the tire side walls. Here, eight (08) peaks and four (03) troughs are highlighted during the study of side wall's stress history. The first peak of every impact is generated due to initial contact on the relevant fold as shown in Figure 3a and the second

peak highlights the climax of the impact. Furthermore, the magnitudes of both the first and the second peaks are very close to each other. However, the second peak contains a higher magnitude than the first peak at every impact.

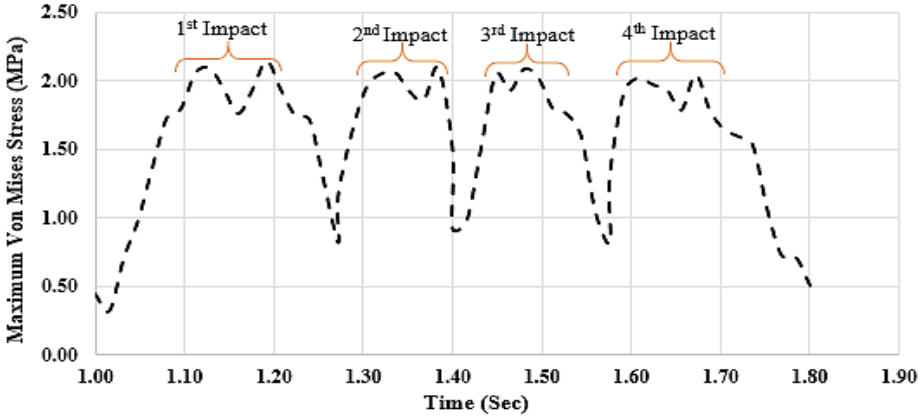


Figure 4. Tire Impact on Folds and Maximum von Mises Stress Distribution in the Tire Sidewall

Figure 3 presents the stress distribution of each rubber layer during the tire impact, on and after the fourth fold. According to the analysis, high stresses can be observed in the side walls (2.203 MPa) and the tread layer (2.149 MPa) of the tire. Here, the cushion layer can be identified as a stress transferring medium between the base layer and the tread layer of the tire.

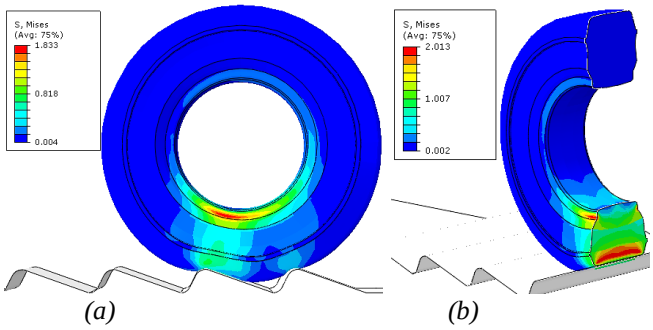


Figure 3. Maximum Von Mises Stress Distribution in the Rubber Layers of the Solid Resilient Tire: (a) Initiation of 4th Impact and, (b)Tire Cross Sectional View at the Climax of 4th Impact

The accumulation of high stresses in the side walls can be determined as the major cause for crack propagation in the tire side walls and thereof the tire failures. Furthermore, a considerable cross-sectional area of the tread layer is found to be covered by localized stress. Hence, a high tendency for layer separations to occur was identified and thereof failures between the tread layer and the cushion layer, when the tire moves over folds or obstacles at high speeds while bearing heavy loads.

4. CONCLUSION

The study was conducted to understand stress generation and failures of moving solid resilient tires on fold surfaces. The numerical model of tire impact analysis on the fold surface was performed by importing validated static results into the *ABAQUS* explicit interface. Based on the tire impact analyses results, high stresses occurred in the tire sidewalls (2.203 MPa) and the tread layer (2.149 MPa). A high tendency for side wall cracks and layer separations to occur was identified, and thereof tire failures when the tire moves on folds or obstacles at high speeds while bearing heavy loads over folds or obstacles. This study can be further developed to see the behaviour of tire impact due to change of

material properties as well as the geometry parameters of the solid tire. In addition, the vibrational effects on full vehicle impact analysis can also be studied.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge with thanks the Elastomeric Engineering Company Ltd., Horana for providing material and laboratory facilities and the Finite Element Simulation Centre, Rubber Research Institute of Sri Lanka, Rathmalana for facilitating licensed applications of the *ABAQUS* package for the analysis of this study.

6. REFERENCES

Azizi, Y. (2020). Chapter 5: Measurement Methods of Tire/Road Noise. In Xu Wang (Ed.) *Automotive Tire Noise and Vibrations*, (pp. 65–90). Elsevier Inc., https://doi.org/10.1016/B978-0-12-818409-7.00005-2

Dechwayukul, C., Kao-ien, W., Chetpattananondh, K., & Thongruang, W. (2010). Measuring service life and evaluating the quality of solid tires. *Songklanakarin Journal of Science and Technology*, *32*(4), 387.

Phromjan, J., & Suvanjumrat, C. (2020). The Contact Patch Analysis of Solid Tire on Drum Testing by Finite Element Method. In *IOP* Conference Series: *Materials Science and Engineering* . 886(1), p. 012049 . doi:10.1088/1757-899X/886/1/012049

Reida, J. D., Boesch, D. A., & Bielenberg, R. W. (2007). Detailed tire 77odelling for crash applications. *International Journal of Crashworthiness*, *12*(5), 521-529.

Shiraishi, M., Yoshinaga, H., Iwasaki, N., & Hayashi, K. (2000). *Making FEM tire model and applying it for durability simulation*. In Proceedings of the 6th International LS-Dyna Users Conference, Detroid.

Suripa, U., & Chaikittiratana, A. (2008). Finite Element Stress and Strain Analysis of a Solid Tyre. *Journal of Achievements in Materials and Manufacturing Engineering*, 31(2), 576–579.

Wei, C., & Olatunbosun, O. A. (2014). Transient Dynamic Behaviour of Finite Element Tire Traversing Obstacles with Different Heights. *Journal of Terramechanics*, 56, 1-16.

Session 04

EXFOLIATION OF GRAPHITE INTO FEW-LAYER GRAPHENE USING DIFFERENT TYPES OF BLACK TEA AS SURFACTANT

Gamachchi G.G.D.M.G.[1*], Thennakoon T.M.A.A.B.[2], Pemasiri B.M.K.[1,2], Bandara T.M.W.J.[1,2]

[1]Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
[2]Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
dmggamachchi@gmail.com[1*]

ABSTRACT: Graphene is a two-dimensional material made of sp^2 hybridized carbon atoms. It has to be mass-produced for its practical application in many fields like optoelectronics, electronics, and energy storage devices. This study elaborates on electrochemical exfoliation of graphite using K_2SO_4 as the electrolyte followed by a sonication process using dimethylformamide (DMF), three different types of black tea which are Flowery Broken Orange Pekoe Fanning's (FBOPF), Broken Mix (BM), Orange Pekoe (OP), and refused tea as the solvent. In this work, vein graphite found in Sri Lanka was used as both electrodes in the electrochemical exfoliation process. For further exfoliation using the sonication process, the precursor was prepared by mixing exfoliated graphite with tea solutions and with DMF to investigate the possibility of replacing harmful chemicals with pure natural tea solutions. UV visible spectrographs were used to identify the graphene exfoliation. Scanning electron microscope images were obtained to study the morphology of intermediates and the yields of the process. X-ray diffraction patterns of the graphene prepared were used to calculate the number of layers. The average number of layers obtained with DMF is 1.79, while that with FBOPF and refused tea are 1.96 and 1.90, respectively. Further analysis was done by measuring Raman spectroscopy, which revealed successful exfoliation of graphite into graphene with less than 3 layers. The investigated tea types, including refused tea, showed the potential of replacing toxic and expensive solvents such as DMF in the graphene exfoliation process.

Keywords: Graphene, Black tea, Electrochemical exfoliation.

1. INTRODUCTION

Carbon is one of the most versatile elements present due to the number of compounds that it can create. Out of them, graphene is a two-dimensional, single-layer sheet of sp^2 hybridized carbon atoms. The in-plane σ_{c-c} bond of graphene is very strong and the out-of-plane π bond provides good electrical conductivity (Bhuyan, Uddin, Islam, Bipasha, & Hossain, 2016). Graphene is a monolayer of graphite, which has a structure similar to polycyclic aromatic hydrocarbon with quasi infinite size. Graphene is considered the thinnest material in the world since it is just one atom thick. Further, electrons in graphene have a linear relationship between energy and momentum, so its bound structure has no energy gap.

Due to many properties as mentioned, graphene is used in many applications such as energy storage devices, transparent conductive layers, sensors, catalysts, optical modulators, antibacterial activities, ultraviolet lens, photodetector, infrared light detection as a light processing, pressure sensors, molecular absorption, body motion, flexible and rollable electronic devices, etc. (Yin et al., 2014)

There are several methods to produce graphene: such as mechanical exfoliation, chemical vapor deposition, carbon dioxide reduction, chemical exfoliation, etc. (Saiful Badri, Salleh, Md Noor, Rahman, & Umar, 2017). Out of the methods mentioned above, electrochemical exfoliation and sonication can be identified as the most convenient methods. Therefore, this work is focused on the exfoliation of vein graphite found in Sri Lanka to graphene using an electrochemical exfoliation and prolonged sonication along with non-toxic and low-cost solvents.

2. METHODOLOGY

The electrolyte for the exfoliation was prepared by dissolving 26.14 g of K_2SO_4 in 300 ml of deionized (DI) water (i.e. 0.5 M). Two graphite flakes were used as electrodes. Before setting up the apparatus, one graphite flake (i.e. anode) was soaked in the K_2SO_4 solution for ~1 hour. The distance between

the two electrodes was kept ~3 cm and the electrochemical exfoliation process was carried out by applying a sufficiently high voltage of 10 V (DC) for about 2 hours between the two electrodes. The top floating layer of exfoliated graphite (EG) was collected and filtered using a Polytetrafluoroethylene (PTFE) membrane filter (0.2 µm pore size). Then, the resulting EG was washed several times with DI water to remove residual salt. Finally, the yield was dried in the oven at 80 ˚C for 3 hours.

Since the concentration of tea polyphenols is affected greatly by the temperature, time, and volume of water (solvent), the brewing process of each tea solution (i.e. BM, OP, FBOPF, and refused tea) was performed under similar conditions. Therefore, 5 g of tea was measured and added into a beaker with 200 ml of DI water. Then, it was heated on a hot plate at 65 °C for 30 minutes. After that, the tea solution was filtered using a PTFE membrane.

For further exfoliation, 1 g of electrochemically exfoliated graphite (EG) was added to 100 ml of filtered tea solution. Then the suspension was sonicated for 90 minutes. Consequently, 75 ml of the supernatant was collected after it was rested for 8 hours. The suspension was then centrifuged at 8000 rpm for 15 minutes and the upper dispersant was removed (which is tea) and DI water was added to wash the resultant graphene. The centrifugation process was repeated another 4 times to remove residual chemicals from graphene. The same procedure was repeated using DMF solvent as the control.

UV-visible absorption measurements were performed using UV-visible spectrophotometer (UV-1800 Shimadzu). The morphology of the sample was observed using field emission scanning electron microscope (FE-SEM, Hitachi SU6600 Analytical Variable Pressure FE-SEM). Raman technique (Renishaw inVia raman microscope) was utilized to identify the successful preparation of few layer graphene. X-ray diffraction (XRD, Cu-kα =1.5405Aº radiation of the D8 advance Bruker) technique was used to study the lattice structure and to calculate the number of layers present in the graphene sample.

3. RESULTS AND DISCUSSION

An SEM image of the vein graphite used as the raw material to exfoliate graphene is shown in Figure 1(a) where properly stacked graphite layers are visible. An SEM image of the electrochemically exfoliated graphite flakes is shown in Figure 1(b). The opening of graphite layers due to electrochemical exfoliation is inferred from this image. SEM image of graphene obtained after sonication is shown in Figure 1(c) where graphene sheets with large areas are present.

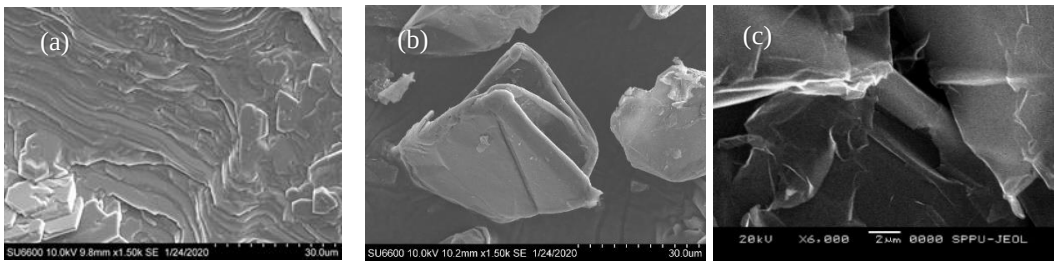


Figure 7. (a) SEM Image of Vein Graphite Used as Raw Material. (b) SEM Image of Electrochemically Exfoliated Graphite Flakes. (c) SEM Image of Graphene Obtained After Sonication.

The UV-Vis absorption spectra for all four tea solutions and DMF are shown in the figure 2(a). This indicates the successful fabrication of graphene (Ismail, Yusoh, Zainal Abidin, Abdullah, & Ismail, 2019). Also, a peak around 200 nm can be observed, and it is attributed to the remaining unbound polyphenols present in the sample solution(Atomssa & Gholap, 2011). As shown in figure 2(a), larger

polyphenol peaks can be observed for graphene prepared using FBOPF and Refused tea than that of OP and BM representing the presence of a higher concentration of polyphenols again.

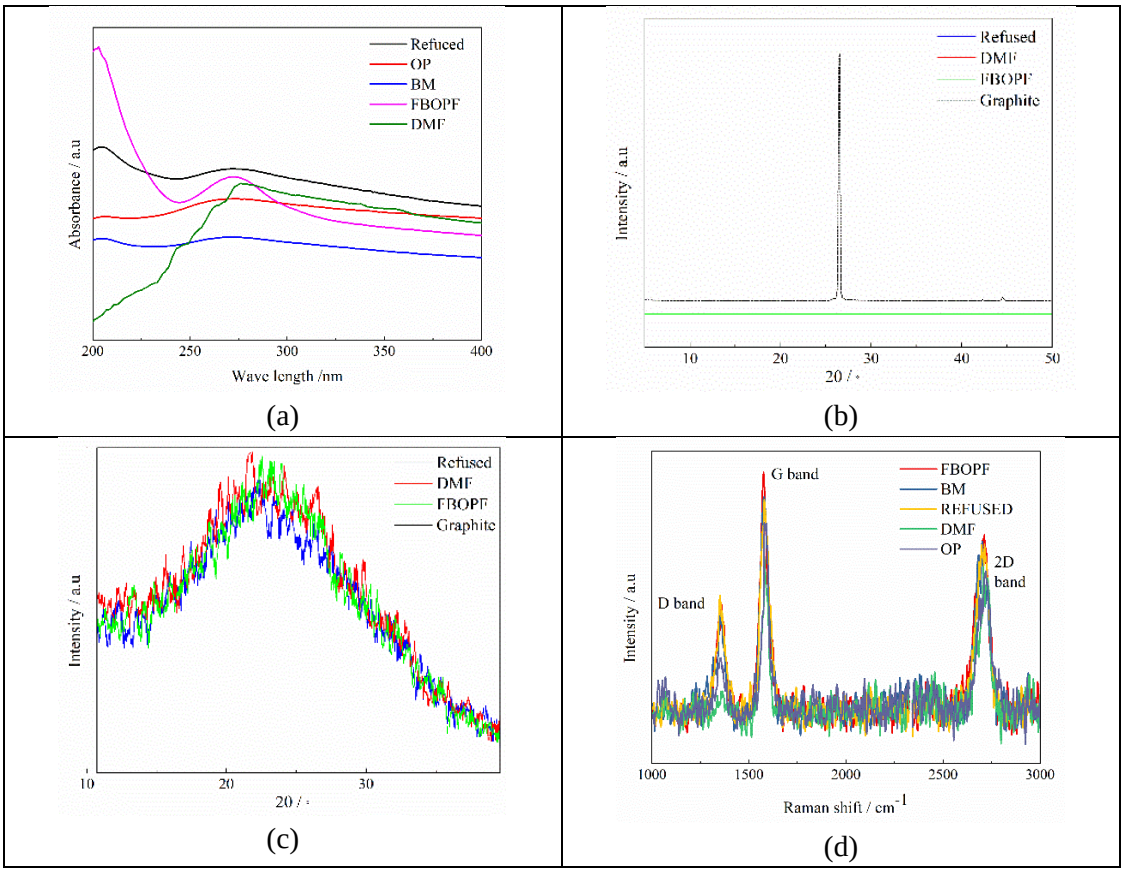


Figure 8. (a)UV spectrum of graphene prepared by DMF and different tea samples. b) XRD spectrum of graphite and graphene prepared using DMF, FBOPF tea, and Refused tea. c) Magnified image of figure 2(b) to visualize the graphene peaks. (d) Raman spectroscopy of graphene prepared using DMF and different tea samples.

XRD pattern of graphite and exfoliated graphene is shown in Figure 2(b). The black line represents the XRD peaks of electrochemically exfoliated graphite flakes, and the others show the XRD of the graphene exfoliated by sonication using the tea solutions. The green line shows XRD of the graphene exfoliated by sonication using a DMF solvent. The number of graphene layers in the resultant samples was calculated using the Debye-Scherrer equation and Bragg's law. According to the peaks (002 plane), the average number of layers obtained with DMF is 1.79, while those obtained with FBOPF and refused tea are 1.97 and 1.90, respectively. The study confirmed that fabricated graphene has less than three layers highlighting the successful exfoliation using the black tea solution.

Table 2: Results Related to Calculations done to find Number of Graphene Layers

Solvent	2θº	d-spacing (nm)	Crystallite size (nm)	Number of layers
DMF	22.546º	0.394	0.706	1.79
FBOPF	22.881º	0.388	0.764	1.97
Refused	22.670º	0.392	0.747	1.90

4. CONCLUSION

In this work, vein graphite found in Sri Lanka is successfully exfoliated to graphene using an electrochemical exfoliation and prolonged sonication. Raw vein graphite pieces were used directly as both electrodes along with aqueous K_2SO_4 electrolyte for the electrochemical exfoliation process, avoiding the use of costly Pt electrodes. Further, in this two-step exfoliation process of vein graphite, the use of toxic and expensive solvents are replaced by tea extractions. Raman spectroscopy confirms that the average number of layers in exfoliated graphene is less than three. According to XRD analysis, the average number of layers obtained with DMF is 1.79, while that with FBOPF and refused tea are 1.96 and 1.90, respectively. The investigated tea types, including refused tea, show their potential for replacing toxic and costly DMF in the exfoliation process of graphene.

5. REFERENCES

Atomssa, T., & Gholap, A. V. (2011). Characterization of caffeine and determination of caffeine in tea leaves using uv-visible spectrometer. *African Journal of Pure and Applied Chemistry*, 5(1), 1–8. http://www.academicjournals.org/journal/AJPAC/article-abstract/FE3679F2409

Bhuyan, M.S.A., Uddin, M.N., Islam, M.M. et al.(2016). Synthesis of graphene. *Nano Letters*, 6, 65–83 . https://doi.org/10.1007/s40089-015-0176-1

Ismail, F. S., Yusoh, K., Zainal Abidin, A. S., Abdullah, A. H., & Ismail, Z. (2019, Setember 4). *Three different types of tea as surfactant in liquid exfoliation of graphite: Green tea, black tea and oolong tea* [Paper presentation]. IOP Conference Series: Materials Science and Engineering, , Kuantan, Pahang, Malaysia . https://doi.org/10.1088/1757-899X/702/1/012036

Saiful Badri, M. A., Salleh, M. M., Md Noor, N. F. ain, Rahman, M. Y. A., & Umar, A. A. (2017). Green synthesis of few-layered graphene from aqueous processed graphite exfoliation for graphene thin film preparation. *Materials Chemistry and Physics*, 193, 212–219. https://doi.org/10.1016/j.matchemphys.2017.02.029

Yin, Z., Zhu, J., He, Q., Cao, X., Tan, C., Chen, H., Zhang, H. (2014). Graphene-Based materials for solar cell applications. *Advanced Energy Materials*, 4(1), 1–19. https://doi.org/10.1002/aenm.201300574

EFFECT OF CARBONIZATION CONDITIONS OF COCONUT SHELL CHARCOAL ON COLOR REMOVAL USING ADSORPTION IN WASTEWATER TREATMENT

Jayakody J.K.G.N. [1], Manchanayake M.D.A.S. [2], Hettiarachchi H.A.I.S.[3]., Karunaratne D.R.M.A.[4], Ranwala R.D.S.[5], Aluthgama K.D.G.M.[6], Jayatunga G.K[7]

[1,2,3,4,5,6,7]Institute of Technology, University of Moratuwa, Sri Lanka
nirmalajayakody_02@gmail.com[1], ayeshamanchanayake@gmail.com[2], irusathsaranie@gmail.com[3], karunarathnemihiri017@gmail.com[4], samanthikar@itum.mrt.ac.lk[5], dumindu37@gmail.com[6], gayanij@itum.mrt.ac.lk[7*] ,

ABSTRACT: Activated carbon adsorption is a widely used unit operation for further purification of wastewater after secondary treatment processes in wastewater treatment plants. Thermally treated agricultural waste has the potential to be used as an adsorbent for water treatment. Adsorption of dyes onto agricultural waste based adsorbent from aqueous solutions was studied. Coconut shells were carbonized in the muffle furnace at four different temperatures; 400 °C, 500 °C, 600 °C and 700 °C for 1 and 2 hour time periods. Batch adsorption experiments were conducted to determine the effect of carbonization conditions on adsorption of dye from of synthetic wastewater. According to the results, coconut shell charcoal carbonized at 700 °C for a 2 hour period was identified as the optimum condition for thermal activation of coconut shells under the investigation. Adsorption capacity of methylene blue to coconut shell carbon is 2.95 mg/g at optimum treatment conditions.

Keywords: Wastewater treatment, adsorption, Coconut charcoal

1. INTRODUCTION

All over the world, environmental pollution takes place in many ways due to industrial and human activities. Large amounts of wastewater is discharged to the environment from many process industries. Both biodegradable and non-biodegradable particles such as clay particles, colors, chemical substances, non-settable particles and more are discharged to the environment through the discharge of wastewater. Therefore, greater attention has been directed towards wastewater treatment operations. Many types of color compounds used in industries are non-degradable and toxic. Wastewater containing colored compounds impedes light penetration, thus affecting the photosynthesis process of aquatic lives and increases the chemical oxygen demand of the water (Holkar et al. 2016). Colored compounds have acute and chronic effects depending on their concentration and chemical formula on the exposed organisms (Saini 2017).

Process industries and government and commercial institutes have their own wastewater treatment plants to ensure that the hydrosphere is not polluted due to the discharge of wastewater and to meet the tolerance limits of discharge specified by responsible authorities. Thus appropriate wastewater treatment plants will help to avoid harming the environment and human health (Eddy & Metcalfy 2002).

Among wastewater treatment processes, adsorption technology is used after secondary treatment processes.(Debiec et al. 2017) Commercially available adsorbents are quite expensive and therefore, there is a need for low cost and readily available material as a substitute for such adsorbents in wastewater treatment processes. Many investigations have been carried out using different types of agricultural waste such as rice husks, coir pith, sawdust etc. as an adsorbent for dye removal from wastewater (Tonucci, Gurgel, and de Aquino 2015). This research was conducted to identify the possibility of using agricultural waste as adsorbents for wastewater treatment.

Although coconut shell charcoal is not a novel application for wastewater treatment, as an initial investigation, coconut shell charcoal was selected to conduct the experiment considering its availability in the country and its significant adsorbent capacity(Babel and Kurniawan 2004).

However, the research team expects to examine the probability of using other types of agricultural waste as adsorbents for dye removal from wastewater in the future.

2. METHODOLOGY

Adsorbates

Synthetic wastewater was used to conduct experiments. Synthetic wastewater was prepared by dissolving a known amount of Methylene blue dye in the distill water.

Adsorbents

Coconut shells obtained from households, were crushed into small pieces (4-5 mm) and washed using tap water and secondly with distilled water. Then the coconut shells were dried in an oven at 105 ^{0}C for 2 hours, cooled and stored in sealed polythene bags.
The washed and dried coconut shell samples were carbonized in a muffle furnace at different temperatures for different time periods. Furnace temperatures of 400 $^\circ$C, 500 $^\circ$C, 600 $^\circ$C and 700 $^\circ$C were maintained and carbonization period was set as 1 hour and 2 hours.

The yield of the charcoal samples were calculated. Then the charcoal obtained from the carbonization process was ground and a sieve analysis was conducted to get 850-2000 µm sized pieces. Then the charcoal was tested for synthetic wastewater. Adsorption capacity of each adsorbent were calculated and optimum operating conditions of the prepared coconut shell charcoal were identified by analyzing the results.

Experimental Analysis

A known weight of the adsorbent and the adsorbate solution of known dye concentration were mixed using the mechanical shaker; the Stuart SSL2 reciprocating shaker at 130 rpm for 2 hours. The residual dye concentration of the treated sample after the batch adsorption process was determined using the calibration curve and the UV-visible spectrophotometer. The effect of carbonization temperature and the time period on thermal treatment of coconut shell charcoal on adoption of methylene blue dye were investigated. The set up used for the batch experiment is shown in Figure 1.

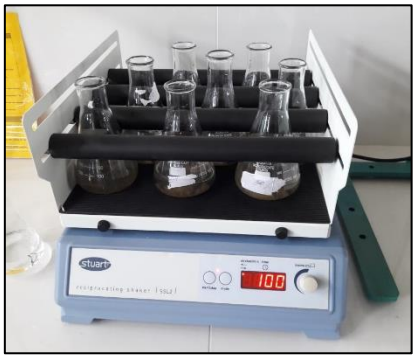


Figure 9. Batch experiment set up

3. RESULTS AND DISCUSSION

The effect of carbonization temperature and time on carbonization yield was examined. Table 1 shows the percentage of yield for the coconut shell charcoal prepared. It is seen that when carbonizing time and temperature increases, the yield of adsorbent decreases. The yield of charcoal varies from 27 % to 8 % when the carbonization temperature is increased from 400 to 800 $^\circ$C.

Table 3. Effect of carbonization conditions on yield

Sample no	Carbonization temperature (°C)	Carbonization Time (h)	Yield %
1	400	1	27.00
2		2	17.08
3	500	1	10.15
4		2	12.80
5	600	1	10.03
6		2	8.72
7	700	1	8.64
8		2	7.99

The effect of carbonization temperature and time on adsorption was then examined. Table 2 shows the effect of carbonization conditions, the percentage of dye removal and the adsorption capacity of methylene blue from aqueous solution using coconut shell charcoal.

Table 2. Effect of carbonization conditions on % removal and adsorption capacity

Sample no	Carbonization temperature (°C)	Carbonization Time (h)	% Removal	Adsorption capacity (mg/g)
1	400	1	76.09	2.52
2		2	80.12	2.65
3	500	1	81.97	2.71
4		2	82.90	2.74
5	600	1	83.23	2.75
6		2	87.35	2.89
7	700	1	84.91	2.81
8		2	89.36	2.95

A high percentage of dye removal can be obtained by a higher carbonizing temperature and longer carbonizing time, but the operation at higher temperatures and long hours are not economical due to high ash and low yield. Results show that the 600 -700 °C range is the optimum temperature range under investigation to produce coconut shell charcoal for adsorption of methylene blue. The increase in adsorption capacity for charcoal carbonized at 700 °C for 2 hours is related to the maximum surface area created and the availability of adsorption sites for the dye molecules (Bagreev, Rahman, and Bandosz 2001).

4. CONCLUSION

Adsorption efficiency depends on the adsorbent preparation methodology. Removal of methylene blue dye is at its highest for the adsorbent prepared at 700 °C carbonization temperature for a 2 hour period. The adsorbents under study are suitable for both decolorizing and adsorbing organic molecules of the solution and it could be efficiently and economically applied to clean wastewater.

5. ACKNOWLEDGEMENTS

The authors are grateful to the Division of Polymer and Chemical Engineering Technology, ITUM for facilitating the conduct of the study. Also, authors wish to acknowledge the assistance given by Ms. Kasuni Samarasinghe of the Energy Engineering and Environmental Engineering Laboratories.

6. REFERENCES

Babel, S., & Kurniawan, T. A. (2004). Cr(VI) removal from synthetic wastewater using coconut shell charcoal and commercial activated carbon modified with oxidizing agents and/or chitosan. *Chemosphere*, 54(7), 951-967. https://doi.org/10.1016/j.chemosphere.2003.10.001

Bagreev, A., Rahman, H., & Bandosz, T. J. (2001). Thermal regeneration of a spent activated carbon previously used as hydrogen sulfide adsorbent. *Carbon*, 39(9), 1319-1326. https://doi.org/10.1016/s0008-6223(00)00266-9

Debiec, K., Rzepa, G., Bajda, T., Zych, L., Krzysztoforski, J., Sklodowska, A., & Drewniak, L. (2017). The influence of thermal treatment on bio weathering and arsenic sorption capacity of a natural iron (oxyhydr)oxide-based adsorbent. *Chemosphere*, 188, 99-109. https://doi.org/10.1016/j.chemosphere.2017.08.142

Eddy & Metcalfy. (2002). *Wastewater Engineering: Treatment and Reuse*. McGraw Hill Education.

Holkar, C. R., Jadhav, A. J., Pinjari, D. V., Mahamuni, N. M., & Pandit, A. B. (2016). A critical review on textile wastewater treatments: Possible approaches. *Journal of Environmental Management*, 182, 351-366. https://doi.org/10.1016/j.jenvman.2016.07.090

Saini, R.D. (2017). Textile organic dyes: Polluting effects and elimination methods from textile Waste water. *International Journal of Chemical Engineering Research*, 9(1):121–36.

Tonucci, M. C., Gurgel, L. V., & Aquino, S. F. (2015). Activated carbons from agricultural by products (pine tree and coconut shell), coal, and carbon nanotubes as adsorbents for removal of sulfamethoxazole from spiked aqueous solutions: Kinetic and thermodynamic studies. *Industrial Crops and Products*, 74, 111-121. https://doi.org/10.1016/j.indcrop.2015.05.003

MULTI-WALLED CARBON NANOTUBE SENSOR FOR DETECTINGPHTHALATES IN SOLUTIONS

Abeysinghe H.[1], Etampawala T. N. B [1,2*], Perera V.P.S.[3], Wikramasinghe G.[4]

[1]Department of Polymer Science, Faculty of Applied Sciences, University of SriJayewardenepura, Nugegoda, Sri Lanka
[2]Center for Advanced Material Research, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka
[3,4] Department of Physics, Faculty of Natural Sciences, The Open University of Sri Lanka, Nawala, Sri Lanka
hhansiniabeysinghe@gmail.com[1]tetampa@sjp.ac.lk[1,2*], vpper@ou.ac.lk[3], gim.chathu@gmail.com[3]

ABSTRACT: Phthalates are a wide class of organic compounds used as plasticizers for many plastic products regardless of its hazardous effects. Since phthalates are not chemically bonded to plastic molecules, they have the ability to leach and migrate to its surroundings. Therefore, development of sensitive, selective but quick and easy technologies for the detection of phthalates in different environment is crucial. Under this study a novel technology for quick and easy detection of phthalates in solutions using a film of freely arranged highly conductive multi-walled carbon nanotubes (buckypaper) has been developed. The detection was done by measuring the change of conductivities of the buckypapers by three-electrode Electrochemical Impedance Spectroscopy. With the adsorption of phthalates on to the buckypaper, a significant increase of Faradaic Impedance in the Nyquist plot with a shift in unique peak system in the Bode Phase plot can be observed compared to the pristine buckypaper. This novel technology has been successfully tested for the detection of Di(2-ethylhexyl) phthalate (DEHP), Dioctyl phthalate (DOP), and Di(2-propylheptyl) (DPHP) in methanol solutions. Significantly, this technology has shown high selectivity for the detection of phthalates compared to other aromatic molecules. This has been proven experimentally through the detection of negligible Faradaic Electrochemical Impedance compared to the pristine buckypaper for the aromatic molecules such as xylene, bisphenol A, toluene, and naphthalene. This novel technology can be developed into a sensor for the quick and easy detection of phthalates in solution without prior sample preparation unlike contemporary analytical techniques use such as GC/MS, HPLC/MS, etc.

Keywords: Phthalate, Buckypaper, Multi-walled carbon nanotubes, Electrochemical Impedance Spectroscopy, Sensor

1. INTRODUCTION

1, 2 - benzenedicarboxylic acid esters, commonly called phthalic acid esters (PAE) orphthalates, are widely used as plasticizers in the plastic manufacturing industry, especially in food and beverage packaging. The main issue associated with these highly effective plasticizers is its inability to form chemical interactions with the polymer structure, which cause phthalates to leach out to its surrounding with prolonged time. It is found that when people are exposed to these phthalates, they may be subject to diseases such as cancer, endometriosis, infertility, asthma, and neurological disorders. (Giuliani, Zuccarini, Cichelli, Khan, & Reale, 2020). Therefore, the detection of phthalates in water, food, solutions, etc. is crucial. Though many researches have been conducted regarding this matter, most of them have followed a common, complicated and time consuming procedure, where the phthalatesextracted from the sample (using different solid phase or liquid-liquid extraction methods) were subjected to analytical analysis. Gas chromatography-Mass spectrometry (GC/MS) and High-Performance Liquid Chromatography (HPLC) are the most successively used analytical techniques (Haji Harunarashid, Lim, & Harunsani, 2017) but, the need for expensive instruments, special chemicals, expert operators, and complex processes æsome of their limitations. Therefore, the main focus of this study is to develop a simple, quick, easy and low-cost phthalate detection method that can overcome these issues and limitations associated with the conventional methods.

Carbon nanotubes (CNT) have been used as a highly effective sorbent for phthalates in solid phase extraction methods, mainly because of their ability to form π- π electron donor – acceptor

interactions (Haji Harunarashid et al., 2017, Wang, Yao, Sun, & Xing, 2010). This study was focused on developing a phthalate detection method based on property changes of the adsorbent observed upon phthalate adsorption. This was carried out on the hypothesis that the adsorbed phthalate, which is non-conductive, would interfere with the electron transfer among CNTs, resulting in a change in electric conductive behavior of CNT. For this novel technique, a thin film of freely arranged Multi-Walled Carbon Nanotubes, called buckypaper (sensing material), was used as the adsorbent. The conductivity behavior that changed with the adsorption of phthalates was detected by observing the Faradaic Impedance change that occurred at the interface of the buckypaper when it was used as a working electrode in a three electrode electrochemical cell. This was analyzed using the Electrochemical Impedance Spectroscopy (EIS) analysis. The EIS technique has been widely used in recent researches that are focused on rapid phthalate detection (Jiang, Xie, Wan, Zheng, & Wang, 2020; Zia et al., 2015). In this study the detection of Di (2-ethylhexyl) phthalate (DEHP), Dioctyl phthalate (DOP), Di(2-propylheptyl) (DPHP) and other aromatic molecules like xylene, bisphenol A, toluene, and naphthalene in methanol solutions were tested.

2. METHODOLOGY

2.1 Chemicals: NANOCYL®NC7000^{TM} series thin Multi-Walled Carbon Nanotubes (MWCNT), Technical Grade Cetrimethylammonium bromide (CTAB), Di(2-ethylhexyl) phthalate (DEHP), Dioctyl phthalate (DOP), and Di(2-propylheptyl) (DPHP), and AnalyticalGrade Xylene, Bisphenol A, Toluene, Naphthalene, Acetone, and Methanol.

2.2 Synthesis of buckypaper: The Homogenized MWCNT - CTAB dispersion was vacuum filtrated using a 0.45μm pore sized MCE (Mixed Cellulose Ester) filter paper and later the filter paper was washed with acetone. (Yahya, Mastura Mustaza, & Abdullah, 2019).

2.3 Sample preparation: Different phthalate solutions were prepared with 1:1 phthalate : methanol composition. Then 2 cm × 3 cm strips of buckypapers immersed in these solutions were sonicated using an ultrasonic bath sonicator to maximize the adsorption process.

2.4 Raman Analysis: Raman analysis of pristine and phthalate-adsorbed CNTs and buckypapers was done by using DXR2 SMART Raman Spectrometer with 785 nm excitation wavelength.

2.5 Electrochemical Impedance Spectroscopy (EIS) analysis: EIS analysis was done by Metrohm Autolab PGSTAT204 potentiostat, using buckypaper as the working electrode, AgCl/Ag as the reference electrode and glassy carbon rod as the counter electrode in the presence of redox probe, $[Fe(CN)_6]^{3-/4-}$ (Jiang et al., 2020). The presence of phthalate was detected by observing the changes of charge transfer resistance (R_{ct}) in Nyquist plots and peak shifts in Bode Phase plots of pristine and phthalate-adsorbed buckypapers (within 1Hz– 1MHz frequency range). The same procedure was done for other aromatic molecules such as xylene, bisphenol A, toluene, and naphthalene to detect the selectivity of this technique for phthalates.

3. RESULTS AND DISCUSSION

3.1 Buckypaper as a sensing material: Ability to form π-π interactions among the aromatic rings of CNT and phthalate make buckypaper a good adsorbent for phthalates. In this study, phthalate adsorbent (buckypaper) was directly subjected to EIS analysis as a working electrode in the electrochemical cell. The effect of adsorbed non-conductive phthalate on the interfacial electron transfer kinetics of conductive buckypaper was observed as the parameter that detects the presence of phthalates.

Figure 1. Buckypaper

3.2 Raman Analysis:According to Figure 2, both phthalate adsorbedCNT and the buckypaper show the occurrence of surface modificationsthrough the increase in I_D/I_G intensity ratio of 0.12 and 0.09 respectively compared to their pristine forms. This could only happen because of the formation of physical interactions between CNT and phthalates. This conforms the ability of CNT in thin film form (buckypaper) to adsorb phthalates in a solution just as CNT in powder form, which was an usual form used in extraction processes (Haji Harunarashid et al., 2017).

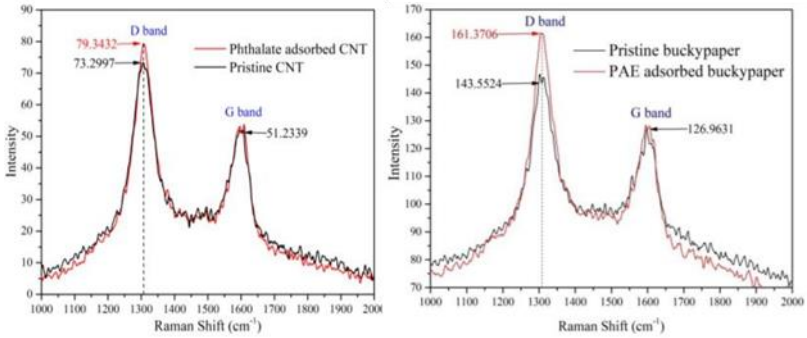


Figure 2. Raman Spectroscopy (Normalized to G band)

3.3 Electrochemical ImpedanceSpectroscopy (EIS) analysis: Nyquist plots in Figure 3 show that the charge transfer resistance (R_{ct}) of phthalate adsorbed buckypapers (>2500Ω) were significantly higher than the pristine buckypaper (~650Ω). The resistance between the electrolyte and the buckypaper (working electrode) during the interfacial charge transfer has caused the low R_{ct} for pristine buckypaper (high conductivity).The high R_{ct} for phthalate adsorbed buckypapers may have resulted due to the retardation of interfacial charge transfer kinetic that occur with the adsorption of nonconductive phthalates on to the surface of the buckypaper (low conductivity), which confirms the hypothesis usedin this study. In addition, Figure 4 shows the unique peak shifts that were only observed with Bode phase plots of phthalate adsorbed buckypapers. These results confirmed the phthalate detection ability of this novel technique. The sensitivity of this technique was tested in the presence of other aromatic molecules, since molecules with aromatic rings have the ability to adsorb on to the buckypaper by forming π-π interactions. But having similar Nyquist and Bode phase plots as of pristine buckypaper shows the ability of this technique to detect phthalates even in the presence of other aromatic molecules. In addition, based on the different R_{ct} values obtained for different phthalates as shown in Figure 3, this technique can be used to distinguish different phthalate types as well.

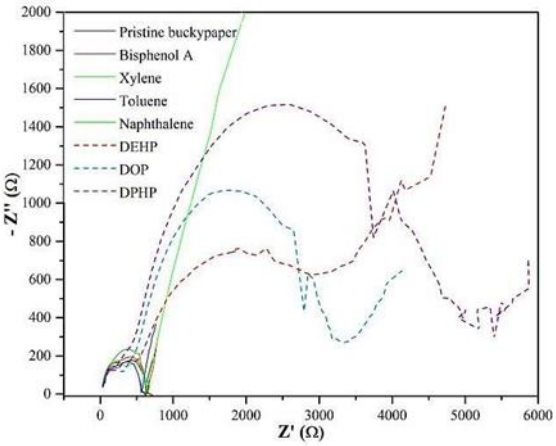


Figure 3. Nyquist plot

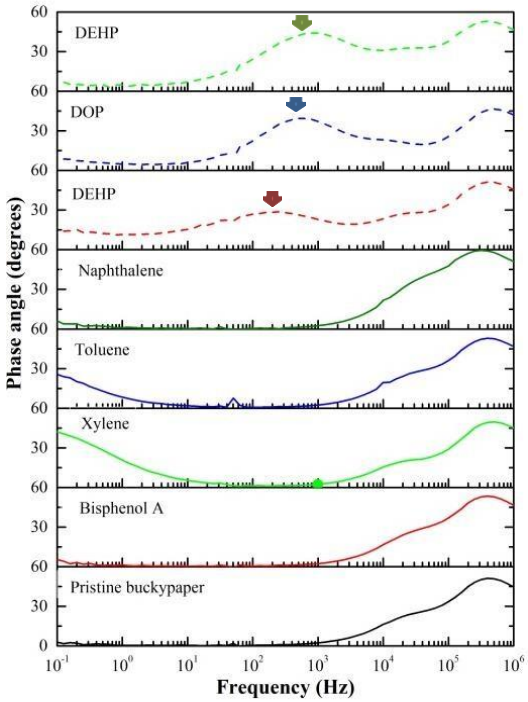


Figure 4. Bode Phase Plot 10

4. CONCLUSION

This novel technique, which is based on studying the conductivity property changes (high R_{ct}in Nyquist plots and unique peak shifts in Bode phase plots obtained by EIS analysis) of the adsorbent (buckypaper), can be used for the selective detection of phthalates in solutions. In addition, different phthalates can be distinguished based on the R_{ct} values obtained in the Nyquist plot. The safety and health issues and the need of additional separation methods (centrifugation or filtration) upon the use of CNT powder as the adsorbent in solid phase extraction methods were overcame by the use of buckypaper. Also, the use of EIS analysis, which is a non-destructive method that needs no special chemicals, makes this a low cost technique. Therefore, compared to the conventional methods, this technique is simple, quick, easy, and of low cost. With further study, this technique can be developed into an electrochemical sensor for phthalate detection. Furthermore, quantitative studies on the sensitivity of this method are scheduled to be conduct in the future.

5. ACKNOWLEDGEMENT

This research was partially supported by the Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher Education funded by the WorldBank.

6. REFERENCES

Giuliani, A., Zuccarini, M., Cichelli, A., Khan, H., & Reale, M. (2020). Critical review on the presence of phthalates in food and evidence of their biological impact. *International Journal of Environmental Research and Public Health*, 17(16), 5655. https://doi.org/10.3390/ijerph17165655

Haji Harunarashid, N. Z. I., Lim, L. H., & Harunsani, M. H. (2017). Phthalate sample preparation methods and analysis in food and food packaging: A Review. *FoodAnalytical Methods*, 10(12), 3790-3814. doi:10.1007/s12161-017-0938-7

Jiang, X., Xie, Y., Wan, D., Zheng, F., & Wang, J. (2020). Enrichment-free rapid detection of phthalates in Chinese liquor with electrochemical impedance spectroscopy. *Sensors (Basel)*, 20(3). doi:10.3390/s20030901

Yahya, I., Mastura Mustaza, S., & Abdullah, H. (2019). Carbon nanotube-activated thin film transparent conductor applications. *Transparent Conducting Films*. https://doi.org/10.5772/intechopen.79367

Zia, A. I., Mukhopadhyay, S. C., Yu, P. L., Al-Bahadly, I. H., Gooneratne, C. P., & Kosel, J. R. (2015). Rapid and molecular selective electrochemical sensing of phthalates in aqueous solution. *Biosens Bioelectron*, 67, 342-349. doi:10.1016/j.bios.2014.08.050

THE EFFECT OF A TYPE OF ELECTRON DONOR ON SULFATE REDUCTION

Samarathunga I.R.[1] and Rathnasiri P.G.[2]

[1]Institute of Technology University of Moratuwa, Sri Lanka
[2]University of Moratuwa, Sir Lanka
imeshars@gmail.com[1], rathnasirip@gmail.com[2]

ABSTRACT: Effluents discharged from some industries contain high concentrations of aqueous sulfate. If sulfate is not treated up to the standards before discharging, it will contaminate the surface or ground waterbodies. Although sulfate does not cause any direct impact on the environment, biological degradation of sulfate under anaerobic conditions produces toxic hydrogen sulfide. This research study, investigatesthe influence of a type of electron donor, a complete oxidizer and a partial oxidizer on sulfate reduction. During the biological reduction of sulfate to sulfide, complete oxidizers such as acetate convert into CO_2, HCO^-, whereas partial oxidizers such as ethanol convert into intermediate products such as lactate and acetate. It was found that for skim latex waste water, the optimum influent COD (Chemical Oxygen Demand)/SO_4^{-2} ratio was 5. Thus, the prepared synthetic waste water with the influent COD/SO^{-2} ratio of 3 was further increased to 5 using two types of electron donors, the Acetate as the complete oxidizer and the Ethanol as a partial oxidizer which convert to acetate in sulfate reduction. According to the results, both ethanol fed and the acetate fed reactors gained 100% aqueous sulfate reduction, but the highest rate of sulfate degradation was observed with ethanol. A complete reduction of sulfate with ethanol was achieved at 30 hours after feeding while with acetate it was 48 hours. The highest rate of sulfate reduction was observed with ethanol which was 51.9 mg/l.hr whereas with acetate it was 28.3 mg/l.hr. This occurred just after feeding the reactor. The average TDS (Total Dissolved Sulfide) concentration of acetate fed and ethanol fed anaerobic reactors were 3.54 ± 2.1 mg/l and 0.4 ± 0.26 mg/l respectively, whereas the gaseous H_2S concentrations were 710 mg/l and 420 mg/l respectively. Therefore, when these results are commercialized for sulfate rich wastewater treatment, precautions have to be taken to add ethanol than acetate when a higher rate of sulfate reduction is required.

Key words: Influent COD/SO^{-2} ratio, Partial oxidizer, Complete oxidizer, sulfur reducing bacteria

1. INTRODUCTION

Sulfate is discharged to the environment through a wide spectrum of effluents such as domestic, industrial and agricultural runoff (Lens & Hulshoff, 2004a). Skim latex industry, tannery, seafood processing and paper pulp manufacturing are some of the major industries which produce high concentrations of sulfate wastewater in Sri Lanka. Sulfate doesn't cause any direct impact on the environment as it is a nontoxic, non-volatile and chemically inert compound (Lens & Hulshoff, 2004a), but sulfate is transformed biologically into sulfide through anaerobic degradation by Sulfur Reducing Bacteria (SRB). If this sulfate rich wastewater is discharged to the environment without proper treatment, this conversion process may take place in natural water bodies causing a threat to the environment and to health as well as creating corrosion in concrete buildings. SRB are not capable of degrading complexorganic matter. SRBs compete for intermediate substrates generated with acetogenesis and methanogenesis as electron donors for sulfate reduction. Hence COD/SO_4^{-2} ratio is a dominantfactor which affects sulfate reduction. Therefore, when treating sulfate rich wastewater, environmental engineers have to take sufficient precautions to add a suitable type and amount of electron donors to maintain the COD/SO_4^{-2} ratio as a safe margin for complete sulfate reduction and to achieve the desired quality of the wastewater compatible with recommended environment standards.

Two major microbial pathways can be identified in a biological degradation process. In the presence of sulfate, some SRBs produce CO_2, HCO_3^- and sulfide through complete oxidization. In addition, there are some other SRBs that produce intermediate products such as lactate, acetate and sulfide from partial oxidation. Sulfate acts as an electron acceptor of this bacterial respiration. Electron donors are usually hydrogen and organic compounds with higher and branched fatty acids, ethanol

and higher alcohols, other organic acids, alkanes andaromatic compounds (Lens & Hulshoff, 2004a). In the presence of sulfate, SRBs follow normal metabolic pathways, accepting electron donors, while reducing sulfate to sulfide as shown in Eq^{n} 1 (Krayzelova et al., 2014). As per the Chemical and physical equilibrium shownin Eq^{n} 2 and 3, dissolved sulfide ions, convert to gaseous hydrogen sulfide. The reaction rates in H_2S ion formation are high in acidic pH levels whereas in high pH levels the resultant HS^- ion formation is high. Hence the resultant products are affected by the pH level and the temperature of the wastewater.

SO_4^{-2}(aq) + Organic matter → S^{-2}(aq) + H_2O(l) + HCO_3^-(aq) ….(1)

$2H^+ + S^{-2} \leftrightarrow H^+ + HS^- \leftrightarrow H_2S$(aq) ….(2)

$H_2S(l) \leftrightarrow H_2S(g)$ ….(3)

Apart from the Gibbs free energy and the kinetic reactions, there are some other factors whichaffect sulfate reduction such as COD/SO_4^{-2} ratio, the type of substrate, the relative population and the characteristics of specific kinds of SRBs and other microorganisms, sensitivity towards sulfide inhibition of each species, temperature and pH levels (Chen Y. et al., 2008).

2. METHODOLOGY

1.1 Experimental Setup

Completely mixed, identical 3-litres reactors were used in the experiment and the temperature was controlled at mesophilic temperature, 35±1 ºC. The working volume of the reactors were 2 litres whereas the head space volume was 1 litre. These two reactors were acclimated and initially operated for about 8 months before being used for this experiment to allow the micro- organisms to grow well.

1.2 Substrate for the experiment

Experiments were conducted using a synthetic media made of acetic acid. Sulfate concentrations were adjusted using Sodium sulfate. Basal nutrients and trace nutrients were mixed with 1 litreof base solution prepared using acetic acid and sodium sulfate (Visser et al., 1993). Synthetic wastewater was developed to contain the same influent COD/SO_4^{-2} ratio compatible with skim latex wastewater. The COD of the prepared synthetic wastewater was again increased to influent COD/SO_4^{-2} ratio of 5 using acetic and ethanol and two synthetic wastewater mixtures were developed. Finally, the influent pH of each synthetic wastewater was adjusted to 3.

2.2 Experimental procedure:

Two anaerobic reactors were fed with 100 ml of the above mentioned pre-prepared synthetic wastewater mixture in which the influent COD/SO_4^{-2} ratio was adjusted by acetic acid and the feeding cycle time was 5 days. Then the same procedure was carried-out for the synthetic wastewater mixture with the influent COD/SO_4^{-2} ratio of 5 which had already been adjusted by ethanol. From the reactor bulk liquid, a 10ml sample was taken out daily for analysis.

2.3 Parameters measured

Aqueous sulfate concentration, Total Dissolved Sulfide (S^{-2}(aq), HS^-(aq), H_2S(aq)) concentration, gaseous hydrogen sulfide composition, pH and Total Ammoniacal Nitrogen (TAN) were measured. All parameters were measured according to the standard method givenby American Public Health Association (APHA).

3 RESULTS AND DISCUSSION

Measured average aqueous sulfate concentrations vs time after feeding, is shown in figure 1. During the experiment, anaerobic bulk liquid showed sufficient buffer capacity. Hence the

measured pH was in the range of 7.4 -7.65 and no significant pH variation was observed in both phases with influent COD/SO $^{-2}$ ratio adjusted with either acetate or ethanol. Further the observed TAN values were always below the inhibition level (Data not shown). Since the behaviour of both the reactors showed a similar pattern, only average results are presented.According to the graph (Figure 1), the highest degradation pattern with the steepest gradient was observed with ethanol and the fastest sulfate reduction also took place with ethanol than with acetate.

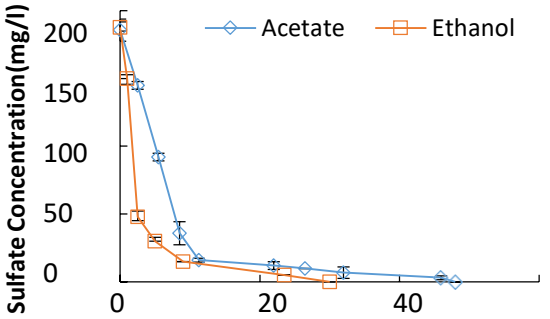


Figure 1: Sulfate Concentration Vs Time

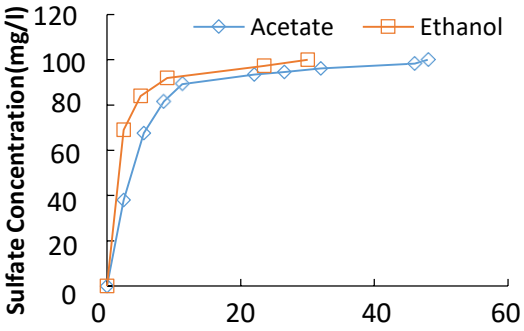


Figure 2: Cumulative percentage sulfate Vs Time

A complete reduction of sulfate with ethanol was achieved at 30 hours after feeding while withacetate it was 48 hours. The highest rate of sulfate reduction with ethanol was 51.9 mg/l.hrwhereas with acetate it was only 28.3 mg/l.hr. This occurred just after feeding the reactor. Percentage cumulative sulfate reduction is shown in figure 2. According to figure 2, the curvecorresponding to ethanol lies always above the acetate curve. Thus, the cumulative percentage sulfate reduction of ethanol is higher than the acetate. Although at the beginning of the sulfate degradation, soon after feeding until 5hrs, the cumulative sulfate percentage reduction was lienearly very close, but after 5hrs the gap between the curves increased rapidly.

Although little information is available about the effect of ethanol and acetate on sulfate reduction, similar results were observed by several researches which can be well explained bytheory. (Lens & Hulshoff, 2004a). Hence the type of electron donor whether it is a partial oxidizer, or a complete oxidizer highly affects sulfate reduction. Although both ethanol and acetate are electron donors, ethanol is considered as a partial oxidizer whereas acetate is a complete oxidizing agent. SRB converts sulfate to sulfide easily and directly transforms ethanol to acetate in the first stage.

It is also evidenced in Gibb's free energy values that the Gibb's free energy for sulfatereduction using ethanol is -132.7 kJ which is the more negative than acetate which is -47 kJ (Hu et al., 2015). Therefore, sulfate reduction is easy and fast with a partial oxidizer such as ethanol. Nevertheless, Lui B. and his team has found that the addition of ethanol promoted the sulfate reduction rate as well as facilitated good synergetic metabolism of sulfate reducing and methane producing bacteria (Lui et al., 2010).

SO_4^{-2} + 2Ethanol→HS^- + $2H_2O$ +2$Acetate^-$+H^+ ; $\Delta G° = -132.7$ kJSO_4^{-2} + $Acetate^-$ → HS^- + $2HCO_3^-$; $\Delta G° = -47.3$ kJ

Further, the above sulfate degradation results agreed with the measured TDS and gaseousH_2S. The other major difference observed in the ethanol fed phase and acetate fed phases was that the TDS concentration was high in the liquid phase when influent COD/SO_4^{-2} ratio was adjusted with acetate. The average TDS concentration of acetate fed and ethanol fed anaerobic reactors were 3.54

± 2.1 mg/l and 0.4 ± 0.26 mg/l respectively, as shown in figure 3.

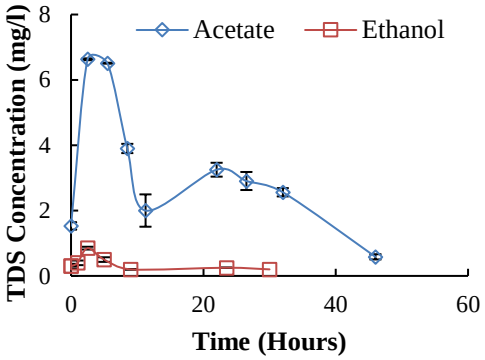


Figure 3: Total Dissolved Sulfide (TDS) Concentration Vs Time

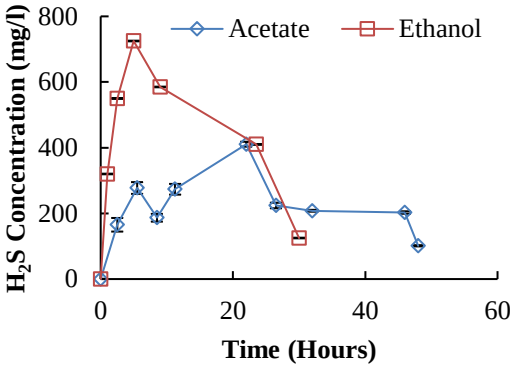


Figure 4: H2S Concentration in biogas Vs Time

However, the gaseous H_2S concentration was high when influent COD/SO^{-2} ratio was adjusted using ethanol as shown in figure 4. The gaseous hydrogen sulfide and aqueous TDS, in the acetate fed and ethanol fed anaerobic reactor phases showed a significant variation. In the ethanol added phase, the aqueous sulfide concentration was low, whereas the gaseous H_2S concentrations were high. But for the acetate added system it was vice versa. The pH values of both phases were nearly the same. It can be assumed that, because of the high rate of biogas production as well as the sulfate reduction rate with ethanol, most of the sulfide had escaped as hydrogen sulfide, bubbling through the liquid medium.

4 CONCLUSION

After analyzing all the results obtained from the experiment, it is evident that the rate of sulfate reduction increased more when a partial oxidizer such as ethanol was added than when a complete oxidizer such as acetate was added. When, ethanol was added as the external electron donor, the aqueous sulfide concentration was low whereas the gaseous H_2S concentrations were high. However, when acetate was added, it was vice versa. pH values of both phases were nearly the same. It is expected that most sulfide ions escaped as hydrogen sulfide bubbling through the bulk liquidof the reactor due to a high rate of biogas production as well as sulfate reductions. Although this experiment was carried out using synthetic wastewater compatible for skim latex wastewater, similar experiments can be carried out in the future using natural skim latex wastewater to comprehensively study the sulfate reduction by the addition of external electron donors, before applying it for sulfate rich industrial wastewater treatment.

5 REFERENCES

Chen, Y., Cheng, J. J., & Creamer, K. S. (2008). Inhibition of anaerobic digestion process: A Review. *Bioresource Technology*, *99*(10), 4044–4064.

Hu, Y., Jing, Z., Yuta, S., Niu, Q., Du, J., Wu, J., & You, Y. (2015). Effect of influent COD/SO4 2 ratios on UASB treatment of a synthetic sulfate-containing wastewater. *Chemosphere*, *130*,24–33.

Krayzelova, L., Bartacek, J., Kolesarova, N., & Pavel, J. (2014). Micro-aeration for hydrogen sulfide removal in UASB reactor. *Bioresource Technology*, *172*, 297–302.

Lens, P., & Hulshoff, L. (2004a). *Environmental technologies to treat sulfur pollution: Principles and Engineering*. IWA.

Lui, B., Wu, W., Zhao, Y., Gu, X., Li, S., Zhang, X., Wang, Q., Li, R., & Yang, S. (2010). Effect of Ethanol/Sulfate ratio and pH on mesophilic sulfate reduction in UASB reactors. *African Journal of Microbiology*, *4(21)*, 2215–2222.

Visser, A., Gao, Y., & Lettinga, G. (1993). Effect of short term temperature increases on the mesophilic anaerobic breakdown of sulfate containing synthetic wastewater. *Water Research*, *27*(4), 541– 550.

IMPACT OF THE QUALITY OF WASTE COOKING OIL ON BIODIESEL PRODUCTION

Thilakarathne D.[1], Arachchige U.S.P.R.[2], Jayasinghe R.A.[3], Weerasekara N. A. [4], Miyuranga K.A.V.[5]

[1,2,3,4,5] Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka
udara@sjp.ac.lk*

ABSTRACT: Renewable energies are important to replace fossil fuel requirements as well as to maintain environmental sustainability. Biodiesel is one of the leading renewable energy sources to replace mineral diesel. The biodiesel production from waste cooking oil supports reducing the production cost. The free fatty acids (FFA) of the waste cooking oil are the main factor in identifying the potential of biodiesel production and yield. In this study, the free fatty acid value variation with the reusing attempts of the waste cooking oil was analyzed. In addition, the qualities of the biodiesel from waste cooking oil were analyzed and compared with conventional diesel. The FFA% was increased with the number of reusing attempts, whereas the increment in FFA% was marginal. According to the FFA% of the waste cooking oil, biodiesel's quality had a slight deviation.

Keywords: Waste Cooking Oil, Reusing attempts, Esterification, Biodiesel

1. INTRODUCTION

The world's energy demand has been steadily increasing over the years due to economic growth and population expansion. International Energy Outlook (2016) projected that the total world consumption of marketed energy will expand by 48% from 2012 to 2040 (Conti et al., 2016). Moreover, it was reported that the world fuel oil demand would reach up to 109.4 million barrels per day by 2040, where demand for diesel is expected to have the highest growth (Figure 1).

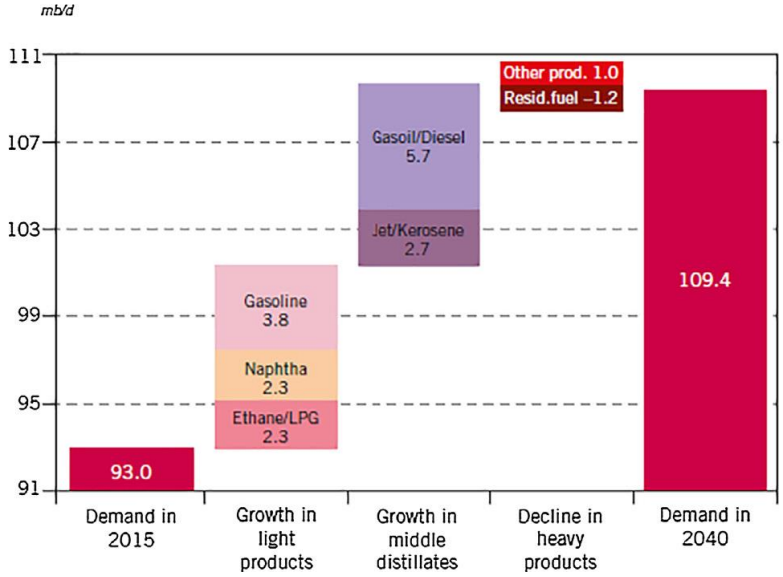


Figure 1. Oil demand growth by type from 2015 to 2040 (Conti et al., 2016)

Today the most dominant energy supply resources are crude oil, coal, and gas (Conti et al., 2016). However, the limited reserve and negative environmental impact of conventional fossil fuels emphasize the importance of searching for better and long-lasting alternative fuels from renewable energy sources. Most renewable fuels have environmental advantages over conventional fuels, such as greenhouse gas and pollution reduction (Ellabban et al., 2014). As a result, many developed countries have focused on improving or developing sustainable renewable fuels. The IEA Renewable

Energy Medium-Term Market Report 2016 indicates that the renewable energy share in total energy consumption is expected to have a 39% increment by 2021 (International Energy Agency, 2016). Among many alternative renewables, biodiesel has attracted greater attention for some reasons. It can be produced from various resources, including waste cooking oil and grease trap waste (Olkiewiczet al., 2016, and Tran et al., 2018)

The biodegradability, zero sulfur content, higher flash point, and inherent lubricity are advantages of biodiesel over conventional diesel fuel. Moreover, it releases less particulate matter, carbon monoxide and hydrocarbons (Hasan and Rahman, 2017). Thus, greater use of biodiesel could result in a reduced output of pollutants and transferable carcinogenic matters.

Trans Esterification is the most common process employed in the production of biodiesel (Gopalakrishnan et al., 2017). The economic feasibility of biodiesel depends on the availability of low-cost feedstocks. The critical issue for large-scale biodiesel application compared to petroleum diesel is biodiesel's high cost, which is directly related to the cost of feedstock oils as both the edible and non-edible oils are limited. Moreover, it has been reported that nearly 60-95% of the total production cost is related to the cost of raw materials. Similarly, the cost of the catalyst also affects the overall production cost (Saini, 2017). The raw material cost can be overcome by using Waste Cooking Oil (WCO) as raw material, which can effectively reduce the feedstock cost to 60-70%. It is a common practice to reuse cooking oil several times even though it is unhealthy. This study analysed the quality of biodiesel according to the number of reusing attempts of WCO.

2. METHODOLOGY

Five WCO samples were prepared by changing the reusing attempts. The samples were numbered 1-5. The 6th sample was a mixture of all five samples. The percentage of free fatty acid (FFA%) of WCO samples was analyzed before biodiesel production as elsewhere (Sampath et al., 2008). After calculating the FFA% of WCO, the biodiesel production process was carried out with all five samples. The alkaline transesterification process was followed as it is the most viable method. The produced biodiesel was separated and washed with distilled water to remove unreacted catalysts and other soap particles. The pH of the washed biodiesel was around pH 7, when it was characterized. Otherwise, the washing step will be repeated until the pH of the biodiesel reaches the required level of 7. The simplified production flow diagram is given in Figure 2.

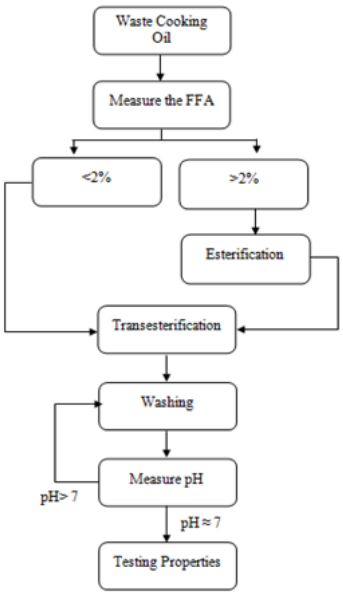


Figure 2.Biodiesel Production Process

3. Results and Discussion

The FFA% of the WCO samples are given in Figure 3. It can be clearly seen that the FFA% depends on the reusing attempts of the WCO sample. When the reusing attempts increased, the FFA% also increased. The biodiesel parameter analysis was performed to check the flashpoint, density, viscosity and the acid value to compare with standard biodiesel. The analysis is reported in Table 1.

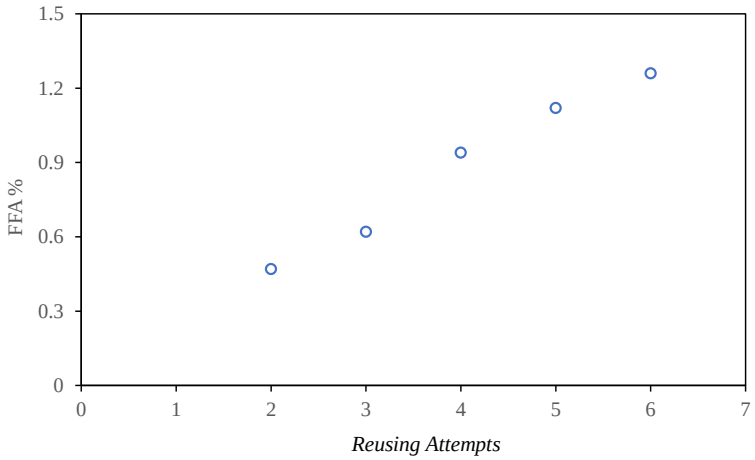


Figure 3. FFA% Variation with the reusing attempts

Table 1. Parameter analysis of the Biodiesel samples

Parameter	Method	Reference Value[a]	Reference Value[b]	Number of Frying attempts of WCO sample					
				1	2	3	4	5	Mixed Sample
Acid Value (mg KOH/g Oil)	ASTM D664	0.5	0.18	1.82	2.10	2.38	2.38	2.46	2.38
Density (g/cm^3)	ASTM D4052	860 - 900	0.887	0.866	0.866	0.866	0.866	0.866	0.866
Flash Point (ºC)	ASTM D93-20	130	186	130	136	135	133	136	136
Viscosity (mm^2/s)	ASTM D445-19a	1.9-6.0	4.46	4.15	4.45	4.16	4.46	4.46	4.07

[a] ASTM D6751Standards for B100 , [b](Prachasanti et al., 2012)

4. Conclusion

FFA% was increased with the increase of reusing attempts. However, increase in FFA% was not very significant. According to the FFA% of the waste cooking oil, biodiesel's quality had a slight deviation. The biodiesel qualities, such as flash point, density, viscosity and the acid value were in good agreement with the standard biodiesel. It is thus concluded that the WCO was a suitable raw material for biodiesel production. Further experiments have to be conducted to check the impact of the food type and the cooking parameters' effect on the quality of waste cooking oil.

5. References

Arachchige, U. S. P. R., Samarakoon, S. P. A. G. L., Ismail, F. M., Gunawardena, S. H. P. (2008). *Biodiesel production from high FFA rubber seed oil* [Abstract], 14th ERU symposium of the Faculty of Engineering, University of Moratuwa, Sri Lanka.

Alternative fuels data center: ASTM biodiesel specifications. (n.d.). EERE: Alternative Fuels Data Center. https://afdc.energy.gov/fuels/biodiesel_specifications.html,

Conti, J., Holtberg, P., Diefenderfer, J., LaRose, A., Tumure, J. T., Westfall, L. (2016). *International energy outlook 2016 with projections to 2040.USDOE Energy Information* Administration (EIA).

Ellabban, O., Abu-Rub, H., &Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, 39, 748-764.

Gopalakrishnan, S., Ubaidullah, J., Shanmugasundaram, P., Yuvaraj, K., &Tamilarasu, T. (2017 March). Production of biodiesel from used cooking oil [Conference paper], National Conference on Recent Advancements in Mechanical Engineering (RAME'17) Namakkal, Tamil Nadu, India.

Hasan, M., & Rahman, M. (2017). Performance and emission characteristics of biodiesel–diesel blend and environmental and economic impacts of biodiesel production. *Renewable and Sustainable Energy Reviews*, 74, 938-948.

IEA. (2016). *Renewable Energy, Medium Term Market Report*. International Energy Agency: Paris, France.

Olkiewicz, M., Torres, C. M., Jiménez, L., Font, J., Bengoa, C. (2016). Scale-up and economic analysis of biodiesel production from municipal primary sewage sludge. *Bioresource technology*, 214, 122-131.

Prachasanti, T., Kulachate, P., Ittipon, W. (2012). Acid esterification-alkaline transesterification process for methyl ester production from crude rubber seed oil. *Journal of Oleo Science*, 61 (2), 081-088.

Saini, R. D. (2017). Conversion of waste cooking oil to biodiesel. *International Journal of Petroleum Science and Technology*, 11 (1), 009-021.

Tran, N. N., Tišma, M., Budžaki, S., McMurchie, E. J., Gonzalez, O. M. M., Hessel, V., & Ngothai, Y. (2018). Scale-up and economic analysis of biodiesel production from recycled grease trap waste. *Applied energy*, 229, 142-150.

A COMPARATIVE STUDY OF GREEN RATING SYSTEMS IN JAPAN, SINGAPORE AND MALAYSIA WITH RESPECT TO CHARACTERISTICS OF GREENSL RATING IN SRI LANKA

Jayasooriya J.M.S.N. [1] and Denagama T.D. [2]

[1, 2] Department of Construction Technology,
University of Vocational Technology, Sri Lanka
sudeeranuwan500@gmail.com[1]*, tdenagama@yahoo.com

ABSTRACT: The green building concept is a sustainable construction method and it emphasizes saving water, energy and material resources in construction and maintenance of buildings that can reduce or eradicate adverse impacts on the environment and residents. Buildings constructed based on the green building concept should follow a set of standards named, green building rating system. A majority of the Asian countries also form and establish their own green rating systems. Selected green rating systems in Asian countries were studied through a comprehensive literature review covering local and global contexts to clearly identify the research gap and the background of green rating systems. Information was gathered using both primary and secondary data. The desk review included searching official websites and interviews over the telephone with the Green Building Council of Sri Lanka, as appropriate. Among the selected rating systems, the CASBEE green evaluation system can be taken as the most mature green evaluation system. The BCA GM rating system charges the highest amount for both medium and smaller scale buildings according to their rating tool while the GBI charges the lowest amount in this regard. When considering the weighting scores, the GREENSL rating system considers the highest number of criteria among other rating tools and 'quality of services' is the only criterion which is not included in the GREENSL. The GREENSL can be called a qualitatively successful green building evaluation system based on a number of factors. However, the number of certified buildings by GREENSL throughout a decade is comparatively lower than in the other rating tools studied. Therefore, society and targeted customers should be encouraged to motivate the evaluation of green buildings using the GREENSL rating tool within Sri Lanka.

Keywords: BCA GM, CASBEE, GBI, GREENSL, Rating tool

1. INTRODUCTION

Green architecture can be defined as environmentally friendly architecture under all classifications and contains some universal consent (Burcu, 2015). According to Cole (1999), Green building rating systems are types of certification systems which rate or reward relative levels of agreement or performance with specific environment goals and necessities. The motivation towards sustainable building technology has increased after launching the world's first green rating system, Building Research Establishment's Environmental Assessment Method (BREEAM) in 1990 in the United Kingdom (Doan *et al.,* 2017). When considering the Asian green building market, the number of green buildings is increasing in Asia. Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, BCA Green Mark (BCA GM) in Singapore and Green Building Index (GBI) are some predominantly used Asian green rating systems (Abdullah *et al.,* 2015). A locally developed green building rating system, GREENSL was introduced to Sri Lanka by the Green Building Council of Sri Lanka together with the Institute for Construction Training and Development (ICTAD).

This study therefore, aims at providing a synergistic view of the green rating system of Sri Lanka, and to compare it with the emerging and popular green assessment methodologies of Asian countries with similar climatic features. The specific objectives of this study are, overall comparison of similarities, differences and other specific characteristics of CASBEE, BCA GM and GBI with respect to the GREENSL rating system and to provide suggestions for further improvements of the green credit system in Sri Lanka.

2. STUDY DESIGN AND METHODS

The main method used for this study is a comprehensive literature review. The Primary data for the study were collected using a desk study regarding the selected green rating systems and a direct telephone interview with the Green Building Council, Sri Lanka. The CASBEE for building (new construction) technical manual 2014 edition (Japan), the BCA Green Mark for residential buildings 2016 revision log (Singapore), the GBI assessment criteria for residential new construction 2013 version 3.0 (Malaysia) and the GREENSL rating system for built environment 2018 version 2.0 (Sri Lanka) were used in order to gather the secondary data for the study. The content analytical technique was used for the comparative analysis and it covered a general comparison of the selected green rating tools and a comparison of the weighting scores of those tools.

3. RESULTS AND DISCUSSION

3.1 Overall Comparison of the systems

The following Table 1 presents the general comparison regarding the selected green building evaluation systems.

Table 1: General comparison of selected green rating systems

Country		Japan	Singapore	Malaysia	Sri Lanka
Rating tool		CASBEE	BCA-GM	GBI	GREEN SL
Established year		2001	2005	2009	2009
Latest version		2014	2016	2013	2018
Maximum points		BEE-5	140	100	100
Rating level		Excellent, Extremely good, Good, Rather poor, Poor	Platinum, Gold plus, Gold	Platinum, Gold, Silver, Certified	Platinum, Gold, Silver, Certified
Number of certified buildings (Up to 2020)		450 (in 2016)	1699	1063	61
Validity period (Years)		3	3	3	3
Assessment cost (Rs million)	Small	1.1	2.7	0.2	*Vary with size
	Medium	1.4	4.7	0.9	*Vary with size
	Mega	1.7	6.5	**Project basis	2.0

Source: Author compiled.

* The cost varies according to the area of the building (Ex: Number of square feet)
** The cost is varies according to the project type (Ex: Mega scale-hotels, residential buildings)

Among the rating systems, the CASBEE and the BCA GM green evaluation systems can be taken as the most matured green evaluation systems according to the year of establishment. Versions of the CASBEE and the GREENSL cover both residential and non-residential types. The GREENSL has the newest updated version among other rating systems. All the selected green credit systems have a points based evaluation systems while only the CASBEE has a Built Environment Efficiency (BEE) scoring system. It denotes the 'environmental quality' of the building divided by 'environmental load of the building'. The CASBEE has the highest number of rating levels among other green rating systems.

According to the cost mentioned in Table 1, the BCA GM rating system charges the highest amount for both medium and smaller scale buildings according to their rating tool while the GBI charges the

lowest amount in that regard. When considering Mega projects, the highest and the lowest assessment costs are shown by the BCA GM rating system and the CASBEE rating system, respectively. Since the maximum cost of the GREENSL rating system is two million rupees, it can be concluded that the cost for the mega projects in GREENSL is closer to the assessment costs of the CASBEE, because the cost of mega projects under the CASBEE is also around 1.7 million rupees.

3.2 Analysis of Weighting Scores of Green Tools

Table 2 represents the criteria-wise point break down in selected four ratings.

Table 2: Comparison of Weights Allocated for Criteria

Criteria	CASBEE (%)	BCA-GM (%)	GBI (%)	GREENSL (%)
Sustainable Site	23	25	33	25
Resource / Materials	17	16	12	14
Energy	10	18	23	22
Indoor Environment	27	18	12	13
Water Efficiency	4	9	12	14
Innovation	0	14	8	4
Quality of Services	19	0	0	0
Management	0	0	0	4
Social and Cultural awareness	0	0	0	4

Source: Author compiled.

All four rating tools consider five common criteria: ‘sustainable site’, ‘resource/ materials’, ‘energy’, ‘indoor environment’ and ‘water efficiency’. Other than that, the BCA GM, the GBI and the GREENSL have another mutual criterion termed ‘innovation’. Only the CASBEE has a criterion named ‘quality of services’ while the GREENSL has two other criteria as ‘management’ and ‘social and cultural awareness’. According to the points allocated overall, three of these rating tools give their highest weights for ‘sustainable sites’ as GBI-33% and both BCA GM and GREENSL -25%. However, the CASBEE allocates its highest weight (27%) for ‘indoor environment’ while it places a considerable high weight (23%) on ‘sustainable sites’. Both the BCA GM and the CASBEE allocate their lowest weights for ‘water efficiency’ as 9% and 4%, respectively. Nevertheless, both the GBI and the GREENSL allocate their lowest weights for ‘innovation’ as 8% and 4%, respectively. However, the GREENSL has allocated the same amount of weight for ‘resources/ materials’ and ‘water efficiency’ and the value is 14%. In the GBI rating system, 12% of a similar weight has been assigned to ‘resources/ materials’, ‘indoor environment’ and ‘water efficiency’. Significantly, the CASBEE has paid a lesser consideration for ‘energy’ while a higher consideration is paid to ‘indoor environment’. The CASBEE has another special criterion called ‘quality of service’ and earthquake resistance, floor load margin and system renewability are considered under this criterion.

The GBI and the CASBEE tools can achieve 50% by fulfilling two criteria while the GREENSL and the BCA GM have to fulfill three criteria to achieve that amount. Only the ‘water efficiency’ criterion of the GREENSL rating system has been allocated the highest value among the other three rating tools. When considering as a whole, the GREENSL rating system considers the highest number of criteria (8) among other rating tools and the ‘quality of services’ is the only criterion which is not included in the GREENSL. Most significantly, the ‘social and cultural awareness’ criterion has only been considered in the GREENSL rating system.

4. CONCLUSION

The CASBEE is the most mature rating system between the BCA-GM, the GBI and the GREENSL, however the BCA-GM, launched in 2005, have certified the largest number of buildings. Although both the GREENSL and the GBI were established in 2009, it can be observed that, they have issued only a very low number of green certifications in Sri Lanka over the past decade. The assessment tool for new construction in Sri Lanka is the most recent tool among others. However, the evaluation scoring system of the CASBEE is specific and in addition to scoring, all the CASBEE scores are rated BEE with a multiplier factor where the Number of evaluation levels and nomenclature are similar to the GBI and the GREENSL. The GBI charges a minimum fee for small and medium scale projects, taking into account the cost to the customer for the evaluation, and the GREEN SL does not offer a specific or maximum price for evaluation. The maximum price limit of the GREENSL is limited to 2 million and this non-exposure price factor may cause customers not to move to a green rating system for their buildings and therefore the number of certifications is limited to 61 buildings for more than 10 years.

When considering content, GREENSL pays special attention to Management and Social and Cultural awareness in addition to the general criteria of Sustainable Site, Resource / Materials, Energy, Indoor Environment and Water Efficiency. The objective of a green evaluation is eco-friendliness and sustainability, with a score of 50%. Green SL and the BCA GM in weight comparison show that consumers are motivated to reach that goal in more areas at least in three of the criteria. The GREENSL aims to prioritize unique environmental issues through placing first, second and third emphasis on Sustainable Site, Energy and Water Efficiency, respectively. Accordingly, the issues currently faced by Sri Lanka which need addressing such as Energy and the efficient use of water, have been indirectly contributed through the Green Evaluation.

Overall, it is clear that the GREENSL is qualitatively and successfully based on a number of factors, including a greater share of coverage, a unique social and cultural awareness, and a single assessment system that focuses on management. This should be addressed within the community and it is appropriate to offer a range of exposure and money to motivate the customer to join the green building evaluation process.

5. REFERENCES

Abdullah, L., Jumadi, N., Sabu, R., Arshad, H. and Fawzy, F.F.M. (2015). Assessment criteria on sustainable rating tools used in Asian countries. *Jurnal Teknologi*, 1(1), 1-11.

Burcu, G. (2015). ‘’Sustainability’’ Education by sustainable School Design. *Procedia Social and Behavioral Sciences*. 186, 868-873.

Cole, R.J. (1999). Environmental performance of buildings: Setting goals, offering guidance, and assessing progress. *Reshaping the Built Environment Ecology, Ethics and Economics*. pp. 276.

Doan, D., Ghaffarianhoseini, A., Naismith, N., Zhang, T., Ghaffarianhoseini, A., & Tookey, J. (2017). *A critical comparison of green building rating systems*. Building and Environment, 123, 243-260.

Session 05

CLUSTERING ONLINE RETAIL DATA SET

Uduweriya R.M.B.P.M.[1] and Napagoda N.A.D.N.[2]

[1, 2] Department of Mathematical Sciences, Faculty of Applied Sciences,
Wayamba University of Sri Lanka
mekhalauduweriya@gmail.com[1], namalee6@yahoo.com[2]

ABSTRACT: Online retailing is the sale of goods and services over the internet. Presently it is growing at an astonishing rate, resulting in gathering a heavy amount of retailing data. Since online retail data cannot be handle easily due to the rapid production of data in many forms it ends with a huge amount of raw data. Therefore, this study proposes a way of finding optimal clusters, using the Elbow method for online retail datasets. Gower algorithm is applied to the online retail data set to find the dissimilarity matrix since it supports both text and numerical data. Furthermore, clustering can be performed for finding homogeneous groups within the retail dataset. Finding groups from online retail data is an important method since a retailer's reputation can be fostered as a 'go-to retailer' for a specific range of products and the retailer can reduce unnecessary stock holdings, and can cater to the target market more effectively. For the experimentation of the research, a standard data set of online retail stores which consisted of eight attributes of both numerical and text data and an approximately five lakhs of recorded retail transactions were used. For the improvement of the quality, data preprocessing, and exploratory data analyses were used by understanding the properties of data before clustering. Subsequently, 10 random samples were taken to find the best sample which consumes less run time. Optimal cluster count 3 was obtained from the Elbow method and the research was performed by clustering sample data sets into three groups. Since the proposed method accurately clusters the online retail dataset in the least possible time, it helps in predicting customer purchase patterns more effectively.

Keywords: Dissimilarity matrix, Gower algorithm, Clustering, Elbow method

1. INTRODUCTION

Online retailing is a type of electronic commerce where consumers purchase goods or services directly from a seller through the Internet. Online retailing plays a major role in real life due to its easy and comfortable usage. Clustering online retail data into homogeneous groups is important as it can cater to the target market more effectively. Accurate clustering of the online retail dataset helps in predicting customer purchase patterns. Therefore, several research papers related to cluster analysis are reviewed in this study.

Kettani et al., (2014) proposed a method which is a straightforward and fast algorithm for agglomerative clustering. The proposed method is easy to implement, without imposing any tuning parameter, except k, the number of clusters. The experiments were conducted on several standard datasets and demonstrated the effectiveness of the proposed approach which could be successfully used as an initialization method for the k-means algorithm. Since a suitable data preprocessing method was not performed in the study it lead to a reduced accuracy of the clustering. Thus, the study found a reduction in the accuracy of clustering for some datasets.

Khandare et al., (2016) presented an efficient clustering algorithm with improved cluster quality and modified the k-means clustering algorithm to develop an efficient algorithm with quality clusters. The work was carried out in a standard data set of online retail stores with eight attributes and approximately five lakhs of instances of online retailing. Firstly, the standard k-means algorithm was applied to the retail dataset. Thereafter clustering aggregation and spectra analysis were used to analyze the properties of the retail data. This was used for selecting the initial centroids. A new algorithm was created by using the standard k-means algorithm with some additional steps. Then the proposed algorithm was compared with the standard clustering algorithm but it did not show much efficiency due to the focus on cluster quality only. Productivity was low as a result of low efficiency.

Kalsoom et al., (2013) displayed different clustering methods to group the driving data. In addition, the driving state of the driver was analyzed and the results are compared to find the most appropriate

and effective clustering for the data. The 2011 driving simulator was used to collect data and a total of 5 minutes of dynamic data with a 10 second time window for observation was used for each driver. First, k-means and hierarchical clustering algorithms were applied to the dataset for grouping according to the driver's behavior. The results were compared and showed that k-means clustering, groups the data correctly according to similar attributes while hierarchical clustering performance was not as good, compared to k-means clustered data.

In the present study, the dataset is preprocessed, which lead to handling outliers, the redundant data, and the missing data. Furthermore, the Gower algorithm is proposed for the retail dataset to analyze and produce a dissimilarity matrix most efficiently, since this method is supported by both numerical and text data. An experiment was performed which lead to finding the best sample of the online retail data set, using the Elbow method in order to increase the efficiency of finding optimal clusters.

2. METHODOLOGY

Initially, Data preprocessing was performed to clean the online retail data. First, tuples were removed where tuples contain missing values, negative quantity, and duplicate instances. After that, redundant attributes were removed. The exploratory data analysis was applied to obtain a better understanding of the variables. Eighty thousand distinct random samples were employed in the study and 10 different samples were created from them. Moreover, the dissimilarity matrix was calculated using the Gower method for each sample. The time before and after the dissimilarity matrix calculation was obtained for each sample. The difference between the start and the finish time was taken as the consumed time for the calculation. Only the process time of the matrix calculation was computed and taken into account. The operating system consumed time was neglected. After that, the best sample and the produced dissimilarity matrix which had the least time in most of the experiments were taken. The Elbow method was the heuristic used in determining the number of clusters in the data set since an optimal number clusters can be extracted using this method.

3. RESULTS AND DISCUSSION

The experiment was repeated 10 times and the inspection of the same data set indicates different consumption times as in Table I

Table 4. Time Consumption For 10 Data Sets.

Dataset	1st time	2nd time	3rd time	4th time	5th time	6th time	7th time	8th time	9th time	10th time
Dataset_1	5.00	5.08	5.17	5.09	5.02	5.06	5.14	5.03	5.13	5.12
Dataset_2	5.11	5.02	4.92	5.08	5.17	4.90	4.94	4.85	5.14	5.06
Dataset_3	5.06	4.86	5.09	5.22	5.05	4.80	5.00	5.11	4.91	4.83
Dataset_4	5.14	5.15	5.02	4.99	4.98	4.99	4.92	5.03	5.03	5.16
Dataset_5	4.99	4.99	5.19	5.15	5.00	5.03	4.97	5.09	4.95	5.04
Dataset_6	5.06	5.00	5.11	5.00	5.08	4.95	5.06	4.92	5.16	5.09
Dataset_7	5.03	5.12	5.18	4.99	5.11	4.95	5.06	4.97	5.01	5.06
Dataset_8	5.11	4.99	4.99	5.09	5.08	5.10	4.81	5.10	5.16	5.02
Dataset_9	5.16	4.93	5.08	5.09	5.07	5.00	5.07	4.98	5.09	5.20
Dataset_10	5.01	5.02	5.11	4.94	5.00	5.00	5.01	4.98	5.10	4.99

Finally, as a conclusion, "Dataset_3" was taken as the best sample dataset, which consumed less time than the other datasets, most of the time. Thenceforth, a dissimilarity matrix was created for "Dataset_3" which contains 8000 rows and 8000 columns as in Figure 1.

0.0000000	0.5150851	0.4858749	0.4925193	0.4558762	……..	……..
0.5150851	0.0000000	0.3862299	0.4114578	0.2563146	……..	……..
0.4858749	0.3862299	0.0000000	0.5119735	0.4494710	……..	……..
0.4925193	0.4114578	0.5119735	0.0000000	0.3810592	……..	……..
0.4558762	0.2563146	0.4494710	0.3810592	0.0000000	……..	……..
……	……	……	……	……	……..	……..
……	……	……	……	……	……..	……..

8000x8000

Figure 1. Dissimilarity Matrix of Dataset_3.

Finally, the optimal number of clusters was obtained using the Elbow method. Figure 2 indicates that k=3 is the optimal number of clusters for this method.

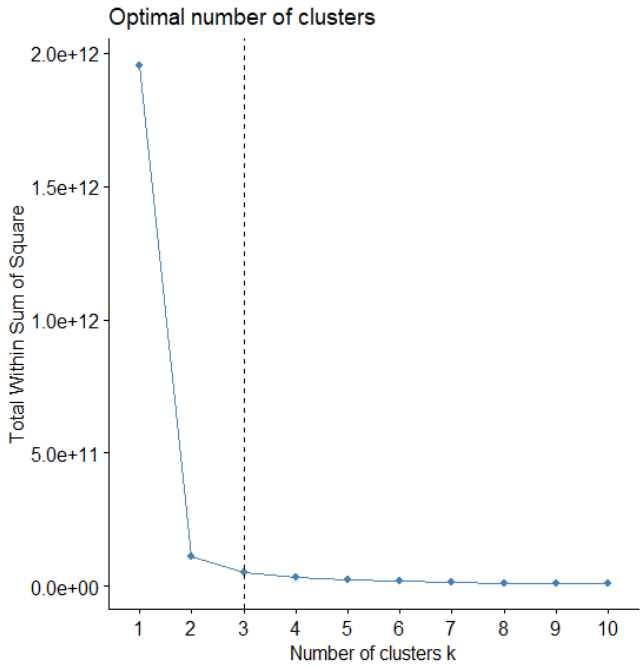


Figure 2. Optimal Number of Clusters.

4. CONCLUSION

The proposed dissimilarity matrix generation is very convenient to cluster a data set efficiency while maintaining the quality of the clusters. This method used data preprocessing and exploratory data analyses to analyze properties of the input data before creating a dissimilarity matrix using the Gower algorithm. Furthermore, this algorithm was applied to a standard online retail store data set. In this research, 10 random samples are compared with run time. Finally, the Elbow method was used to obtain the optimal number of clusters for the retail dataset to predict customer purchase patterns efficiently. This study can be extended further by the design of a scalable clustering algorithm which will work for large and more than one type of data sets effectively and efficiently and would be helpful in clustering method comparisons.

5. REFERENCES

Ali M., Li X., Dong, Z.Y. (2005) *Efficient Spatial Clustering Algorithm Using Binary Tree*. In: Gallagher M., Hogan J.P., Maire F. (eds) *Intelligent Data Engineering and Automated Learning* - IDEAL 2005. IDEAL 2005. Lecture Notes in Computer Science, vol 3578. Springer, Berlin, Heidelberg. https://doi.org/10.1007/11508069_39

Chen, D., Sain, S. L., & Guo, K. (2012). Data mining for the online retail industry: A case study of RFM model-based customer segmentation using data mining. *Journal of Database Marketing & Customer Strategy Management*, *19*(3), 197–208. https://doi.org/10.1057/dbm.2012.17

Dua, D. and Graff, C. (2019). *UCI Machine Learning Repository* [http://archive.ics.uci.edu/ml]. Irvine, CA: University of California, School of Information and Computer Science.

Gowda, K. C., & Krishna, G. (1978) *Agglomerative clustering using the concept of mutual nearest neighborhood, Pattern Recognition*, Volume 10, Issue 2, 1978, Pages 105-112, ISSN 0031-3203, https://doi.org/10.1016/0031-3203(78)90018-3.

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2009*). An Introduction to Statistical Learning with Applications in R (2nd ed.).*

Kettani, O., Ramdani, F., & Tadili, B. (2014). An agglomerative clustering method for large data sets. *International Journal of Computer Applications*, *92*(14), 1–7. https://doi.org/10.5120/16074-4952

Khandare, A., & Alvi, A. (2018). Efficient clustering algorithm with enhanced cohesive quality clusters. *International Journal of Intelligent Systems and Applications*, *10*(7), 48–57. https://doi.org/10.5815/ijisa.2018.07.05

CRITICAL HURDLES OF BLOCKCHAIN ADAPTATION TOWARDS IMPROVING SUPPLY CHAIN INFORMATION SHARING

Dhananjaya D.D.[1] and Balachandra K.M.[2]

[1,2] Department of Transport and Logistics Management, Faculty of Engineering,
University of Moratuwa, Sri Lanka
d.dineth.dananjaya@gmail.com[1*], kmbalachandra@gmail.com[2]

ABSTRACT: A supply chain is a network of stakeholders (e.g., suppliers, manufacturers, distributors & retailers) who are involved in the movement of materials, money, and information, collaboratively. Although all these flows are significant and inseparable from each other for a smooth supply chain operation, the information flow plays a paramount role since it directs the movement of materials and money along the network. However, the flow of information should be reliable, and provide real-time access to heterogeneous information, while ensuring that the right information is delivered to the intended recipients at the right time. Existing literature outlines that blockchain is a silver bullet for the establishment of such an informational flow. Despite the anticipated benefits and the numerous announcements of pilot cases, very few successful implementations have emerged with blockchain Technology solutions in the supply chain field. Notwithstanding the academics and practitioners believing that developing a blockchain-based supply chain solution is stressful, they agree on its necessity. However, literature has not extensively explored the barriers and challenges of moving towards a blockchain based supply chain. This paper is an attempt to identify the critical hurdles among selected ten barriers in blockchain adaptation in supply chain information sharing in a systematic manner. The Analytical Hierarchical Process (AHP) as a Multi-Criteria Decision Making (MCDM) method was used to analyze the opinions taken from industry experts. Unsurprisingly, higher expenses that the practitioners must bear in the implementation could be identified as the most critical barrier. It is believed that this might be an influential input for the developers of this technology, and supply chain professionals to focus in applying this disruptive technology in order to gain its best in practice.

Keywords: Blockchain, Supply chain, Disruptive technologies, Analytical Hierarchical Process, Information sharing

1. INTRODUCTION

Economic progress around the world has resulted in increased organizational competitiveness and as a result, ways of improving the effectiveness and efficiency of operations have become the highest interest among many. Thus, supply chain collaboration is a prominent concern within industrial communities. Information sharing can be identified as the heart of supply chain collaboration (Min et al., 2005) from which information types such as inventory, sales, order, quality, freight transportation status are widely shared. Consciousness on inventory information along a supply chain gives an organization the ability to decrease stock-outs, repetitions, and total stocks that eventually cause to reduce the total inventory cost. Zhao Y, (2002) mentioned that manufacturers have the capability of reducing inventory costs by 5 – 35% through accurate information sharing and the reduction of the bullwhip effect, delivery cycle time, improved resource utilization, optimized capacity utilization, and improved visibility which are identified as key benefits that can be obtained.

However, despite these advantages, sharing supply chain information involves certain challenges such as confidentiality and privacy of shared information, timeliness and accuracy of the information, and the reliability of the technology that is used. Especially, the general centralized data management structure has become a hindrance to supply chain data management due to server processing issues in handling extensive amounts of data and the risk of single-point failure. Although integrated supply chain information models are considered an essential feature nowadays, the critical barrier that stands against the sharing of information between supply chain partners is the inability to verify its privacy and security.

Thus the requirement for a more trusted network for supply chain information sharing emerges (Razavi & Iverson, 2006). Blockchain technology has been identified as a panacea for this concern. The white paper published with the name Satoshi Nakamoto (Nakamoto 2008) identifies blockchain technology as the core component of bitcoin crypto currency. However, the content within this technology was realized before long as a valuable application mode that does not limit only to crypto currencies (Bhardwaj, 2018). Hence, blockchain has become a nascent technology that utilizes a distributed network for data manipulation. Blockchain brings forth the ability to experience transparency in a supply chain by enabling robust information sharing and eliminating the trust issues (Amr et al. 2019). It is expected that organizations will be able to ensure the trust and reliability of information across the network and also relationships between the entities will be enhanced from the successful deployment of this technology (Kshetri 2017).

However, blockchain adaptation in supply chain information sharing apparently has not bought the expected changes to the industry yet. Banafa, (2017) mentioned that hurdles such as limited development of the technology, lack of legislation and standards, lack of a skilled workforce, and scalability issues had made a substantial impact on this. Some studies elaborate on the requirement of faster communication protocols rather than the existing consensus agreements (Viriyasitavat & Hoonsopon, 2018). Hence, it is doubtful that blockchain technology would be able to bring the expected outcome amidst these difficulties. It is timely therefore, to study the reasons for the negative impact on this technology with a view of bringing the field of supply chain information to another level.

2. METHODOLOGY

The existing hurdles faced by the practitioners of blockchain based supply chain information sharing are identified mainly through the literature review and reliable articles. Initially, 30 variables were extracted in this context and they were further summarized into 10 criteria based on similarities obtained from inputs by academicians. This is further illustrated in Table 1 below:

Table 1. Identified hurdles to analyze.

No	Criteria	Variables
1	Technological immaturity	Lack of OTS (Off the Shelf) systems, lack of experts, technological unfamiliarity, lack of standards
2	Complex implementation	Industry specificity, system integration issues, application development complexity, higher computational overhead
3	Security and privacy issues	Technological uncertainty, switching difficulty in existing practices
4	Throughput quality issues	Inability to gain total benefits, poor existing data quality
5	Complex data management	Data entering inefficiency, inability to change data, difficulty in scaling on demand
6	Higher expenses	SME (Small and Medium Enterprises) adaptation issues, implementation cost, breakeven difficulty
7	Insufficient legislation	Lack of legal compliance, gaps in existing legislations
8	Challenging policies and cultures	Lack of encouragement from authorities, unsupportive administrative structures, lack of consumer interest
9	Behavioral resistance	Unsupportive critical employees, myths on failures
10	Problematic stakeholder consolidation	Difficulty to establish solely, different levels of benefits to different parties, lack of existing operational solidarity between partners, fear for transparent operations, unclear benefits for the users

The Analytical Hierarchy Process (AHP) was used as a Multi Criteria Decision Analysis (MCDA) method to identify the most critical hurdles/criteria based on ranking. AHP is a structured technique for analyzing decision making problems giving weights for each. The inputs required for the AHP to rank those hurdles were taken from selected 12 respondents, who were involved in managerial positions relating to supply chain operations, having specific knowledge about blockchain technology. As obtaining a higher number of samples would lead to a higher inconsistency in the AHP, it was decided to limit the sample to a small number with expertise in the relevant subject matter.

For data collection and analysis purposes, the Excel based AHP tool developed by the (Geopel & Klaus, 2013) was utilized in this study. As an advantage of this tool, the respondents had the ability to change their opinions if certain comparisons provided by them were inconsistent, ensuring the reliability of the given responses. For the comparison of criteria, a linear scale was used for collecting data from respondents. The ultimate consolidated results were taken through the geometric mean of results for all the responses, as it is the mostly widely accepted approach to aggregate the multiple responses in AHP.

3. RESULTS AND DISCUSSION

Consistency Ratio (CR) of all the responses were ranged from 0.06 – 0.09, accepting it from the generally accepted threshold of 0.1. The following figure 1 depicts the results of the study illustrating the calculated and ranked weights for each hurdle with the error. Higher expenses can be identified as the most critical hurdle impact towards the acceptability of blockchain technology for supply chain information sharing. There is no doubt that blockchain technology is one of the most expensive technological solutions that brings fear to the practitioners as they have to bear the risk. The second most critical hurdle is specific to the field, as the problematic stakeholder consolidation might come along with issues faced when collaborating with the stakeholders in practice. However, it can also be guessed that these two hurdles might be in relation to the developing countries since the respondents were taken locally. Apart from that technology-oriented hurdles such as technological immaturity, complex data management and complex implementation has higher weights respectively. This is quite reasonable for a newbie tech.

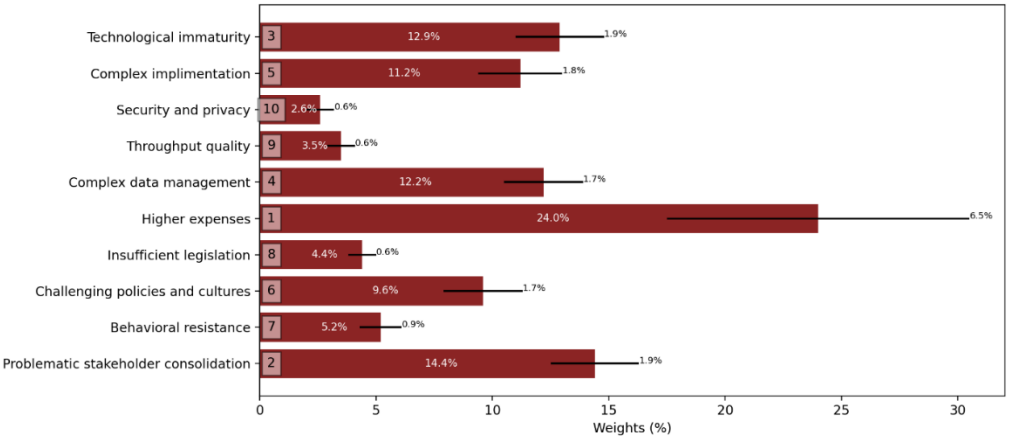


Figure 1. Calculated and ranked weights of hurdles with error rates.

Then organizational hurdles such as impact from policies, cultures and behavioral resistance of employees have somewhat lower weight compared to the above. Surprisingly, legislation issues have a lower weight, indicating its negligence by the practitioners. However, it is obvious that blockchain

as a tech. that promote higher security for the information has the lowest weight from respondents among these selected criteria.

4. CONCLUSION

Information sharing is a vital remedy to streamline supply chain operations. Blockchain facilitates a fine-tuned platform in information sharing as it ensures transparency during the whole supply chain although deploying the blockchain platform is a challenging task in a supply chain setting. Despite having only a few studies on identifying those challenges, literature has not extensively studied on identifying and ranking them. The study was aimed at extracting these hurdles and ranking them in relation to the adoption of blockchain in the supply chain. AHP as a MCDA method was used for analysis purposes, with the opinion of industry experts. Among the identified hurdles, higher expenses of this technology stands as the most critical one. Then the problematic stakeholder consolidation issues that are commonly faced by the practitioners in day today supply chain operations are highlighted. Apart from these two, technology-based issues also showed higher weights. One possible limitation of the study could be that the decisions were based only on the opinions of local respondents. Hence, it is encouraged to conduct future research covering the opinions of practitioners from other countries with different economical standings as well.

5. REFERENCES

Amr, M. A., M. M. Eljazzar, S. S. Kassem, and M. Ezzat. 2019. "*Merging Supply Chain and Blockchain Technologies.*" Managing Technology for Inclusive and Sustainable Growth - 28th International Conference for the International Association of Management of Technology, IAMOT 2019 224–28.

Banafa, A. 2017. "*IoT and Blockchain Convergence: Benefits and Challenges.*" IEEE Internet of Things.

Bhardwaj S., Kaushik M. 2018. "*Blockchain—Technology to Drive the Future*." Pp. 263–71 in Smart Computing and Informatics.

Goepel, Klaus D. (2013). *Implementing the Analytic Hierarchy Process as a Standard Method for MultiCriteria Decision Making In Corporate Enterprises* – A New AHP Excel Template with Multiple Inputs, Proceedings of the International Symposium on the Analytic Hierarchy Process 2013, p 1 -1

Kshetri, N. 2017. "*Blockchain's Roles in Strengthening Cybersecurity and Protecting Privacy.*" Telecommunications Policy 41(10):1027–1038.

Lu, Y. (2018). Blockchain and the related issues: A review of current research topics. *Journal of Management Analytics, 5*(4), 231–255. https://doi.org/10.1080/23270012.2018.1516523

Min S., Roath A.S., Daugherty P.J., Genchev S.E., Chen H., Arndt A.D., Richey R.G. 2005. "*Supply Chain Collaboration: What's Happening?*" International Journal of Logistics Management 16:237–57.

Nakamoto, Satoshi. 2008. "*Bitcoin: A Peer-to-Peer Electronic Cash System.*"

Razavi, M. N., & Iverson, L. (2006). A grounded theory of information sharing behavior in a personal learning space. *Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work - CSCW '06*. https://doi.org/10.1145/1180875.1180946

Tian, F. 2016. An agri-food supply CHAIN TRACEABILITY system for China based on RFID & blockchain technology. *2016 13th International Conference on Service Systems and Service Management (ICSSSM)*. https://doi.org/10.1109/icsssm.2016.7538424

Viriyasitavat, W., & Hoonsopon, D. (2019). Blockchain characteristics and consensus in modern business processes. *Journal of Industrial Information Integration*, *13*, 32–39. https://doi.org/10.1016/j.jii.2018.07.004

Zhao, X., Xie, J., & Zhang, W. J. (2002). The impact of information sharing and ordering co-ordination on supply chain performance. *Supply Chain Management: An International Journal*, *7*(1), 24–40. https://doi.org/10.1108/13598540210414364

DESIGN A CLUSTER BASED SMART MICRO-GRID CONTROL ALGORITHM VIA HVDC LINE

Jayasekara M.J.A.M.S.S.[1], Bandara K.V.D.K. [2], Kariapper M.H.M.S. [3], Juhaniya A.I.S. [4], Aashiq M.N.M. [5]

[1,2,3,4,5] Department of Electrical & Telecommunication Engineering, [5]Department of Computer Engineering, South Eastern University of Sri Lanka, Oluvil, Sri Lanka
sankasri8@gmail.com [1], netballdhane@gmail.com [2], safnas.mhm@seu.ac.lk [3], juhani90@seu.ac.lk [4], aashiqmnm@seu.ac.lk [5]

ABSTRACT: Electrical energy is one of the most important commodities in today's world. It is important to match electricity supply with demand to provide a reliable power supply because of unpredictable increase in electricity consumption. Instead of building a large power supply system anda HVAC transmission line, a smart micro-grid and a HVDC transmission line can be seen as a promising option for remote installations. This research was to design a cluster based smart microgrid and develop a control algorithm to transfer power between two microgrids via HVDC line. These microgrids can operate in both grid-connected mode and off-grid connected mode. Rather than using a conventional HVAC transmission line, a HVDC line was used to enable power transmission between microgrids. The entire microgrid system is simulated in the MATLAB Simulink platform and the results are analyzed. The simulation model of the microgrid includes the Solar panel, Micro Hydro, Battery Bank, critical loads and non-critical loads. The performance of the system is analyzed under the two different transient conditions and the simulation results are verified.

Keywords: Micro Grid, HVDC, HVAC, MATLAB, transient condition

1. INTRODUCTION

Electrical energy production for utilization comprises complex systems in the three phases; electricity generation, transmission and distribution to consumers. It is challengingto guarantee a reliable power gird with minimum interruptions due to mismatch between demand and supply. The National Grid in Sri Lanka has a drawback. When a failure occurs in the utility grid there is a countrywide blackout. This problem can be addressed by designing cluster based smart microgrids (MGs) with HVDC transmission lines to transfer electrical energy between microgrids.

MG is a newly developed concept in power system architecture that comprises electricity generation sources and small loads [1]. When power interruptions occur in the utility grid, MGscan operate in self-sustained mode with intelligent control over the entire microgrid. MG offersmany advantages such as better power quality, resiliency, reliability and being more economical and more environment friendly.

HVDC transmission does not have a stability problem because it does not have limitations for frequency components and it is not limited by transmission distance. So, it can transmit power over long distances. In general, HVDC transmission lines impacts less on the environment and therefore, HVDC transmission lines have better performance than HVAC transmission lines [2].

1.1 Problem Formation

Reliability and resilience are more important for sustainable power delivery. This issue can be managed by implementing AC MGs with HVDC transmission line to transfer electrical power between micro grids. As the utility grid and most loads use AC, the AC micro grid can easily integrate with the national grid.

2. METHODOLOGY

MATLAB 2019a Software was used to simulate the entire micro grid system. The overall structure of the system is shown in figure 1. It consists of 230-V, 50-Hz, single phase two AC microgrids and HVDC line to transfer energy between them. Each MG comprises a PV array, Battery Bank, Inverter, Micro hydro, critical loads and non-critical loads.

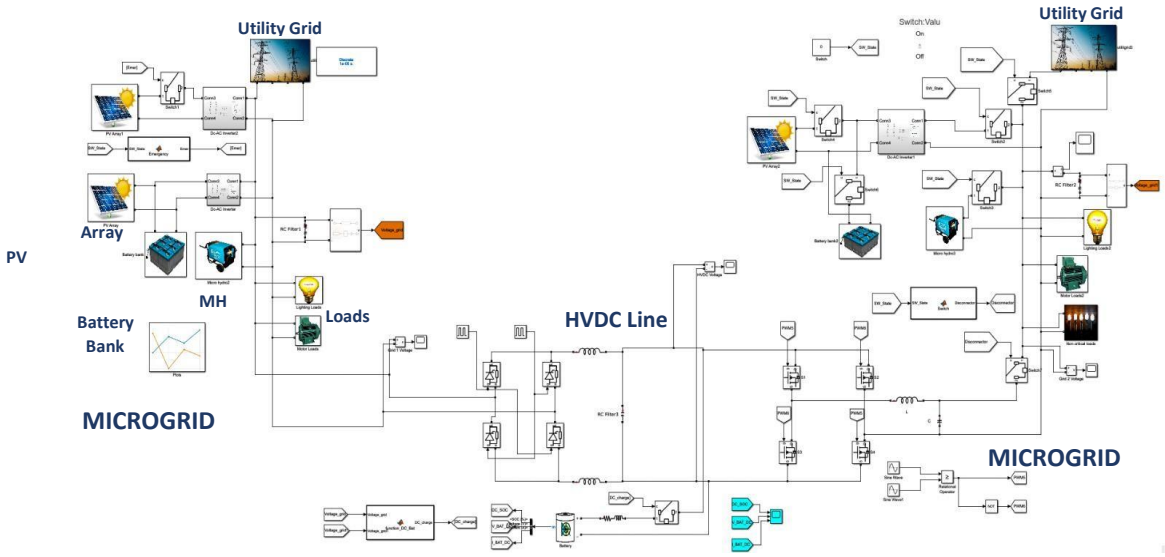


Figure 1:Structure of complete MATLAB Simulation system

2.1 PV Array

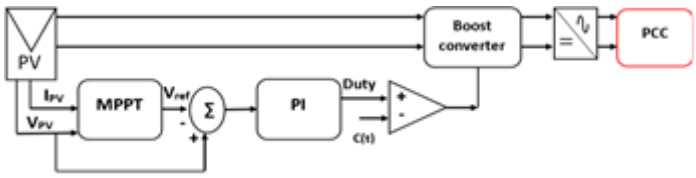


Figure 2: MPPT Close loop control diagram

A PV array is one of the renewable energy sources which is connected to the microgrid using a micro inverter. Due to photovoltaic action, DC power is generated. This power is given to MPPT (maximum power point track) which transfers maximum efficient power to the DC-DC boost converter.

2.2 DC – AC Inverter

A single-phase inverter is used to connect PV array to the single-phase AC grid which converts DC into a form of AC. Power generated by the PV array is not stable all the time. This inverter helps in ensuring grid stability by the integration of the PV power output.

2.3 Micro-hydro

A three phase asynchronous machine is used to model the micro-hydro. The C2C method is used to convert it into a single phase. In this method proper rotating direction of the rotor should be ensured. Unbalanced arrangement of capacitance helps to compensate for the unbalanced load on the generator and the derating factor when the unbalanced motor operation is 80% of the motor the rating.

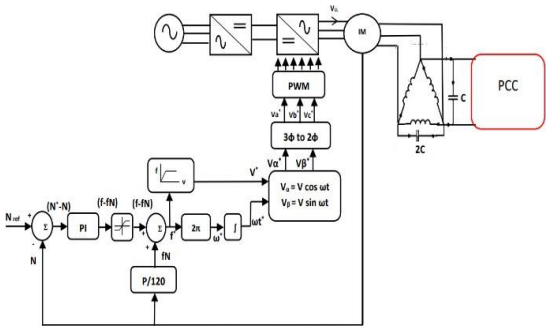


Figure 3: V/F control of Micro-hydro

2.4 HVDC transmission system

Mainly, an HVDC transmission system can be divided into three parts; 1) First converter station to convert AC to DC. 2) Transmission line. 3) Second converter station to convert DC to AC. An extra battery is connected to the HVDC line. When the grid voltage is higher than 230-V the battery will charge by using excess power.

2.5 Control algorithm

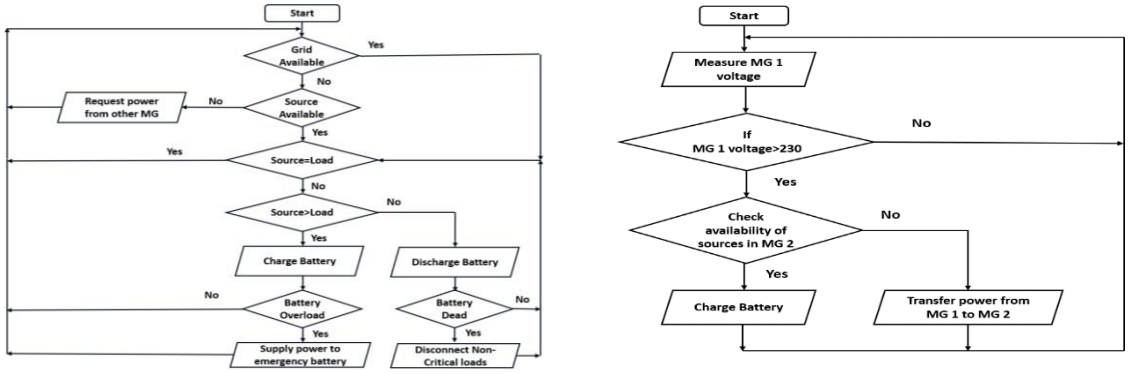


Figure 4: Control Algorithm for Microgrid (a) and HVDC line (b)

3. RESULTS AND DISCUSSION

Two case studies are verified through this project and the stability of the voltage and the frequency of the proposed system are examined.

Case A: When power interruption occurs at the Utility grid

This means island mode of the MG. At this time energy is generated by micro sources. The microgrid voltage variation is illustrated in figure 5. The voltage of the system illustrated in the graph is stable after 0.3 seconds and it is nearly equal to the 230-V.

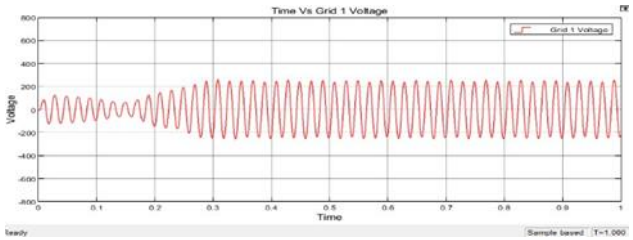
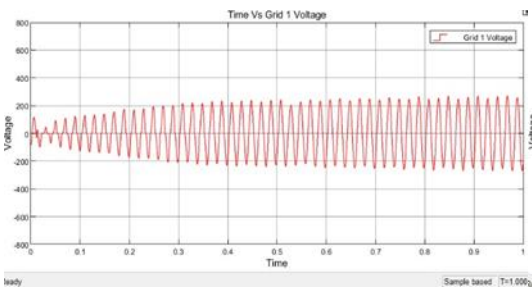


Figure 5: Microgrid voltage

Case B: Transient at the Utility grid and energy sources

In this case an assumption has been made as a transient occurs in MG 2. During this condition, the excess power in MG 1 is supplied to loads of MG 2. The entire system performance is simulated for the duration of 1 second. First 50% is simulated with transient and the rest of the part is simulated without transient. The microgrid 1 voltage is illustrated in figure 6 and microgrid voltage 2 is illustrated in figure 7. It can be observed that in both graphs, the system voltage is stable and almost equal to 230-V.



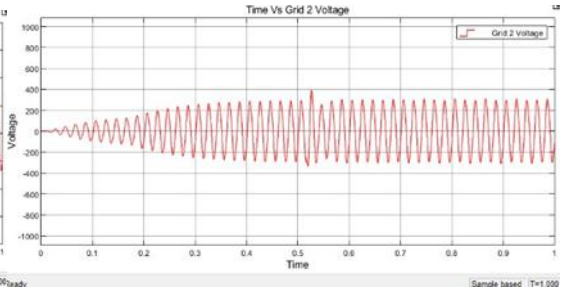


Figure 6: Voltage of Microgrid 1 *Figure 7: Voltage of Microgrid 2*

In this case, MG 1 supplies power to MG 2 via HVDC line. The HVDC line voltage is illustrated in figure 8.

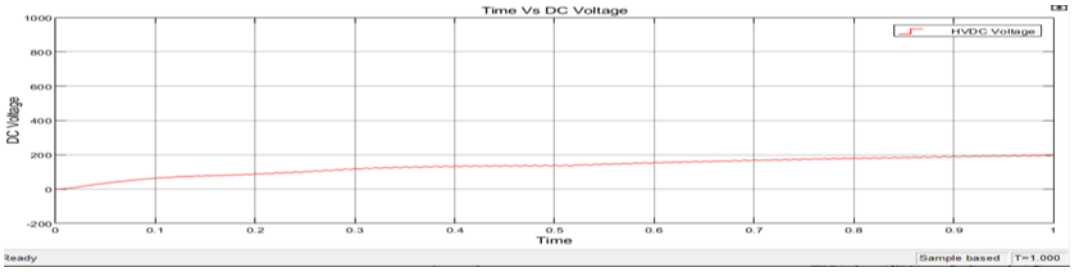


Figure 8: HVDC line voltage

4. CONCLUSION

This project mainly focused on designing a cluster based smart micro grid and developing a control system for transferring power between two micro grids via an HVDC line. The specialty of the project is that this microgrid can operate in both grid-connected mode and off grid connected modes. The whole system is controlled in autonomous mode according to the given inputs. This MATLAB model has been tested under two transient conditions called “transient at the utility grid” and “transient at utility grid and energy sources”. Eventually, the proposed microgrid system can be operated in both cases.

5. ACKNOWLEDGEMENTS

We would like to express our heartrending gratitude and sincere thanks to our coordinator forthe Project, Dr Aslam Saja for guiding us through the process, Dr. PMK Alahakoon, the Head of the Department of Electrical and Telecommunications Engineering and Dr. Junaideen, the Dean of the Faculty of Engineering of the South Eastern University of Sri Lanka.
Also, we would like to thank all the lecturers who have been provided the necessary information with their subject knowledge during our university period and all the otheracademic and non-academic staffs of the Electrical and Telecommunication Engineering Department. Finally, we would like to thank the South Eastern University for offering us an environment conducive for studies and supplying all supportive materials whenever we needed them.

6. REFERENCES

Dinushi, H. M., Kariapper, M. H., Porawagamage, G. D., Rathnayaka, P. K., Srimal, U. P., & Hemapala, K. T. (2015). Defining multi agent system for a reliable micro-grid. *2015 Moratuwa Engineering Research Conference (MERCon)*. https://doi.org/10.1109/mercon.2015.7112327

Meah, K., & Ula, S. (2007). Comparative evaluation of HVDC and HVAC transmission systems. *2007 IEEE Power Engineering Society General Meeting*. https://doi.org/10.1109/pes.2007.385993

Shah, M., & Somkun, S. (2017). Efficiency evaluation of three phase and single Phase C2C Self-Excited INDUCTION generator for micro hydro power application. *Energy Procedia, 138,* 193–198. https://doi.org/10.1016/j.egypro.2017.10.149

Wu ,M., Dahal,S., Weng, Y., (2019). "Comparative Study of HVAC and HVDCTransmission System with Proposed Machine Learning Algorith for Fault LocationDetection", Arizona State University.

Yergude, A, Kasulkar, P.,Dhoke,P., Pimpalkar,S. (2020), "Single Phase Invester using MOSFET. *International Research Journal of Engineering and Technology (IRJET)*

STATISTICAL MODELS FOR LONG TERM TRAFFIC IN ENTERPRISE NETWORKS

Atugoda A.W.C. K.[1] and Premarathna M.A.U.K.[2]

[1]Division of Elec trical,Electronics & Telecommunication Engineering technology, University of Moratuwa, Sri Lanka
[2] Department of Electronics & Telecommunications Engineering, University of Moratuwa, Sri Lanka
atugodac@itum.mrt.ac.lk[1] , upeka.academic@gmail.com[2]

ABSTRACT: This paper presents three types of statistical models as Pareto distribution, Beta-Prime distribution and Exponential distribution for predicting traffic in Enterprise Networks. Traffic peaks are caused by a large amount of data being requested such as in a download. With the rapid development of the internet more networks are being combined together. This expanded development has resulted in huge internet traffic loads and network congestion. For solving this key issue, it is important to predict traffic peaks in a network. For predicting traffic peaks in Enterprise Networks, the distributing fitting method is used to derive statistical models. The analysis is conducted by looking at the predictability of a peak in terms of level crossing of a preset level. The results demonstrate that the Pareto distribution provides a lesser average error when compared to the actual behavior of the network. It shows the best statistical model for predicting traffic peaks in a network. After predicting the traffic peak then non-critical traffic from another network can be scheduled to avoid the peak to reduce congestion and maximize bandwidth utilization.

Keywords: Traffic Peak, Level Crossing, Statistical Models

1. INTRODUCTION

Internet traffic has been constantly increasing with complete developments in communication networks and applications. This expanded development of communication methods has not only increased the demand for internet access, but also brought heavier network traffic loads. As revealed in (A Dainotti, 2012), most IP traffic will be doubled with more integrating devices to networks in the next few years. So different techniques also have been derived as a solution for network management in order to improve the quality of a network. This will enhance the accuracy and efficiency of the network (Akaike, 1974), (A W Moore, 2005).

The question is how to avoid packet losses and maximize utilization of the bandwidth. An efficient method to address the network traffic issue is to monitor the network performance based on a long term network traffic analysis for non-identical data collected from different fields. This would facilitate the identification of network traffic patterns so that an effective and fair solution could be proposed for avoiding traffic in the network. If it can predict trends in the traffic early, then resources can be scheduled to reduce or avoid the occurrence of congestion and improve the utilization of network resources. However, establishing the corresponding prediction model is the key to network traffic prediction. This mechanism can be applied directly for industrial automation networks and enterprise networks. The aim of this study is to investigate network traffic peaks in enterprise networks in order to schedule non critical traffic from an Industrial Automation Network to avoid peaks in order to reduce congestion and maximize the utilization of the bandwidth.

2. METHODOLOGY

Data sets were collected for analysis, summarized as shown in table 1. Single Machine, Downlink and Uplink data are classified as Individual data collection. This data was collected from a Wireshark installed in a single computer. Then the Wireshark application was used to filter the Downlink and Uplink data. Institutional data was collected through the backbone link of the Institutional Network

which was captured using the RRD tool. Seventy-three institutes were considered when collecting the required data for analysis. The data was collected in different time scales such as within 1 second, within 6 seconds, within 24 seconds and within 288 seconds.

Table 1. Summary of data for desired analysis

Source	No. of Samples	Duration of traffic slot	No. of Packets
i) Single Machine	100	1hr	6.2M pkts
ii) Downlink	100	1hr	2.1M pkts
iii) Uplink	100	1hr	1.5M pkts
iv) Institutes	73	1second	85.5G pkts
	73	6seconds	125.7G pkts
	73	24seconds	167.1G pkts
	73	288seconds	244.4G pkts

2.1 Developing variables

The Chi-Square Test for independence which compares two variables is used to test for independence of No. of packets (X) and difference of consecutive packets (Y).

Chi-Square equation for expected value (E_{ij}) and calculated value (x^2):

$$E_{i,j} = \frac{\sum_{k-1}^{c} O_{i.j} \sum_{k-1}^{r} O_{k,j}}{N} \quad \text{——————} \quad 1$$

$$x^2 = \sum_{i-1}^{r} \sum_{j-1}^{c} \frac{\left(O_{i,j} - E_{i,j}\right)^2}{E_{i,j}} \quad \text{——————} \quad 2$$

According to the given data, the expected value is 16.332 and the calculated chi square value is 10.085. Table Chi-Square value is taken considering a 95% level of confidence. It is 32.671. So;

Calculated value < tabulated value.

This means rejection of the alternative hypothesis and the expectation of the null hypothesis. This indicates that the two variables are independent.

5.2 Joint Probability Density Function

If two continuous random variables are independent, Joint Probability Density Function is shown by

$$f_{X,Y(x,y)} = f_X(x).f_Y(y) \quad \text{——————} \quad 3$$

The relationship between two different functions in JPDF is used for Rice's Formula.

Rice's Formula (H T Yura, 2010), (Rainal, 1988) represents the average number of times of stochastic stationary process X(t) per unit time($t \in [0,1]$) that crosses a fixed level u. Then Rice's formula is given by

$$v_{(u)} = \int_{-\infty}^{\infty} |\dot{x}|\, P_{x,\dot{x}}\,(u,\dot{x}) d\dot{x} \quad \text{——————} \quad 4$$

Variable (X) represents three different distribution models as Pareto Distribution, Beta-Prime Distribution and Exponential Distribution while variable (Y) represents Normal Distribution. Table 2 shows the estimated parameters for these distribution functions.

Table 2: Estimated parameters for distribution function

Distribution Model	**Parameter1**	**Parameter2**	**Parameter3**	**PDF**
Pareto $P_1(x)$	α(shape) = 0.12546 $\alpha > 0$	β(scale)=0.000298 $\beta > 0$	-	$P_1(x) = \frac{\alpha\beta^{\alpha}}{x^{\alpha+1}}$
Beta-Prime $P_2(x)$	α_1(shape) =0.57249 $\alpha_1 > 0$	α_2(shape)=0.13395 $\alpha_2 > 0$	B (beta function)	$P_2(x) = \frac{x^{\alpha_1-1}(1+x)^{-\alpha_1-\alpha_2}}{B(\alpha_1,\alpha_2)}$
Exponential $P_3(x)$	$\lambda\,(scale)$=1434.6 $\lambda > 0$	-	-	$P_3(x) = \lambda e^{-\lambda x}$
Normal $P_4(y)$	μ(location) = 0.00019381	σ^2(scale) =0.00062371	-	$P_4(y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(y-\mu)^2/2\sigma^2}$

3. RESULTS AND DISCUSSION

Results were taken for three statistical models and the average error was calculated for each time slot.

$$Average\ Error\ Percentage = \frac{|(Predicted\ Value - Actual\ Value)|}{Predicted\ Value} \times 100$$

The predicted value was taken from the Joint Probability Density Function. Two constraints were derived for counting the number of up crossings and the down crossings.

Constraint 1: $if\ x(t_1) < L\ \ and\ x(t_1 + 1) \geq L \ldots\ldots\ldots\ldots ndc = ndc + 1$

Constraint 2: $if\ x(t_1) > L\ \ and\ x(t_1 + 1) \leq L\ \ \ldots\ldots\ldots\ldots nuc = nuc + 1$

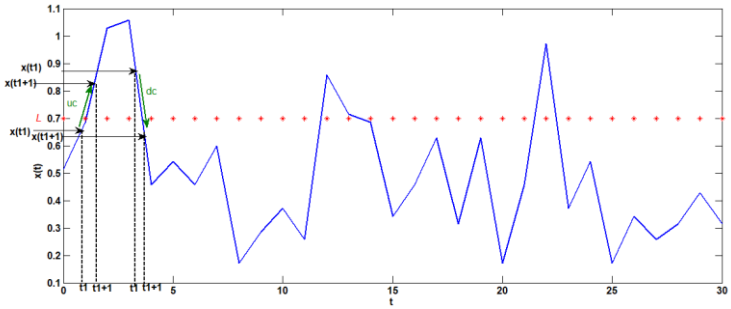


Figure 1: Counting actual number of level crossings.

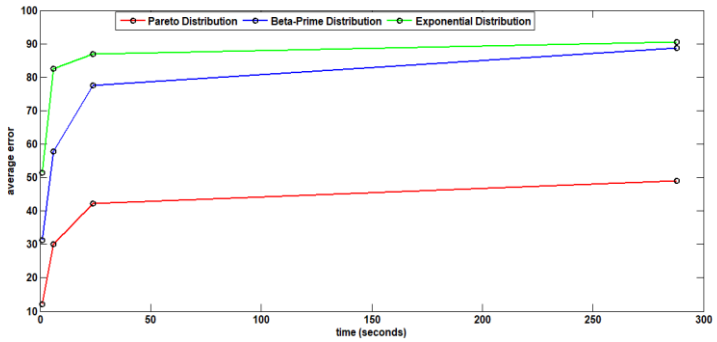


Figure 2: Average Error

4. CONCLUSION

Three types of statistical models were used to predict the traffic in Enterprise Networks. Prediction of traffic in networks is important to utilize the bandwidth efficiently. According to the results, Pareto Distribution shows the best result for analyzing traffic distribution compared to the other two distributions; the Beta-Prime Distribution and the Exponential Distribution. The Pareto Distribution was the best distribution which presented a 29.6% average error. Average errors of 82.6% and 95.1% is presented by the Beta-Prime Distribution and the Exponential Distribution, respectively. Future works of this study can be extended to observe the accuracy of these statistical models for predicting traffic peaks in high speed networks like the fiber link.

5. ACKNOWLEDGEMENTS

We acknowledge with thanks the Lanka Education and Research Network (LEARN) for providing essential data for the research.

6. REFERENCES

Akaike, H. (1974). A new look at the statistical model identification. *IEEE Transactions on Automatic Control*, *19*(6), 716–723. https://doi.org/10.1109/tac.1974.1100705

Dainotti, A., Pescape, A., & Claffy, K. (2012). Issues and future directions in traffic classification. *IEEE Network*, *26*(1), 35–40. https://doi.org/10.1109/mnet.2012.6135854

Moore, A. W., & Zuev, D. (2005). Internet traffic classification using bayesian analysis techniques. *Proceedings of the 2005 ACM SIGMETRICS International Conference on Measurement and Modeling of Computer Systems - SIGMETRICS '05*. https://doi.org/10.1145/1064212.1064220

Rainal, A. J. (1988). Origin of rice's formula. *IEEE Transactions on Information Theory*, *34*(6), 1383–1387. https://doi.org/10.1109/18.21276

Yura, H,T,.Hanson, S. G. (2010). Mean level signal crossing rate for an arbitrary stochastic process. *Optics image science and vision*, 27, 797-804.

CHARACTERISTIC EVALUATION OF PID CONTROL USING A DC MOTOR AS A DEMONSTRATION DEVICE

Gamage M.D.G.M.[1], Arumathanthri R.B.[2] and Gunasekara J.M.P.[3]

[1,2,3]Institute of Technology, University of Moratuwa, Sri Lanka
gayanig@itum.mrt.ac.lk, rancimalb@itum.mrt.ac.lk, maling@itum.mrt.ac.lk*

ABSTRACT: Direct current (DC) motors play an important role in industries when converting electrical energy to mechanical energy. The speed of a DC motor is important in the process control industries so the speed of a DC motor has to be controlled. For the speed control of a DC motor, proportional-integral-derivative (PID) controllers are often used. For better performance and optimum parameters, PID tuning is done using different techniques. This paper presents the development and characteristic evaluation of the speed control of a DC motor using a PID controller. The PID controller is developed using the Arduino platform and different tuning characteristics are modeled for better understanding. Moreover, the system is designed to be used as a demonstration device to demonstrate PID tuning methods and characteristics of a PID controller.

Keywords: DC Motor Speed Control, PID Control, PID Tuning

1. INTRODUCTION

Direct current (DC) motors are popular in many industrial equipment and domestic applications due to its wide range of speed control capabilities (S. D. Sahputro et al, 2017). At present, control and automation plays a vital role in industries and controllers like fuzzy logic controllers, neural network controllers, proportional integral (PI), proportional derivative (PD), and proportional integral derivative (PID) controllers can be used for controlling the speed of DC motors (J. Jing et al, 2016). A proportional–integral–derivative controller (PID controller) is a closed loop control mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. In the literature, different techniques and optimization algorithms are used to tune the PID parameters. (Xinghong Qiao et al, 2016), Genetic algorithm (GA) is used for tuning the PID controller in the wastewater treatment process. (Y. Liu et al, 2016), Differential evolution (DE) is used in control of super-heated steam temperature. Furthermore, Particle Swarm Optimization is used to tune the PID parameters for DC motor speed control and (K. R. Das et al, 2015) grey wolf optimizer (GWO) is used for tuning PID parameters to control the speed of a DC motor.

All the optimization algorithms mentioned above require algorithm-specific parameters and these parameters are application dependent. Some researchers have researched modeling, control, simulation (A. Ma'Arif et al, 2020). However, research is not just about simulation, but hardware implementation. Simulation outputs may vary with hardware implementations (V. Yadav et al, 2018) (S. Balamurugan et al, 2020). Thus, a simple trial and error tuning of PID parameters were used by the authors to tune the PID controller of the system and the characteristics of the tuned PID controller were evaluated by controlling the DC motor speed over an increasing and decreasing function of RPM and observing its output.

The rest of the paper comprises the following: Section II presents the methodology of the research. Section III presents the experiments and results while the conclusion and future work is presented under Section IV.

2. METHODOLOGY

The Anti-windup formulation concept of a PID is used in Arduino code to calculate PID gains. Timer interrupts are used to calculate the error. The PID takes in error, e(t) which is the difference between the desired output and real-time output, and processes it according to the equation (1). The Trapezoidal rule is used calculate error values.

$$u(t) = K_p e(t) + K_i \int_{t_1}^{t_2} e(t)dt + K_d \frac{de(t)}{dt}$$

A 10-1000 RPM High Torque Speed Reduction 12V DC Motor is used here. The rated speed of the motor is (RPM): 1000, 500, 200, 130, 100, 60, 50, 40, 30, 20, 15, 10. 60RPM is used as the set point. DC motor position and speed is tracked by encoder and it is controlled according to pre-defined trajectory. The L298N Motor Driver is used as the motor driver which uses an H-Bridge to easily control the direction and speed of the DC motor. "EN" (Speed Control Pins) pins are used to change the motor speed using the PWM (Pulse Width Modulation). The "EN-A" pin controls the speed of the left motor and the "EN-B" pin controls the speed of the right motor. The DC motor is plugged into the terminals labeled "OUT3" and "OUT4". The Direction of the motor is controlled using "IN3" pin and the "IN4" pin of the motor driver.

Arduino is programmed to calculate angular speed and position, to calculate error, to minimize error and to write proper voltage to the DC motor. Figure 1 shows the wiring diagram of the system.

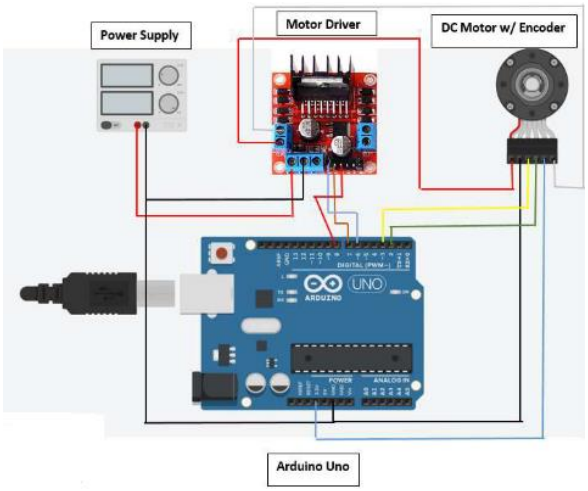


Figure 1 – Wiring diagram

3. EXPERIMENTS AND RESULTS

An experimental setup consisting of a DC motor with the encoder driven by an L298 Motor controller Arduino UNO and a DC power supply was used. The Arduino UNO is used to run the control algorithm and 12V DC power supply was used to power the system. A personal computer was used to obtain the results using the Arduino IDE. Figure 2 shows the experimental setup and a snapshot of the experiment.

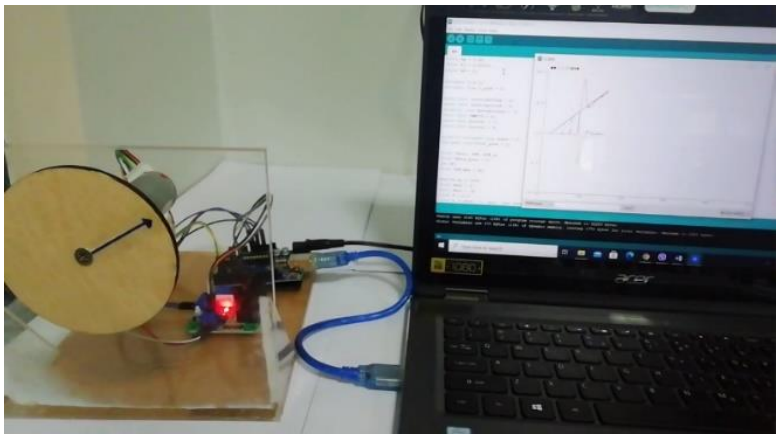


Figure 2 - Experimental setup

a. Experimental tuning of PID controller for DC motor

There are several methods for tuning a PID loop. The most effective methods generally involve the development of some form of a process model and then choosing Kp, Ki, and Kd, based on the dynamic model parameters. Manual tuning methods can be relatively time-consuming. However, the idea of this device is to use it as a demonstration device. A trial and error technique was used to tune the PID and the output RPM of the motor was observed with respect to the set RPM value. Results are shown in Figure 3 and Figure 4.

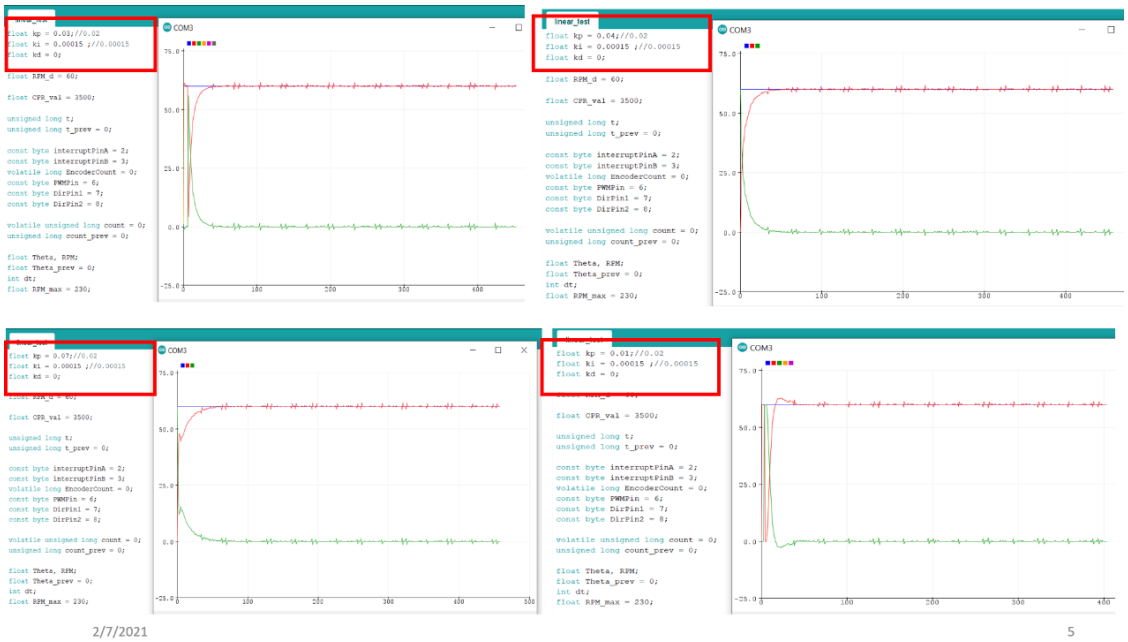


Figure 3 – Step Input and Motor RPM output curves

Figure 4 - Step Input and Motor RPM output curves

b. Controlling motor speed over an increasing and decreasing function of RPM.

To evaluate the performance of the controller after tuning the Kp, Ki and Kd values, the motor speed was controlled over an increasing and decreasing function of RPM and the output was observed. Results are shown in Figure 5.

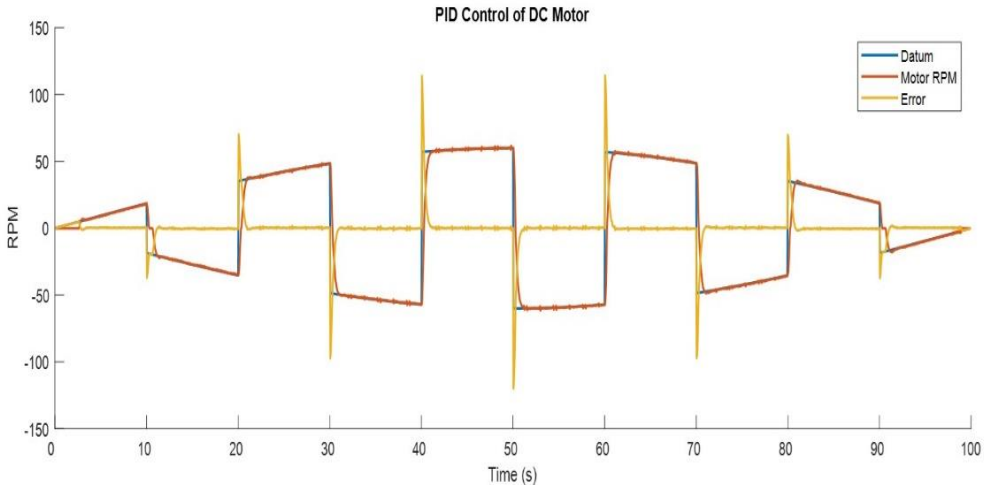


Figure 5 – RPM vs Time Curve of DC Motor

4. CONCLUSION AND FUTURE WORK

In this paper a real time application of a PID Controller was demonstrated and different results suggest that the PID algorithm behaves accordingly. The tuning of the PID controller was done using a trial and error method. The PID controller works well on SISO (single input- single output) systems, where a desired set point can be supplied to the system control input. This device can be used to demonstrate PID tuning methods and the characteristics of a PID controller.

As future work a MATLAB/SIMULINK simulation model for the same DC motor can be developed and a comparison of hardware implementation results and simulation results can be done.

Furthermore, a manual method to adjust the Kp, Ki and Kd values can be implemented and a user interface (UI) can be developed to ease demonstration purposes.

5. REFERENCES

Balamurugan, S. and Umarani, A. (2020). "*Study of Discrete PID Controller for DC Motor Speed Control Using MATLAB,*" in 2020 International Conference on Computing and Information Technology (ICCIT-1441), Sep. 2020, no. 1, pp. 1–6, doi: 10.1109/ICCIT-144147971.2020.9213780.

Das K. R., Das, D., and Das, J. (2015). "*Optimal tuning of PID controller using GWO algorithm for speed control in DC motor,*" in 2015 International Conference on Soft Computing Techniques and Implementations (ICSCTI), Oct. 2015, pp. 108–112, doi: 10.1109/ICSCTI.2015.7489575.

Iswanto, A. M., Raharja, N. M., Rosyady P. A., Baswara, A. R. C. and Nuryono, A. A. (2020). "*Control of DC Motor Using Proportional Integral Derivative (PID): Arduino Hardware Implementation,*" Proceeding - 2020 2nd Int. Conf. Ind. Electr. Electron. ICIEE 2020, pp. 74–78, 2020, doi: 10.1109/ICIEE49813.2020.9277258.

Jing, J., Wang, Y., and Huang, Y. (2016). "*The fuzzy-PID control of brushless DC motor,*" in 2016 IEEE International Conference on Mechatronics and Automation, Aug. 2016, no. 2, pp. 1440–1444, doi: 10.1109/ICMA.2016.7558775.

Liu, Y., Zhou, C. and Xiang, W. (2016). "*DE Algorithm Fuzzy Control of Super-Heated Steam Temperature,*" Proc. - 2016 9th Int. Symp. Comput. Intell. Des. Isc. 2016, vol. 1, pp. 282–285, 2016, doi: 10.1109/ISCID.2016.1071.

Qiao, X., Luo, F. and Xu, Y. (2016). "*Robust PID controller design using genetic algorithm for wastewater treatment process,*" in 2016 IEEE Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC), Oct. 2016, pp. 1081–1086, doi: 10.1109/IMCEC.2016.7867378.

Sahputro, S. D., Fadilah, F., Wicaksono, N. A., and Yusivar, F. (2017)."*Design and implementation of adaptive PID controller for speed control of DC motor,*" in 2017 15th International Conference on Quality in Research (QiR) : International Symposium on Electrical and Computer Engineering, Jul. 2017, vol. 2017-Decem, no. 1, pp. 179–183, doi: 10.1109/QIR.2017.8168478.

Yadav, V. and Tayal, V. K. (2018). "*Optimal Controller Design for a DC Motor using PID Tuner,*" in 2018 International Conference on Power Energy, Environment and Intelligent Control (PEEIC), Apr. 2018, pp. 442–445, doi: 10.1109/PEEIC.2018.8665658.

NOTES

Contact Details

Research Unit,
Institute of Technology University of Moratuwa,
Diyagama,
Homagama,
Sri Lanka.

Tel: 011-212-4000
E-mail: researchunit@itum.mrt.ac.lk
Website: www.rs.itum.mrt.ac.lk

ISSN 2773-7055