An eco-friendly strategy for dairy wastewater remediation with high lipid microalgae-bacterial biomass production

Tethi Biswas [a,b], Shashi Bhushan [c,d,1], Sanjeev Kumar Prajapati [e], Shaon Ray Chaudhuri [a,*]

[a] Department of Microbiology, Tripura University, Suryamaninagar, Tripura West, 799022, India
[b] Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata, Nadia, West Bengal, 741249, India
[c] Department of Chemical and Biochemical Engineering, Indian Institute of Technology Patna, Bihta, Patna, Bihar, 801106, India
[d] Agricultural and Biosystem Engineering, North Dakota State University, Fargo, ND, 58108-6050, USA
[e] Environment and Biofuel Research Lab (EBRL), Department of Hydro and Renewable Energy, Indian Institute of Technology (IIT) Roorkee, Roorkee, Uttarakhand, 247667, India

ARTICLE INFO

ABSTRACT

The present study attempts to integrate phyco-remediation and enhanced lipid productivity using microalgae-bacterial consortium enriched from wastewater fed aquaculture pond. Metagenomic analyses and microscopic images of the consortium revealed the presence of Chlorella variabilis, Parachlorella kessleri, Thermosynechococcus elongatus, Chlamydomonas, Phaeodactylum tricornutum, Oscillatoriales, Synechocystis sp., Microcystis aeruginosa, Nostocales, Nostocales, Stramenopiles, other members of Chlorophyceae, Trebouxiophyceae, and Chroococcales along with potential bacterial bioremediators. During a 30 days trial run (15 days stabilization and 14 days remediation studies) for phyco remediation drastic reduction in the nutrient and COD content from the tested wastewater samples was seen. There was up to 93% and 87.2% reduction in chemical oxygen demand (COD) and ammonium concentration, respectively. Further, almost 100% removal of nitrates and phosphates from the dairy wastewater upon 48 h of treatment with polyculture under ambient temperature (25 ± 2 °C) with 6309 lux illumination and mild aeration, was observed for all the seven cycles. Interestingly, the nutrient and COD concentrations in the treated water were below the discharge standards as per Central Pollution Control Board (CPCB) norms. In addition, biomass (reported as dry cell weight) was enhanced by 67% upon treatment with ammonia-rich dairy wastewater exhibiting 42% lipid, 55% carbohydrate, and 18.6% protein content enhancement. The polyculture mainly grown as attached biofilm to the surface, offered an easy harvesting and separation of grown biomass from the treated wastewater. Overall, dairy wastewater was found to be a potential nutrient source for microalgae bacteria cultivation thereby making the treatment process sustainable and eco-friendly.

1. Introduction

Indiscriminate use of water in industrial and agricultural sectors has affected the water quality, rapidly leading to fresh water scarcity. In order to achieve the target of industrial development, the environmental management aspect was largely ignored earlier. The wastewaters contain excess organic and inorganic nutrients, including heavy metals and other toxic pollutants resulting from domestic, agricultural, and industrial activities that have found their way into the aquatic ecosystem (Mouchet, 1986; Lim et al., 2010; Kumar and Singh, 2017). The dairy industry is one of the primary pollution sources due to the copious volume of wastewater generation and its high nutrient content. In India, dairy industries produce 58.6 m³ of milk annually, utilizing 8.7 m³ of water per m³ of milk produced, resulting in 6 m³ of wastewater per m³ of processed milk (Brar et al., 2019). Though there are several strategies to treat nutrient rich wastewater (Kushwaha et al., 2010; Slavov, 2017), conventional treatment methods require a relatively large amount of space owing to their multiple treatment steps (7-8 steps), extended time (105-120 h), energy consumption (70 kW for 500 m³ wastewater per day) (Biswas et al., 2019) with bulky sludge production. Although the sludge generation represents 1-2%

of the wastewater volume, sludge management accounts for 20-60% of total wastewater treatment operating costs (Perimal et al., 2017). The work of Halder et al. (2020) has resulted in the conversion of the total volume of dairy wastewater into ammonia rich liquid biofertilizer through a microbial approach, within 16 h, without sludge generation. However, it is unsuitable for urban dairies as they would not utilize the enormous volume of generated liquid biofertilizer due to the limitation of surrounding farmlands. The disposal of excess liquid biofertilizer would damage the aquatic environment severely.

With the advances in biotechnology, phycoremediation has become an effective approach to decontaminate the environment and ensure resource restoration (Hammouda et al., 1995; Hoffmann, 1998; Olguin, 2003; Marchello et al., 2015). A paradigm shift in the last few years has led to the consideration of wastewater as a precious resource rather than mere waste. The wastewater contains energy rich organics, nutrients such as nitrogen (N) and phosphorus (P), and other micro and macronutrients required for microalgal growth. Algal proliferation in wastewater fed ponds contributes to dissolved oxygen production with nutrient assimilation and treatment. Besides the wastewater characteristics, microalgal productivities are strongly influenced by microalgal strains used for the cultivation. Typical algal species that grow in

* Corresponding author. Tripura University, Suryamaninagar, Tripura West, 799022, India.
E-mail address: shaonraychaudhuri@tripurauniv.in (S. Ray Chaudhuri)

Contents lists available at ScienceDirect

Journal of Cleaner Production

A novel strategy for microbial conversion of dairy wastewater into biofertilizer

Mandakini Gogoi [a], Tethi Biswas [a, b], Prasandeep Biswal [a], Tuhin Saha [a], Ajoy Modak [a],
Lalit Mohan Gantayet [c], Rajib Nath [d], Indranil Mukherjee [b], Ashoke Ranjan Thakur [e],
Mathumal Sudarshan [f], Shaon Ray Chaudhuri [a, *]

[a] Department of Microbiology, Tripura University, Suryamaninagar, Tripura, 799022, Tripura West, India
[b] Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata, Nadia, West Bengal, 741249, India
[c] Formerly Beam Technology Development Group, Bhabha Atomic Research Centre and Homi Bhabha National Institute, 4A, Divya jyoti, Plot 51, Sector-29, Vashi, Navi Mumbai, 400703, India
[d] Department of Agronomy, Bidhan Chandra Krishi Viswa Vidyalaya, Mohanpur, Nadia, 741252, India
[e] Formerly Department of Biophysics, Molecular Biology and Genetics, University of Calcutta, 92 APC Road, Kolkata, West Bengal, 700009, India
[f] Formerly Trace Element Laboratory, Inter University Consortium, Kolkata, Kolkata Centre, Sector III (Plot LB 8, Salt Lake, Kolkata, 700098, West Bengal, India

ABSTRACT

Dairy industry generates copious amount of wastewater from its milk processing unit ($1-10$ m^3 of wastewater per m^3 of processed milk) which needs to be treated before getting discharged. The conventional treatment processes are tedious, energy intensive, and an additional burden for the dairy industry. This study attempts to develop an alternative strategy to convert the dairy wastewater into liquid biofertilizer. A tailor made microbial consortium-based biofilm reactor with 8.64 m^3 d^{-1} processing capacity, within 16 h of hydraulic retention time (HRT) at ambient temperature produced biofertilizer containing 96.01 mg L^{-1} ammonia from dairy wastewater at a flow rate of 360 L h^{-1} with associated 73.72% nitrate, 72.46% phosphate, 61.30% Biological Oxygen Demand (BOD) and 57.23% Chemical Oxygen Demand (COD) reduction. A similar system of 10.94 m^3 d^{-1} processing capacity at 456 L h^{-1} flow rate produced 298.79 mg L^{-1} ammonia with nitrate, phosphate, BOD and COD reduction of 42.71%, 84.80%, 89.55% and 76.68% respectively. This liquid biofertilizer could enhance grain yield in maize (Zea mays var. Vijay) by 1.19-fold. It increased biomass yield in Sorghum Sudan grass (Sorghum sudanense) by 3.5-folds and Lemongrass (Cymbopogon citratus var. Dhaniri and var. Krishna) by 2.1 and 2.64 folds respectively. It enhanced gel content in Aloe vera (Aloe elongata var. Chikuan) by 163-folds when compared to chemical fertilizer treatment. This single-step dairy wastewater treatment system requires ten times less energy with the development of a value-added product (biofertilizer). It could make the dairy wastewater management a revenue earning (USD 10.28 d^{-1} for 600 m^3 d^{-1} processing capacity reactor), eco-friendly, zero discharge process preventing the use of freshwater and chemical fertilizer in agriculture, and saving 89.99% carbon dioxide equivalent (CO$_2$ eq.) gas emission leading to environmental protection.

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1. Introduction

India, with the largest livestock population of the world, is among the significant producers of milk (FAO, 2020) and dairy products and is known for "Operation Flood"/"White Revolution" initiated in 1970. Dairy industry generates $1-10$ m^3 of wastewater per m^3 of processed milk (Britz et al., 2006) and the volume of milk processing is expected to increase (Bogusiewicz-Zablocka et al., 2019) to satisfy the growing demand for dairy products (Egas et al., 2019). It uses large volumes of freshwater for downstream processing. The dairy wastewater comes from equipment washing (with detergents, alkali, and nitric acid), spilled milk and its products as well as the runoff from yard area contaminated with unne

* Corresponding author. Department of Microbiology, Tripura University, Suryamaninagar, Tripura West 799022, India.
E-mail address: shaonraychaudhuri@tripurauniv.in (S. Ray Chaudhuri).

3

An eco-friendly strategy for dairy wastewater remediation with high lipid microalgae-bacterial biomass production

Tethi Biswas [a, b], Shashi Bhushan [c, d, 1], Sanjeev Kumar Prajapati [e], Shaon Ray Chaudhuri [a] ☒

[a] Department of Microbiology, Tripura University, Suryamaninagar, Tripura West, 799022, India

[b] Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata, Nadia, West Bengal, 741249, India

[c] Department of Chemical and Biochemical Engineering, Indian Institute of Technology Patna, Bihta, Patna, Bihar, 801106, India

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[e] Environment and Biofuel Research Lab (EBRL), Department of Hydro and Renewable Energy, Indian Institute of Technology (IIT) Roorkee, Roorkee, Uttarakhand, 247667, India

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

4

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Minimal medium optimization for soluble sulfate removal by tailor-made sulfate reducing bacterial consortium

Chaitali Chanda[a], Mandakini Gogoi[b], Indranil Mukherjee[a,c], and Shaon Ray Chaudhuri[b]

[a] Centre of Excellence in Environmental Technology and Management. Maulana Abul Kalam Azad University of Technology, Haringhata, India [b] Department of Microbiology, Tripura University, Agartala, India [c] Department of Management Sciences, Maulana Abul Kalam Azad University of Technology, (Formerly known as West Bengal University of Technology), Haringhata, India

ABSTRACT

Modified medium DSMZ 641 used for the growth of SRB consortium developed in the laboratory through enrichment of soil slurry from wastewater fed aquaculture pond at Kolkata India, contained various components that added to the Chemical Oxygen Demand of the solution, making large scale operations using this consortium non-viable. The minimal medium optimization study was carried out using a "one at a time" approach analyzing sulfate reducing ability of the consortium. The consortium reduced soluble sulfate concentration by 70 and 78% (starting from an initial concentration of 2000–3000 mg/L) under suspended and immobilized states, respectively, in 50 mL working volume. The process upon scaling up to 9 L in a vertical biofilm reactor under batch mode could reduce sulfate from the optimized medium by 76% in 4 h, while the same in modified DSMZ 641 was 74%. Response Surface Methodology revealed the optimum concentration of Carbon (Lactic Acid), Nitrogen (Yeast Extract, Ammonium Chloride), and Phosphorus (Potassium Phosphate) in the medium to be 6 mL/L, 500 mg/L each and 750 mg/L respectively.

CONTACT Shaon Ray Chaudhuri shaonraychaudhuri@tripurauniv.in ○ Department of Microbiology Tripura University, Agartala 799022, India.

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

Optimization of bio-chemical degumming of Ramie fiber for improved strength & luster

Shaon Ray Chaudhuri[a,*], Mandakini Gogoi[d], Tethi Biswas[a,b], Soumya Chatterjee[c], Chaitali Chanda[b], Ronald Jamatia[a], Ajoy Modak[a], Sunil K. Sett[d], Indranil Mukherjee[b,c]

[a] Department of Microbiology, Tripura University, Suryamaninagar, West Tripura, 799022, India
[b] Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad University of Technology, (Formerly known as West Bengal University of Technology), Haringhata, Nadia, West Bengal, 741249, India
[c] Department of Management Sciences, Maulana Abul Kalam Azad University of Technology, (Formerly known as West Bengal University of Technology), Haringhata, Nadia, West Bengal, 741249, India
[d] Department of Jute and Fibre Technology, Calcutta University, 35 Ballygunge Circular Road, Kolkata, 700019, West Bengal, India

ARTICLE INFO

ABSTRACT

Textile industries are currently not showing much interest in Ramie fibers due to the difficulties associated with their post harvest downstream processing. The degumming chemicals are often detrimental to the environment upon discharged. Chemical degumming alone results in fibril released coarse and brittle fibers. This problem has been addressed by combining partial chemical treatment with microbial degumming of the fibers for 72 h at 37 °C using a novel microbial formulation with *Bacillus thuringiensis* MCC2138 and *Bacillus subtilis* ABDR01. The extracellular microbial enzyme-based

A novel strategy for microbial conversion of dairy wastewater into biofertilizer

Mandakini Gogoi [a], Tethi Biswas [a, b], Prasandeep Biswal [a], Tuhin Saha [a], Ajoy Modak [d], Lalit Mohan Gantayet [c], Rajib Nath [d], Indranil Mukherjee [b], Ashoke Ranjan Thakur [e], Mathumal Sudarshan [f], Shaon Ray Chaudhuri [a, *]

[a] Department of Microbiology, Tripura University, Suryamaninagar, Tripura, 799022, Tripura West, India
[b] Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad University of Technology, West Bengal, Haringhata, Nadia, West Bengal, 741249, India
[c] Formerly Beam Technology Development Group, Bhabha Atomic Research Centre and Homi Bhabha National Institute, 4A, Divyajyoti, Plot. 51, Sector. 29, Vashi, Navi Mumbai, 400703, India
[d] Department of Agronomy, Bidhan Chandra Krishi Viswa Vidyalaya, Mohanpur, Nadia, 741252, India
[e] Formerly Department of Biophysics, Molecular Biology and Genetics, University of Calcutta, 92 A.P.C. Road, Kolkata, West Bengal, 700009, India
[f] Formerly Trace Element Laboratory, Inter University Consortium, Kolkata, Kolkata Centre, Sector III/Plot LB-8, Salt Lake, Kolkata, 700098, West Bengal, India

ARTICLE INFO

ABSTRACT

Dairy industry generates copious amount of wastewater from its milk processing unit ($1-10$ m^3 of wastewater per m^3 of processed milk) which needs to be treated before getting discharged. The conventional treatment processes are tedious, energy intensive, and an additional burden for the dairy industry. This study attempts to develop an alternative strategy to convert the dairy wastewater into liquid biofertilizer. A tailor made microbial consortium-based biofilm reactor with 8.64 m^3 d^{-1} processing capacity, within 16 h of hydraulic retention time (HRT) at ambient temperature produced biofertilizer containing 96.01 mg L^{-1} ammonia from dairy wastewater at a flow rate of 360 L h^{-1} with associated 73.72% nitrate, 72.46% phosphate, 61.30% Biological Oxygen Demand (BOD) and 57.23% Chemical Oxygen Demand (COD) reduction. A similar system of 10.94 m^3 d^{-1} processing capacity at 456 L h^{-1} flow rate produced 298.79 mg L^{-1} ammonia with nitrate, phosphate, BOD and COD reduction of 42.71%, 54.80%, 89.55% and 76.68% respectively. This liquid biofertilizer could enhance grain yield in maize (Zea mays var. Vijay) by 1.19-fold. It increased biomass yield in Sorghum Sudan grass (Sorghum sudanense) by 3.5-folds and lemongrass (Cymbopogon citratus var. Dhaniri and var. Krishna) by 2.1 and 2.64 folds respectively. It enhanced gel content in Aloe vera (Aloe elongata var. Ghikuari) by 1.63 folds when compared to chemical fertilizer treatment. This single-step dairy wastewater treatment system requires ten times less energy with the development of a value-added product (biofertilizer). It could make the dairy wastewater management a revenue earning (USD 10.28 d^{-1} for 600 m^3 d^{-1} processing capacity reactor), eco-friendly, zero discharge process preventing the use of freshwater and chemical fertilizer in agriculture, and saving 89.99% carbon dioxide equivalent (CO_2 eq.) gas emission leading to environmental protection.

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1. Introduction

India, with the largest livestock population of the world, is among the significant producers of milk (FAO, 2020) and dairy products and is known for "Operation Flood"/"White Revolution" initiated in 1970. Dairy industry generates $1-10$ m^3 of wastewater per m^3 of processed milk (Britz et al., 2006) and the volume of milk processing is expected to increase (Bogucniewicz-Zablocka et al., 2019) to satisfy the growing demand for dairy products (Egas et al., 2019). It uses large volumes of freshwater for downstream processing. The dairy wastewater comes from equipment washing (with detergents, alkali, and nitric acid), spilled milk and its products as well as the runoff from yard area contaminated with urine

* Corresponding author. Department of Microbiology, Tripura University, Suryamaninagar, Tripura West 799022, India.
E-mail address: shaonraychaudhuri@tripurauniv.in (S. Ray Chaudhuri).

ASCE

Microbial Consortium–Based Conversion of Dairy Effluent into Biofertilizer

Nabanita Halder[1]; Mandakini Gogoi[2]; Jaweria Sharmin[3]; Manjila Gupta[4]; Srimoyee Banerjee[5]; Tethi Biswas[6]; Basant Kumar Agarwala[7]; Lalit Mohan Gantayet[8]; Mathummal Sudarshan[9]; Indranil Mukherjee[10]; Arindam Roy[11]; and Shaon Ray Chaudhuri[12]

Abstract: Dairy wastewater (DWW) is nutritionally rich and extremely hazardous to the environment if discharged untreated. The conventional treatment is time-, labor-, and energy-intensive. A tailor-made microbial consortium converted DWW into a biofertilizer with the ability to enhance biomass and yield in mung bean (*Vigna radiata* var. MEHA). The consortium produced ammonia from DWW at a rate of 1.65×10^{-6} mol s^{-1} 100 mL^{-1} within 16 h of incubation in a biofilm bioreactor at 37°C with highest production of 10.11 mg 100 mL^{-1} demonstrating 41.83% nitrate and 45.83% phosphate removal. The scalability was tested at ambient temperature in a 72-L bioreactor with an ammonia production rate of 3×10^{-8} mol s^{-1} 100 mL^{-1}. Irrigation using the treated effluent resulted in a 1.7-fold increase in biomass, 49-fold decrease in root nodulation, and 2.6-fold increase in seed yield in mung bean while providing protection from aphid (*Aphis craccivora* Koch) infestation. The total wastewater was converted into biofertilizer for use as a substitute for chemical fertilizer and fresh water for irrigation. This approach makes DWW management not only a zero-discharge process but also a self-sustainable one. **DOI: 10.1061/(ASCE)HZ.2153-5515.0000486.** © 2019 American Society of Civil Engineers.

Author keywords: Ammonia; Mung bean; Biofertilizer; Dairy wastewater; Eco-friendly.

Introduction

Wastewater is generated from different activities in huge quantities and often contains essential nutrients, such as nitrate and phosphate [agricultural runoff, domestic discharge, dairy wastewater (DWW), proteins (DWW), and sulfate (mining industry)], which are detrimental to the environment unless they are removed before discharge. On the other hand, freshwater reserves are rapidly getting drained with a major portion (above 80%) being used for nonpotable application (agriculture) (Hao et al. 2013). Freshwater scarcity is expected to hit 40% of the world's population by 2025 (Ray Chaudhuri 2019; United Nations, Department of Economic

and Social Affairs 2014). Hence, an alternative strategy would be to treat the wastewater and reuse it for the purpose of groundwater recharging as well as nonpotable applications such as agriculture and aquaculture (Busaidi and Ahmed 2017; Ray Chaudhuri et al. 2013, [Ray Chaudhuri et al., "Microbial consortium for nitrate and phosphate sequestration for environmental sustenance", Bangladesh Patent No. 1,005,753, 2014], 2014).

A combination of biological and physicochemical methods is used for conventional wastewater treatment. However, this is more time-consuming, which causes a bottleneck. Longer incubation needs larger treatment plants and hence more land involvement, making it revenue-intensive. Recently, researchers have been

[1]Research Scholar, Dept. of Microbiology, Tripura Univ., Suryamaninagar, West Tripura 799022, India; Dept. of Biotechnology, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[2]Research Scholar, Dept. of Microbiology, Tripura Univ., Suryamaninagar, West Tripura 799022, India.

[3]Student, Dept. of Biotechnology, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[4]Student, Dept. of Biotechnology, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[5]Research Scholar, Dept. of Microbiology, Tripura Univ., Suryamaninagar, West Tripura 799022, India; Dept. of Biotechnology, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[6]Research Scholar, Dept. of Microbiology, Tripura Univ., Suryamaninagar, West Tripura 799022, India; Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[7]Formerly, Professor, Dept. of Zoology, Tripura Univ., Suryamaninagar, West Tripura 799022, India.

[8]Formerly, Director, Beam Technology Development Group, Bhabha Atomic Research Centre, Homi Bhabha National Institute, 4A, Divyajyoti, Plot 51, Sector-29, Vashi, Navi Mumbai, Maharashtra 400703, India.

[9]Scientist F, Laboratory of Trace Elements, Inter Univ Consortium, Kolkata Centre, West Bengal, Kolkata 700098, India.

[10]Director, Centre of Excellence in Environmental Technology and Management, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India; Associate Professor, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India. ORCID: https://orcid.org/0000-0002-5342-6051

[11]Student, Dept. of Biotechnology, Maulana Abul Kalam Azad Univ. of Technology, Haringhata, Nadia, West Bengal 741249, India.

[12]Associate Professor, Dept. of Microbiology, Tripura Univ., Suryamaninagar, West Tripura 799022, India (corresponding author). Email: shaonraychaudhuri@tripurauniv.in; shaon.raychaudhuri@gmail.com

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J. Hazard. Toxic Radioact. Waste

J. Hazard. Toxic Radioact. Waste, 2020, 24(1): 04019039

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

To

Dr. Mrinal Kanti Bhowmik
Assistant Professor
Dept. of Computer Science & Engineering
Tripura University (A Central University)
Suryamaninagar – 799022, Tripura

Sub: Grants-in-Aid for research project titled "Development of object detection techniques from degraded complex video sequences due to dynamic variation of scenes by different atmospheric conditions for security & surveillance".

Approval of the competent authority DG (TM) is hereby conveyed for a grant of **Rs. 64.77 Lakh** (Rupees Sixty Four Lakh Seventy Seven Thousand only), to Tripura University (A Central University), Suryamaninagar for pursuing the research on the subject titled project by Dr. Mrinal Kanti Bhowmik, Assistant Professor, Dept. of Computer Science & Engineering, Tripura University (A Central University), Suryamaninagar – 799022, Tripura University as Principal Investigator and Prof. Anjan Kumar Ghosh and Prof. Barin Kumar De. (Tripura University) and Prof. Mita Nasipuri (Jadavpur University) as Co-Investigators.

2. The grant shall be spent as follows:-

The Budget of the project of Tripura University

Expenditure on ↓ (Rs in lakh) during →	Year 1	Year 2	6 Months	Line Total
a Staff : At Tripura University 02 - JRF @ Rs. 25000/- pm + HRA @ 10% for first two years and @ Rs. 28000/- pm + HRA @ 10% for last 6 Months 02 - Studentship @ Rs. 8000/- pm for two and 06 months	8.52	8.52	4.66	21.70
b) Equipment (including spares thereof)	15.36	-	-	15.36
c) Operation and maintenance	-	0.25	0.25	0.50
d) Expendables	-	0.15	0.15	0.30
e) Travel (Domestic)	1.00	1.00	0.50	2.50
f) Contingencies	0.80	0.35	0.20	1.36
g) Visiting faculty or Research Consultant	1.00	1.00	0.70	2.70
h) Procured services (other than (g)) and metered utilities	-	-	-	
i) Institutional Overheads Charge @ 10% of (a)	0.85	0.85	0.47	2.17
Column Totals	27.53	12.13	6.92	46.58

Grand total: Rs. 46.58 Lakh (Rupees Forty Six Lakh and Fifty Eight Thousand only)

The Budget of the project of Jadavpur University

Expenditure on ↓ (Rs in lakh) during →	Year 1	Year 2	6 Months	Line Total
a) Staff : At Jadavpur University 01 - JRF @ Rs. 25000/- pm + HRA @ 30% for first two years and @ Rs. 28000/- pm + HRA @ 30% for last 6 Months	3.90	3.90	2.18	9.98
b) Equipment (including spares thereof)	5.43	-	-	5.43
c) Operation and maintenance	-	-	-	
d) Expendables	-	-	-	
e) Travel (Domestic)	0.50	0.50	0.25	1.25
f) Contingencies	0.31	0.14	0.08	0.53
g) Visiting faculty or Research Consultant	-	-	-	
h) Procured services (other than (g)) and metered utilities	-	-	-	
i) Institutional Overheads Charge @ 10% of (a)	0.39	0.39	0.22	1.00
Column Totals	10.53	4.93	2.73	18.19

Grand total: Rs. 18.19 Lakh (Rupees Eighteen Lakh and Nineteen Thousand only)

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

325-326

Administrative
App. No. MED/2017/107

No. BT/PR25380/NER/95/1168/2017
GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
(NER-DPMC)

Block 2, 6-8th Floors
CGO Complex, Lodhi Road,
New Delhi- 110 003
Dated: 28 / 09 /2018

ORDER

Sanction of the President is hereby accorded, under Rule 18 of the Delegation of Financial Powers Rules ,1978 , for the implementation of the   project entitled: **"Development of polyherbal based functional biopolymer hydrogel for delivery of novel healing agents in excision and burn wound."** for a period of 3 Year 0 Month at a total cost of Rs. 7542600 (Rupees Seventy Five Lakhs Fourty Two Thousand Six Hundred Only) on the terms and conditions detailed here under:-

2 The Project :

    2.1 Title :   **"Development of polyherbal based functional biopolymer hydrogel for delivery of novel healing agents in excision and burn wound."**

    2.2 Details of the Investigatiors:

        Project Cordinator

        Prof. samir kumar sil
        Professor
        Human physiology
        Tripura University
        suryamaninagar, Agartala, Tripura, 799022

        Principal Investigators:

        Prof. Samir kumar sil
        Professor
        Human physiology
        Tripura University
        suryamaninagar, Agartala,Tripura,
        799022

        Prof. Parimal Karmakar
        Professor
        Life Science and Biotechnology
        Jadavpur University
        188 Raja SC Mullick Road,
        Kolkata:700 032, WB, India, ,West
        Bengal, 700032

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(Dr. Deepak Sharma)
Registrar
Tripura University

(74)

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GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
(NER-BPMC)

Block 2, (6-8th Floors)
CGO Complex, Lodhi Road,
New Delhi- 110 003
Date:'/ / /11/2021

RELEASE ORDER

In continuation of this Department's sanction order of even number dated 12th June, 2018 sanction of the President is hereby accorded, under Rule18 of the Delegation of Financial Powers Rule, 1978, for the release of Rs. **1012632/-** (Rupees Ten Lakhs Twelve Thousand Six Hundred and Thirty Two Only) being the second year release for the project entitled **"Neo-therapeutic strategy for Tuberculosis with the combination of conventional antibiotics and natural flavone compounds that inhibits biofilm."**, being implemented by

Dr. Surajit Bhattacharjee, Tripura University, Suryamaninagar, Tripura West, Agartala - 799022, Tripura

The detailed break-up is as given below:

SNo	Institute Name	Recurring						Total Release Amount (Rs)
		Manpower	Consumable	Travel	Contingency	Others	Overhead	
1	Tripura University	114400.00	699238.00	50000.00	48994.00	0.00	100000.00	1012632.00

2. The amount of Rs. **1012632/-** (Rupees Ten Lakhs Twelve Thousand Six Hundred and Thirty Two Only) will be directly credited by the Pay & Accounts Officer, DBT in the account as detailed below:

The Registrar, Tripura University, Suryamaninagar, Agartala - 799022, Tripura

    Bank Name   : State Bank Of India
    Branch Name : Tripura University campus
    A/c No.   : 30371209938
    IFSC Code   : SBIN0010495
    MICR Code : 799002524

3. The expenditure involved is debitable to:

Demand No. 89	Department of Biotechnology
3425	Other Scientific Research 2021-2022
3425.60	Others (Sub Major Head)
3425.60.200	Assistance to other Scientific Bodies (Minor Head)
3425.60.200.29	Biotechnology Research and Development
3425.60.200.29.17	Assistance to Research and Development
3425.60.200.29.17.31	Grants -in-Aid General

4. The Registrar, Tripura University, Agartala, Tripura will submit audited utilization certificates and statements of expenditure in respect of the above-mentioned amount.

डॉ. वैशाली पंजाबी/Dr. VAISHALI PANJABI
वैज्ञानिक 'ई'/Scientist 'E'
बायोटेक्नोलोजी विभाग / Deptt. of Biotechnology
विज्ञान और प्रौ. मंत्रालय / M/o Science & Tech.
भारत सरकार, नई दिल्ली/Govt. of India, N. Delhi

(Dr. Deepak Sharma)
Registrar
Tripura University

5. As per Rule 236 (1) of GFR 2017, the accounts of all Grantee Institutions or Organisations shall be open to inspection by the sanctioning authority and audit, both by the Comptroller and Auditor General of India under the provision of CAG (DPC) Act 1971 and internal audit by the Principal Accounts Office of the Ministry or Department, whenever the Institution or Organisation is called upon to do so.

6. No International Travel will be undertaken from the sanctioned project grant unless specified otherwise.

7. The Institute/Agency will keep the whole of the grant in a Bank Account earning Interest, and the Interest so earned should be reported to DBT in the Utilisation Certificate and Statement of Expenditure. **The interest earned should be remitted to the Consolidated fund of India through Bharat Kosh portal (www.bharatkosh.gov.in) as per GFR-2017-230(8) after finalization of the account for a given Financial Year.**

8. The other terms and conditions governing the financial sanction will remain unaltered.

9. The PI has submitted interest earned amount of Rs. 76434/- to the Consolidated Fund of India (Bharat Kosh – Receipt enclosed).

10. This sanction also carries the permission to carry forward the unspent balance of Rs. 298192/- for Tripura University, Tripura to the current financial year 2021-2022, out of which PI has remitted interest earned amount of Rs. 76434/- to the Consolidated Fund of India. The utilization certificate for the financial year 2020-21 is enclosed herewith.

11. This issues under the powers delegated to Divisional Heads vide IFD order No. BT/04/2015-IFD dated 01.04.2019 and subsequently modified vide order of even number dated 10.05.2019 and 29.12.2020. This has been noted in SAN No. **102/IFD/SAN/1648/2021-2022** dated **09th November, 2021**.

12. This sanction order has been noted at serial no....74....... dated ..11.11.21. in the Register of Grants.

(Dr. Vaishali Panjabi)
Scientist 'E'

To,

The Pay & Accounts Officer,
Department of Biotechnology,
New Delhi – 110 003.

Copy to:
1. The Principal Director of Audit (Scientific Departments), DACR Building, New Delhi- 110 002.
2. The Registrar, Tripura University, Suryamaninagar, Agartala - 799022, Tripura
3. Dr. Surajit Bhattacharjee (Project Co-ordinator), Assistant Professor, Department of Molecular Biology and Bioinformatics, Tripura University, Suryamaninagar, Tripura West, Agartala - 799022, Tripura
4. Dr. Utpal Chandra De, Assistant Professor, Department of Chemistry, Tripura University Suryamaninagar, Tripura West, Agartala - 799022, Tripura
5. Cash Section, DBT (2 copies).
6. Sanction Folder.
7. File Copy.
8. **US (IFD) DBT with a request to re-appropriate an amount of Rs. 1012632/- from respective NER budget.**

(Dr. Vaishali Panjabi)
Scientist 'E'
डॉ. वैशाली पंजाबी/Dr. Vaishali Panjabi
वैज्ञानिक 'ई' / Scientist 'E'
जैवप्रौद्योगिकी विभाग / Deptt. of Biotechnology
विज्ञान और प्रौ. मंत्रालय / M/o Science & Tech.
भारत सरकार, नई दिल्ली/Govt. of India, N. Delhi

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25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

Page No. 12 / 2

$l'1\ell$,

No. BT/PR24783/NER/95/851/2017
GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
(NER-BPMC)

Block 2, 6-8th Floors
CGO Complex, Lodhi Road,
New Delhi- 110 003
Dated: 28 / 01 /2019

ORDER

Sanction of the President is hereby accorded, under Rule 18 of the Delegation of Financial Powers Rules ,1978 , for the implementation of the project entitled: **"INVESTIGATION OF HYDROPHOBICALLY MODIFIED POLYSACCHARIDES FOR NANODELIVERY OF ANTICANCER DRUGS IN THE TREATMENT OF MULTIDRUG RESISTANCE COLON CANCER"** for a period of 3 Year 0 Month at a total cost of Rs. **6596400** (Rupees Sixty Five Lakhs Ninety Six Thousand Four Hundred Only) on the terms and conditions detailed here under:-

2 The Project :

2.1 Title : "INVESTIGATION OF HYDROPHOBICALLY MODIFIED POLYSACCHARIDES FOR NANODELIVERY OF ANTICANCER DRUGS IN THE TREATMENT OF MULTIDRUG RESISTANCE COLON CANCER"

2.2 Details of the Investigatiors:

Project Cordinator

Dr. Pratap Chandra Acharya
Assistant Professor
Department of Pharmacy
Tripura University
Department of Pharmacy, Block-A, Academic building-XI, Tripura University (A Central University), Suryamaninagar, Agartala, Tripura, 799022

Principal Investigators:

Vandal.

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

Dr. Pratap Chandra Acharya
Assistant Professor
Department of Pharmacy
Tripura University
Department of Pharmacy, Block-A,
Academic building XI, Tripura
University (A Central University),
Suryamaninagar, Agartala,Tripura,
799022

Dr. Clara Fernandes
Assistant Professor
SPP School of Pharmacy and
Technology Management
Narsee Monjee Institute of
Management Studies, Mumbai
SPP SPTM, SVKM'S NMIMS, V L
Mehta Road, Vile Parle (W) Mumbai,
Mumbai,Maharashtra, 400056

2.3 Objectives:

Overall Objectives:

1. Synthesis, purification and structural characterization of fatty acid based glycolipid derivatives

2. Physicochemical characterization of the glycolipids for its stability and usefulness as a nanocarrier

3. Formulation of the glycolipids in to their nanocarriers

4. Fabrication of developed glycolipid nanocarriers in combination with anticancer drug 5-Flourouracil

5. Investigation of the glycolipid and the drug loaded nanocarrier to overcome the multidrug resistance in colon cancer and its biological effect on colon cancer cells

6. Investigation of the pharmacokinetic and bio-distribution profile of 5-Flourouracil from the nanoformulation
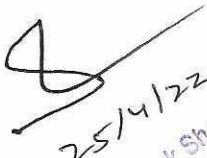
Institute wise Objectives:

Narsee Monjee Institute of Management Studies, Mumbai

1. Fabrication of developed glycolipid nanocarriers in combination with anticancer drug 5-Fluorouracil
2. Characterization of nanocarriers and mechanism of overcoming the multidrug resistance in colon cancer

Tripura University

1. Synthesis, purification and structural charecterization of fatty acid based glycolipid derivatives
2. Physicochemical characterization of the glycolipids for its stabiliy and usefulness as a nanocarrer.

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

S. No. 11(I)/R-85-99/6

85

22

UNIVERSITY GRANTS COMMISSION
BAHADURSHAH ZAFAR MARG
NEW DELHI-110002

No. F. 6-1/2018(IC)

22, March, 2021

2 2 MAR 2021

The Under Secretary (FD-III)
University Grants Commission
Bahadur Shah Zafar Marg
New Delhi-110 002

Subject: Release of Grants-in-aid to **Tripura University, Tripura - 799 022** under **Indo-Israel Joint Research Programme** for the year **2018**.

Sir,

I am directed to convey the sanction of the University Grants Commission for payment of grant of **Rs.16,00,000/- (Rupees Sixteen Lakhs Only)** to **Tripura University, Tripura - 799 022** towards 3rd installment in r/o Project title **"What Role of Tropical Thunderstroms Paly in Driving the Upper Tropospheric Water Vapor Feedback"** under **Indo-Israel Joint Research Programme** for the year **2018**.

Heads	Head of Account	Allocated amount	Grant Already Released	Grant now being released	Total Grant
Personnel Cost		4500000	1500000	1000000	2500000
Research Cost		4000000	3800000	200000	4000000
Cooperation & Exchanges	3(A) 12(i)31	2300000	1600000	0	1600000
Miscellaneous		600000	300000	200000	500000
Overhead		600000	400000	200000	600000
Equipment/Instruments		3000000	3000000	0	3000000
Total		**15000000**	**10600000**	**1600000**	**12200000**

The **sanctioned** amount is debitable under the head of account **3(A) 12(i) 31** and is valid for payment during the financial year **2020-2021** only.

2. The University/Institution shall ensure that all the payments of approval to the beneficiaries/venders shall be made only through the EAT module of PFMS

3. The amount of the Grant shall be drawn by the EO/US (DDO) UGC on the Grants-in-aid bill and shall be disbursed to and credited to the **Registrar, Tripura University, Tripura - 799 022** through Electronic mode as per the following details:

a	Details (Name & Address) of Account Holder	Registrar, Tripura University, Tripura - 799 022
b	Account No	10671301066
c	Name & address of Bank branch	Reserve Bank of India, 6 Sansad Marg, New Delhi - 110 001
e	IFSC Code	RBIS0PFMS01

4. The Grant is Subject to the adjustment on the basis of Utilization Certificate in the prescribed proforma submitted by the University/Institution.

5. The University / Institution shall maintain proper accounts of the expenditure out of the Grants which shall be utilized only on the approved items of expenditure.

6. The University / Institution may follow the General Financial Rules, 2017 and take urgent necessary action to amend their manuals of financial procedures to bring them in conformity with GFRs, 2017 and those don't have their own approved manuals on financial procedures may adopt the provisions of GFRs, 2017 and instructions/guideline there under from time to time.

7. The Utilization Certificate to the effect that the grant has been utilized for the purpose for which it has been sanctioned shall be furnished to UGC as early as possible after the close of current financial year.

25/M/22

(Dr. Deepak Sharma)
Registrar
Tripura University

8. The assets acquired wholly for substantially out of University Grants Commission's Grant shall not be disposed or encumbered or utilised for the purposes other than those for which the grants was given without proper sanction of the UGC and should at any time the University ceased to function, such assets shall revert to the University Grants Commission.

9. A Register of Assets acquired wholly or substantially out of the grant shall be maintained by the University in the prescribed proforma.

10. The grantee institution shall ensure the utilization of grants-in-aid for which it is being **sanctioned / paid**. In case of non-utilization/part utilization thereof, simple interest @ 10% per annum, as amended from time to time on the unutilized amount from the date of drawal to the date of refund as per provisions contained in General Financial Rules of Govt. of India, will be charged.

11. The University / Institution shall follow strictly the Government of India / UGC's guidelines regarding implementation of the reservation policy [both vertical (for SC, ST & OBC) and horizontal (for persons with disability etc.)] in teaching and non-teaching posts.

12. The University / Institution shall fully implement the Official Language Policy of Union Government and comply with the Official Language Act,1963 and Official Languages (Use for Official Purposes of the Union) Rules,1976 etc.

13. The sanction is issued in exercise of the delegation of powers vide UGC Order No. 141/2014[F.No. 10-11/12 (Admn. IA & B)] dated 27-05-2014.

14. The University /Institution shall strictly follow the UGC Regulations on curbing the menace of Ragging in Higher Education Institutions, 2009.

15. The University / Institution shall take immediate action for its accreditation by National Assessment & Accreditation Council (NAAC).

16. The accounts of the University / Institution will be open for audit by the Registrar & Auditor General of India in accordance with the provisions of General Financial Rules, 2017.

17. The annual accounts i.e. balance sheet, income and expenditure statement and statement of receipts and payments are to be prepared strictly in accordance with the Uniform Format of Accounting prescribed by Government.

18. The expenditure of Rs.17,37,215/- out of Rs.1,06,00,000/- has been noted in GIA sanctioned vide this office letter of even number by the university for the purpose for which it was sanctioned.

19. This issues with the concurrence of **IFD** vide Diary No.**774** (IFD) dated **22-10-2020**

20. This issues with the approval of **Secy.**, UGC vide Diary No. **80249** dated **16-03-2021**

Yours faithfully,

(Dr. Mriganka Sekhar Sarma)
Education Officer

Copy forwarded for information and necessary action for:-

1. **The Registrar**, Tripura University, Tripura - 799 022
2. **Dr. Anirban Guha**, Professor, Department of Physics, Tripura University, Tripura - 799 022
3. **Office of the Director General of Audit,** Central Revenues, AGCR Building, I.P.Estate, New Delhi.
4. **Guard File**

P. B. Senchulalesh
(P. B. Senchulakshmi)
Section Officer

25/4/22
Dr. Deepak Sharma)
Registrar
Tripura University
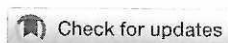
ScienceDirect

Note

On Riesz mean of complex uncertain sequences

Sangeeta Saha [a] ✉, Binod Chandra Tripathy [b] ⚥ ✉, Santanu Roy [a] ✉

[a] Department of Mathematics, National Institute of Technology Silchar, 788010, India
[b] Department of Mathematics, Tripura University, 799022, India

Submitted by E. Saksman

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Abstract

In this paper, we have developed the idea of Riesz mean, Riesz convergent in measure and Riesz convergent almost surely in complex uncertain variables. Also, we have established some relationships.

‹ **Previous**   **Next** ›

Keywords

Complex uncertain variable; Riesz mean; Riesz convergent in measure; Riesz convergent almost surely

Recommended articles   Citing articles (2)

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25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

Almost Convergence of Complex Uncertain Triple Sequences

Birojit Das[1] · Binod Chandra Tripathy[2] · Piyali Debnath[1] · Jagannath Nath[1] ·
Baby Bhattacharya[1]

Abstract In this paper, we present the concept of complex uncertain triple sequences and study almost convergence therein. Almost convergence with respect to all five aspects in uncertain space, viz., almost convergence in mean, measure, distribution, almost surely and uniformly almost surely, are initiated and interrelationships among them are established. We have also studied almost Cauchy triple sequence of complex uncertain variables and established some results. It is known that every convergent sequence is a Cauchy sequence but the converse is not true in general. But taking complex uncertain variables in triple sequences, we find that a complex uncertain triple sequence is an almost Cauchy sequence if and only if it is almost convergent.

Statement In this article we have introduced and investigated almost convergence of triple sequences of complex uncertain variables. Studies on complex uncertain sequences has been initiated in the last decade. Now it is drawing attention of researcher and this article will motivate for further investigation and application.

✉ Binod Chandra Tripathy
tripathybc@yahoo.com; tripathybc@iasst.gov.in;
tripathybc@rediffmail.com

Birojit Das
dasbirojit@gmail.com

Piyali Debnath
piyali87maths@rediffmail.com

Jagannath Nath
jan.21.nath@gmail.com

Baby Bhattacharya
babybhatt75@gmail.com

[1] Department of Mathematics, National Institute of Technology Agartala, Tripura 799046, India

[2] Department of Mathematics, Tripura University, Agartala, Tripura 799022, India

1 Introduction

The theory of uncertainty is first introduced by Liu [1]. After that, it has been studied in various fields of mathematics like calculus [2], risk and stability analysis [3], set theory [4], logic [5], process [6], finance [7], graph theory [8], sequence and series [1]. It became a separate branch of mathematics, and nowadays, the research on uncertainty theory became quite famous. Convergence of sequences plays a pivotal role in the study of fundamental theory of mathematics [9–11]. Liu applied the theory of uncertainty on sequences and established the properties of convergence of uncertain measure by introducing convergence in measure, in mean, in distribution and in almost surely of an uncertain sequence. You [12] extended this study to convergence in uniformly almost surely and established the interrelationship with the previous four types of convergence. Guo and Xu [13] presented a necessary and sufficient condition of convergence in mean square for uncertain sequences via Cauchy sequence. Cheng et. al [14] studied the concept of convergence of uncertain sequences taking complex uncertain variables which was introduced by Peng [15]. Datta and Tripathy [16] studied convergence of complex uncertain double sequences.

In this paper, we introduce triple sequence of complex uncertain variable and study almost convergence in

Ⓐ Springer

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122,123

No. BT/PR25104/NER/95/1017/2017
GOVERNMENT OF INDIA
MINISTRY OF SCIENCE & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY
(NER-BPMC)

Block 2, 6-8th Floors
CGO Complex, Lodhi Road,
New Delhi- 110 003
Dated: 26 /09 /19.

ORDER

Sanction of the President is hereby accorded, under Rule 18 of the Delegation of Financial Powers Rules ,1978 , for the implementation of the project entitled: **"Study of induction and mechanisms of Autophagy in EAC cells upon treatment with Theaflavins"** for a period of 3 Year 0 Month at a total cost of Rs. **7097120** (Rupees Seventy Lakhs Ninety Seven Thousand One Hundred and Twenty Only) on the terms and conditions detailed here under :-

2 The Project :

2.1 Title :   "Study of induction and mechanisms of Autophagy in EAC cells upon treatment with Theaflavins"

2.2 Details of the Investigatiors:

Project Cordinator

Dr. Debasish Maiti
Associate Professor,
Dept. of Human Physiology, Tripura University
Suryamaninagar,, Agartala, Tripura, 799022

Principal Investigators:

Dr. Debasish Maiti
Associate Professor
Dept. of Human Physiology, Tripura University
Suryamaninagar,, Agartala, Tripura, 799022

Dr. Samiran Saha
Assistant Professor
Biotechnology
Visva Bharati University
Department of Biotechnology,
Siksha Bhavana,
Visva-Bharati, Santiniketan,West Bengal, 731235

CO-PI:

Prof. Durgadas Ghosh
Professor
Dept. of Zoology, Tripura University
Suryamaninagar,, Agartala, Tripura, 799022

Vaishali

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डी. वैशाली पंजाबी / Dr. VAISHALI PANJABI
वैज्ञानिक 'डं' / Scientist 'D'
बायोटेक्नोलॉजी विभाग / Dept. of Biotechnology
विज्ञान और प्रौ. मंत्रालय / Min. Science & Tech.
भारत सरकार, नई दिल्ली / Govt of India, N. Delhi

Page No. [1 / 7]

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

2.3 Objectives:

Institute wise Objectives:

Tripura University

1. Determination of possible induction and specific dosage and time point at which the initiation of autophagic cell death if any, occurs in response to treatment with theaflavins
2. Study of immunomodulation activity upon treatment with theaflavin
3. Expression of cytokines in proteins in Spleen and liver from animal

Visva Bharati University

1. Determination of effective dosage for tumor suppression and cytotoxicity assessment for theaflavin treatment
2. Functional characterization of mechanism and regulation of induction of autophagy in EAC cells upon treatment with theaflavins

2.4 Time Schedule:

The duration of the project is 3 Year 0 Month from the date of this sanction order.

2.5 Project Cost:

The total cost of the project is Rs. **7097120/-**(Rupees Seventy Lakhs Ninety Seven Thousand One Hundred and Twenty Only) as per details given below :

Institute	Year I	Year II	Year III	Total Cost(Rs.)
1. Tripura University	2561760	1181760	1228600	4972120
2. Visva Bharati University	975000	525000	625000	2125000
Total (Rs.)	3536760	1706760	1853600	7097120

Institute wise details are:

Budget Head	Year I	Year II	Year III	Total(Rs.)
1. Tripura University				
Equipment	1200000.00			1200000.00
Manpower	401760.00	401760.00	453600.00	1257120.00
Overhead	80000.00	50000.00	50000.00	180000.00
Travel	50000.00	50000.00	50000.00	150000.00
Consumables	800000.00	650000.00	625000.00	2075000.00
Contingency	30000.00	30000.00	50000.00	110000.00
Total (Rs.)	2561760.00	1181760.00	1228600.00	4972120.00
2. Visva Bharati University				
Equipment	450000.00			450000.00
Overhead	25000.00	25000.00	25000.00	75000.00
Travel	50000.00	50000.00	50000.00	150000.00
Consumables	400000.00	400000.00	500000.00	1300000.00
Contingency	50000.00	50000.00	50000.00	150000.00
Total (Rs.)	975000.00	525000.00	625000.00	2125000.00

Dr. VAISHALI PANJABI
Scientist 'C'
Dept of Biotechnology
Min. Science & Tech
Govt of India, N Delhi

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

2.6 Equipment:

The details of the equipment sanctioned for the implementation of the project at Annexure-I

2.7 Manpower:

The details of the manpower sanctioned for the implementation of the project at Annexure-II

3. Head of Account:

The **Non-Recurring** expenditure involved is debitable to:

Demand No. 87	Department of Biotechnology
3425	Other Scientific Research 2019-2020
3425.60	Others (Sub Major Head)
3425.60.200	Assistance to other Scientific Bodies (Minor Head)
3425.60.200.29	Biotechnology Research and Development
3425.60.200.29.17	Assistance for Research and Development
3425.60.200.29.17.35	Grants for creation of capital assets

The **Recurring** expenditure involved is debitable to:

Demand No. 87	Department of Biotechnology
3425	Other Scientific Research 2019-2020
3425.60	Others (Sub Major Head)
3425.60.200	Assistance to other Scientific Bodies (Minor Head)
3425.60.200.29	Biotechnology Research and Development
3425.60.200.29.17	Assistance for Research and Development
3425.60.200.29.17.31	Grants -in-Aid General

4. Terms & Conditions:

Additional Terms and Conditions, specific for Twinning R and D program for NER

a. Both NER and Rest of India (RoI), Institutions scientists should work together for the objectives stated in the sanction of the project and any deviation from this would attract closure of the project at any point of time.

b. In the project review meetings, both the PIs from NER and RoI Institutions should participate and make presentation.

c. The outcomes of the project such as research papers, patents, copy rights etc. should be made jointly.

d. The NER Scientists are to be trained at the collaborating institute appropriately to empower the NER Scientists.

e. The project personal such as Research Associate, JRF or SRF, Research Assistant are also to be trained at least once in the collaborating national institute.

(Dr. Deepak Sharma)
Registrar
Tripura University

25/4/22

f. The collaborating institute scientist should visit NER institutions more frequently to guide NER scientists in design and conduct of experiments.

g. The Non-Recurring items must be procured and installed within 18-months of the sanction of the project, failing which the PIs have to return the remaining/unutilized Non Recurring grant with 10% of Interest.

h. In case the amount of grant-in-aid is refunded, the whole or a part amount of the grant, with an interest at 10% per annum there on shall be recovered.

4.1 The other terms and conditions governing this sanction are attached at Annexure- III.

4.2 A Memorandum of Agreement (MoA) will be signed between the Department of Biotechnology and the grantee institution on Non-Judicial stamp paper Rs. 100/- in the enclosed format and the second release/installment will be made only after signing of MoA between the grantee institutions and DBT. In case of NGO's and Private Institution's, execution of MOA is mandatory before first release. A format of the MoA is enclosed in Annexure-IV

4.3 The Institute/Agency will keep the whole of the grant in a Bank Account earning interest, and the interest so earned should be reported to DBT in the Utilisation Certificate and Statement of Expenditure. The Interest so earned will be treated as created to the Institute/Agency and shall be adjusted towards further installment of the grant and or at the time of Final Settlement of Accounts.

5. No International Travel will be undertaken from the sanctioned project grant unless specified otherwise.

6. The Registrar, Tripura University, Agartala, Tripura and The Registrar, Visva Bharati University, Birbhum, West Bengal would be responsible for submission of Statements of Expenditure (SoE), utilization certificates (UC), Assets Certificates, Manpower staffing & expenditure details in prescribed DBT formats to DBT in respect of grants released in this project from time to time.

7. PI's of DBT sponsored projects can consider appointment of JRF from Category-II merit list of DBT-BET exam so that candidates can be paid fellowships at par with NET/GATE/BET qualified candidates as per DST OM No. A.SR/S9/Z-09/2012 dated on 21 Oct 2014. However, there is no compulsion on PI's to select candidates for JRF in their projects from Category-II of DBT-BET.

8. As per Rule 236 (1) of GFR 2017, the accounts of all Grantee Institutions or Organisations shall be open to inspection by the sanctioning authority and audit, both by the Comptroller and Auditor General of India under the provision of CAG(DPC) Act 1971 and internal audit by the Principal Accounts Office of the Ministry or Department, whenever the Institution or Organisation is called upon to do so.

9. If the Research Project Involves biological resources, the obligations under the Biological Diversity Act 2002 as applicable shall be complied with by the Project Investigator, the details of such obligations can be accessed at www.nbaindia.org

10. If this project works requires any Statutory Clearance (such as Ethical Committee Clearance, Informed Consent, Animal Ethics Committee Clarence, Institutional Bio-safety Committee Clearance, National Biodiversity Authority approval etc.), Project investigator(s) and Host Institution(s) shall compulsory comply the same before undertaking such activities.

11. This issues under the power delegated to this Department and with the concurrence of IFD vide their SAN No.102/IFD/SAN/2063/2019-2020 dated September, 25 2019.

12. This sanction order has been noted at serial no. 122, 123 in the Register of Grants.

(Dr. Vaishali Panjabi)
Scientist 'E'

Page No. 14 /23
Scientist 'E'
Dept. of Biotechnology
Science & Tech.
Govt. of India, N Delhi

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

30

To,
The Pay & Accounts Officer,
Department of Biotechnology,
New Delhi - 110 003.

Copy to:

1 The Principal Director of Audit (Scientific Departments), DACR Building, New Delhi- 110 002.
2 Dr. Debasish Maiti(Project Co-ordinator), Suryamaninagar, Tripura West, Tripura 799022
3 The Registrar, Tripura University, Suryamaninagar, Agartala - 799022, Tripura
4 The Registrar, Visva Bharati University, Santiniketan, Birbhum, Birbhum - 731235, West Bengal
5 Dr. Debasish Maiti, Associate Professor, Human Physiology, Tripura University, Suryamaninagar,, Agartala - 799022, Tripura
6 Dr. Samiran Saha, Assistant Professor, Biotechnology, Visva Bharati University, Department of Biotechnology, Siksha Bhavana Visva-Bharati, Santiniketan - 731235, West Bengal
7 Prof. Durgadas Ghosh, Professor, Zoology, Tripura University, Suryamaninagar, Tripuar 799022, Agartala - 799022, Tripura
8 Cash Section, DBT (2 copies).
9 Sanction Folder.
10 File Copy.

(Dr. Vaishali Panjabi)
Scientist 'E'

डॉ. वैशाली पंजाबी / Dr. VAISHALI PANJABI
वैज्ञानिक 'ई' / Scientist 'E'
जैवप्रौद्योगिकी विभाग / Dept. of Biotechnology
विज्ञान और तकनी मंत्रालय / Min. Science & Tech.
भारत सरकार, नई दिल्ली / Govt. of India, N. Delhi

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

31

Details of the Equipment sanctioned for the implementation of the project entitled **"Study of induction and mechanisms of Autophagy in EAC cells upon treatment with Theaflavins"**:

Tripura University			
SNo.	Name of Equipment	No.	Cost(Rs.)
1.	Cryomicrotome	1	1200000.00
		Total	1200000.00
Visva Bharati University			
SNo.	Name of Equipment	No.	Cost(Rs.)
1.	Ultrasonicator	1	450000.00
		Total	450000.00

(Dr. Vaishali Panjabi)
Scientist 'E'

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

Details of the manpower sanctioned for the implementation of the project entitled "Study of induction and mechanisms of Autophagy in EAC cells upon treatment with Theaflavins":

Head	No. of Position	Year I	Year II	Year III	Total (Rs.)
1. Tripura University					
Junior Research Fellow (JRF) @ Rs.31000/- + 8% HA for the 1st & 2nd yr	1	401760	401760	0	803520
Senior Research Fellow (SRF) @ Rs. 35000/- + 8% HRA for 3rd yr	1	0	0	453600	453600
Total(Rs.)		401760	401760	453600	1257120

Emoluments detail of research personal(s) mentioned in table(s) of Annexure-II shall be applicable only if candidate(s) met educational qualification and eligibility criteria as per DST OM No.SR/S9/Z-08/2018 dated 30.01.2019.

(Dr. Vaishali Panjabi)
Scientist 'E'

डॉ. वैशाली पंजाबी / Dr. VAISHALI PANJABI
वैज्ञानिक 'ई' / Scientist 'E'
नैनोटेक्नोलॉजी विभाग / Dept. of Biotechnology
विज्ञान और प्रौ. मंत्रालय / Min. Science & Tech.
भारत सरकार, नई दिल्ली / Govt. of India, N. Delhi

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

भारतीय प्रौद्योगिकी संस्थान गुवाहाटी
गुवाहाटी 781 039, असम, भारत
Indian Institute of Technology Guwahati,
Guwahati 781 039, Assam, India.

Phone Nos.: +91-361- 258 2082

Fax No. : +91-361- 258 2089
e-mail   : dornd@iitg.ernet.in

Prof Gopal Das
Dean Research and Development & the
Coordinator, NECBH Programme
IIT Guwahati
Assam 781039
Ref: NECBH/2019-20/177

Date : 29-04-2019

PI Name: Swanirbhar Majumder   Sanction Letter
Category: Eureka
Your Project ID: 177
Project Title: Multivariate intrinsic mode functions for electroencephalogram signals using single channel
Duration: 2.5 Years
Total Sanction amount: Rs. 1592462.00

Account Head	For Principal Investigator	For CO PI IITG	For CO PI Other Institutes
Non-Recurring	200000.00	Nil	Nil
Man Power	687500.00	Nil	Nil
Consumables	100000.00	100000.00	Nil
Travel	50000.00	Nil	Nil
Contingency	85000.00	50000.00	Nil
Total	1122500.00	150000.00	Nil
Over Head	112250.00	Nil	Nil
Instrument Maintenance For NECBH		207712.00	
Grand Total		1592462.00	

Sincerely Yours,

Gopal Das

Terms and conditions

1   The principal investigator (PI) has to acknowledge project number BT/COE/34/SP28408/2018 of Department of Biotechnology (DBT), Govt of India for the financial support.

2   Funds will be released in subsequent installation subject to satisfactory performance of the project and availability of fund.

3   The Institute/PI would furnish a Utilization Certificate and an audited statement of expenditure duly signed by the PI, the Head of the Institute and the Head of the Finance wing, pertaining to the grant at the end of each financial year as well as a consolidated statement of expenditure at the end of the completion of the project or whenever it is required

4   The PI is not permitted to seek or utilize funds from any other organization (Government, Semi Government, Autonomous or Private) for this research project

5   Any unspent part of amount would be surrendered to the **Research and Development Section, IITG** and carry forward of funds of the next financial year for utilization for the same project may be considered only with the specific approval of the **Research and Development Section, IITG and Department of Biotechnology (DBT)**

6   IIT Guwahati or DBT reserves the right to terminate the grant at any stage and also to recover the amounts already paid if it is convinced that the grant has not been properly utilized or the work on the project has been suspended for any unduly long period or appropriate progress is not being made

7   The project will become operative with effect from April 29, 2019.

8   A copy of progress report has to be sent in the month of January till the completion of project or whenever it is required.

9. Travel should be used mainly for sample collection, discussion among the PIs not for other purpose. No international Travel will be undertaken from the sanctioned project grant

10 If the Investigator to whom a grant for a project has been sanctioned leaves the institution where the project is being implemented, PI shall submit five copies of complete and detailed report of the work done by him on the project and the money spent till the date of his/her release and shall also arrange to refund the unspent balance, if any to IIT Guwahati

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

34

Research Collaboration:

Project name: Validation of the efficacy of treated dairy effluent as biofertilizer for cultivation of economic crop

UGC-DAE Consortium for Scientific Research
विश्वविद्यालय अनुदान आयोग - परमाणु ऊर्जा विभाग वैज्ञानिक अनुसंधान संकुल
(An autonomous institution of UGC, New Delhi)
(विश्वविद्यालय अनुदान आयोग, नई दिल्ली द्वारा स्थापित स्वायत्त संस्थान)
[Formerly Inter University Consortium for DAE Facilities (IUC-DAEF)]

Kolkata Centre
कोलकाता केन्द्र

UGC DAE CSR KC CRS/9 TU-07/ 1

To
The Registrar
Tripura University
Suryamaninagar, Agartala-799022

Date: 19-10-2020

Sub: UGC-DAE CSR-KC Collaborative Research Scheme (CR), Research Project entitled *Validation of the efficacy of treated dairy effluent as biofertilizer for cultivation of economic crops* of Dr Shaon Roy Chowdhury, Dept of Microbiology Tripura University, Suryamaninagar, Agartala-799022

Dear Sir/Madam,

This is to inform that based on the recommendations of the Project Review Committee, on evaluation of the progress report submitted by the PI, UGC-DAE Consortium for Scientific Research Kolkata Centre, **has extended** the aforementioned CRS for full support research, scholar, contingency, consumables and travel for the second year **w.e.f 1st June 2020**.

It is requested that Utilisation certificate, for the last year, if not submitted earlier, and the claim for the second year with filled UR42 form (enclosed herewith) may please be sent at the earliest for further financial processing at the Centre.

Please note that the fellowship of Project Associate I and Project Associate II have been revised w.e.f 1st June 2019, from Rs 25,000/- and Rs 28,000/- to Rs 31,000/ and Rs 35,000/-, respectively with admissible HRA. There have not been any changes in other categories (fellowship details attached).

All communications pertaining to the CRS are to be made to the undersigned.

Yours sincerely,

Dr Anindita Chakraborty
Research Coordinator (*Trace Element Science*)

Copy to

Dr Shaon Roy Chowdhury, Dept of Microbiology Tripura University, Suryamaninagar, Agartala-799022

Administrative Officer-I (Accounts), UGC-DAE CSR, Kolkata Centre

ब्लोक - एल बी, प्लोट - ८, सेक्टर - III विधाननगर, कोलकाता-७००१०६, इंडिया
Block-LB, Plot-8, Sector III, Bidhan Nagar, Kolkata-700 106, India

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

35

Research Article

A Novel Design Approach for Beam Bridge Structure Pressure Sensor Base on PZT-5A Piezoelectric

Maibam Sanju Meetei[1,*], Aheibam Dinamani Sihgh[2] and Swanirbhar Majumder[3]

[1]Rajiv Gandhi University
[2]Dept. of Electronics and Communication, National Institute of Technology, Imphal
[3]Dept. of Information and Technology, Tripura University, Agartala

Abstract

With the spread of the Internet of things, the smart sensors with low power consumption, high sensitivity and can operate in harsh condition are required for various applications. Piezoelectric based sensors are the better as the sensors operate with high linearity with a wide range of mechanical input, and immune to electromagnetic fields and radiations. It is difficult to expedite for developing such sensors as the literature is widely dispersed over many disciplines. In this study, a new approached of mathematical modelling for PZT-5A piezoelectric base bridge structure pressure sensor has been studied. For validation of the mathematical model, a 3D model of a sensor is designed and simulated with the COMSOL multiphysics simulator. Various factors affecting the output voltages and sensitivity of the sensor described in mathematical modelling. Two parts of mathematical modelling consider mechanical modelling and electrostatic modelling. Mechanical modelling enables to analyse the mechanical stress developed on the surface of the sensor. Electrostatic modelling computes various operating modes of the piezoelectric and output voltage of the sensor. Transverse mode of operation for piezoelectric is applicable for bridge structure designed. The electrical equivalent circuit of the sensor is discussed. Comparative studies are done between the mathematical modelling values and simulated output values. From the comparative studies, the output behaviour and various factors affecting the output of a sensor are observed. The sensor mechanical stresses are linear in magnitude with a positive slope to the applied pressures. The sensor output voltages are linear in magnitude with a negative slope to the applied pressures. Tensile stress and negative voltage are developed on the top of the surface. The sensitivities of the sensor are high and the values are -01.957mV/kPa and -1.7 mV/kPa for calculating and simulated respectively.

Keywords: displacement function, neutral plain, operational mode, sensitivities, stress.

1. Introduction

Various types of Micro-Electro Mechanical Systems (MEMS) pressure sensors are developed and many of them are available in the market and mass-produced. For a researcher or designer, it is difficult to expedient in developing the MEMS pressure sensor. Based on the sensing mechanism, there are various types of pressure sensors. They are

(i) Resistive: this sensor is generally piezo-resistive pressure sensor which changes the resistance to deformation [1][2].This sensor has a limitation which sensitivity is reduced because the strain is reduced as the scaling in size of the sensor,

(ii) Capacitive: this sensor changes its electrical capacitance by the deflection of a diaphragm [3][4]. This sensor exhibit a nonlinear as capacitance is inversely proportional between the gaps,

(iii) Inductive: this sensor work on the principle of magnetic field induction [5][6]. The Main limitation is scaling and magnetic interference due to metal,

(iv)Thermal: this sensor work on the principle of change in thermal conductivity due to change in density by

measure pressure [7]. The main drawback is system complexity,

(v) Optical: this sensor utilized the concept of Fibre Bragg Gratings [8]. This sensor used when there is a need for high immune to electromagnetic interferences, and

(vi) Piezoelectric: this sensor is working on the principle of piezoelectricity and used for measuring dynamic pressure [9][10][16].

All the sensors are active sensor which requires external power sources, except the piezoelectric sensor, which doesn't require any external power sources. Such piezoelectric sensors remove the struggle of engineers with wires and batteries for monitoring the pressure and it has high sensitivity. These piezoelectric sensors are used for sensing vibration or pressure with low or high frequency. These sensors appear hysteresis as an offset which depends on a field level, cycle time and material used. This hysteresis is considerable for high frequency greater than 1 kHz as heat accumulation aftermeach cycle of operation [11].

Piezoelectricity is the property of certain dielectric material to produce electric charges when mechanical deformation or physically deformed in the presences of electric fields [11]. This phenomenon is due to spontaneous polarization caused by the displacement of electrons relative to the atomic centre, so piezoelectric materials are used for sensing continuous varying physical quantity. Because of this

A Mathematical Modelling And 3D Simulation Of Zno Piezoelectric Base Cantilever For Pressure Sensing

Maibam Sanju Meetei, Aheibam Dinamani Singh, Swanirbhar Majumder, Ome Moyong

Abstract: The main study in this work is to derive the mathematical model of the cantilever based pressure sensor. Two steps of mathematical modelling are being applied, mechanical and electrostatic, for finding the factors affecting the output of the sensor. Two main modes of operation for piezoelectric pressure sensor are transverse and longitudinal which are described in details. For 3D structure analysis, COMSOL 5.2 multiphysics simulator is used for simulation to validate the mathematical analyses output. A comparative analysis is done for simulated output of mechanical stress and the mathematical calculated stresses of the sensor. Similarly, the simulated output voltage and mathematical calculated voltage are also analyzed. The factors affecting the sensitivity of the sensor are the length, the thickness of the mechanical structure of the sensor, thickness of the sensing material and the piezoelectric voltage coefficient (g_{31}). The output voltage of the sensor is linearly vary with the input pressure with negative slope. The sensitivity of the sensor for simulated is -0.012 mV/Pa and mathematical is -0.017 mV/Pa.

Index Terms: moment of inertia, operation mode, piezoelectric voltage-coefficient, stress.

---

1. INTRODUCTION

There are different types of pressure sensors viz. capacitive, inductive, piezo-resistive, piezo-electric, electromagnetic, optical, resonance etc. Among these sensors, piezoelectric is a passive sensor which doesn't require any external excitation. Piezoelectric based pressure sensor can be implemented to MEMS sensor. Various applications of MEMS pressure sensors are Automotive application: Tire Pressure Monitoring Systems (TPMS), Gasoline Particulate Filter (GPF), Exhaust Gas Recirculation (EGR), Fuel/Oil Pressure, Air Brakes, Medical Applications: Blood Pressure Monitoring, Continuous Positive Airway Pressure (CPAP), Dialysis Machines, Negative Pressure Wound Therapy, Industrial Applications: Safety Cabinets/Ventilation Hoods, Gas Flow Instrumentation, Liquid Level Measurement, Hydraulic & Pneumatic Pressure, Oil Filled Media Isolated Sensors, Heating Ventilation Air Conditioning (HVAC) Applications: Variable Air Volume (VAV), Fire Pressurization and Smoke Management, Filter Monitoring, Compressors, Consumer Applications: Washing Machines, Vacuum Cleaner, Coffee & Espresso Machines, Water Purifiers, Invasive Medical Applications: Therapeutic Catheter, Endoscope, Robots Application: Robotics Hands, Robotics Legs[1][2][3][4].

In beam structure there are two common structures used in sensor design. They are cantilever and bridge structures. Cantilever structures are clamped at one terminal whereas bridge structures are clamped at two terminals. For a cantilever beam, the maximum deflection is at the free terminal but the maximum stress is at the edges of the fixed

clamped side [5]. For the bridge structure, the maximum deflection is at the center of the bridge but the stress is occurring at both the edges of the fixed terminals. In cantilever, the two most common way of loading of force are the uniform force or pressure which is load through the surface and the fixed point which is loaded at the free end of the cantilever. In mono-morph cantilever, the placement of the sensing layer is done near the fixed edge of the top surface and in bi-morph cantilever the placement of the sensing layer are done near the fixed edge of top and bottom surface of the cantilever. These placements of the sensing layers are done near the fixed edge because the maximum stress occurs at that place. The output of the piezoelectric is directly proportional to the stress. Recently, many researchers developed Zincoxide (ZnO) thin film deposition for various applications. ZnO has a wide application in the filled of semiconductor, photoelectric, photoconductivity [6], energy harvesting [7] and pressure sensor [8]. This study emphasizes on the mathematical modelling and simulation of a cantilever piezoelectric pressure sensor for low pressure. The design model of a cantilever beam structure with ZnO as sensing layer was simulated for applied pressure ranging from 0 to 20 Pa with 2 Pa step size. For improving the output, the thickness of the sensing material may be increased and for the sensor structure, the length and the height should be consider according to the mathematical derived equation. This paper has three main parts. First, explains the mathematical modelling of the sensor which the mechanical modelling and electrostatic modelling are described. Second, explains the design structure and 3D analysis of the designed sensor structure with COMSOL multiphysics simulator. Third, after various comparative analysis of the mathematical analyses outputs and 3D analyses outputs conclude the various factor affecting the sensitivity and the behavior of the designed sensor.

2. SENSOR MODELLING

For a cantilever beam structure pressure sensor based on piezoelectric can be model under two stages.

- Maibam Sanju Meetei is currently working as Assistant Professor at Electronics and Communication Engineering Department in Rajiv Gandhi University, India, PH-+91-9436069533. E-mail: maibam.meetei@rgu.ac.in
- Aheibam Dinamani Singh is working as Associate Professor at Electronics and Communication Engineering Department in National Institute of Technology, India.
- Swanirbhar Majumder is working as Associate Professor at Information and Technology Department in Tripura University, India.
- Ome Moyong is currently pursuing masters degree program in Electronics and Communication Engineering Department in Rajiv Gandhi University, India.
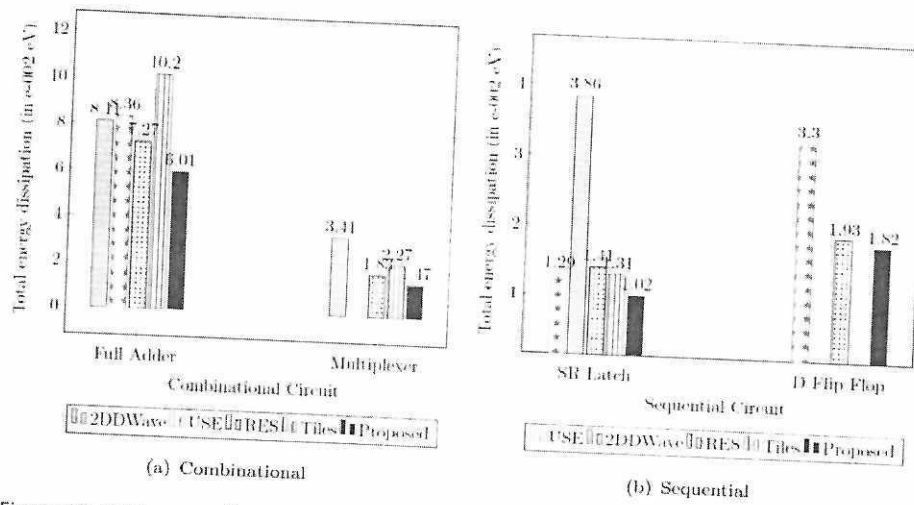
Figure 19. Total energy dissipation for proposed circuits using QCADesignerE.
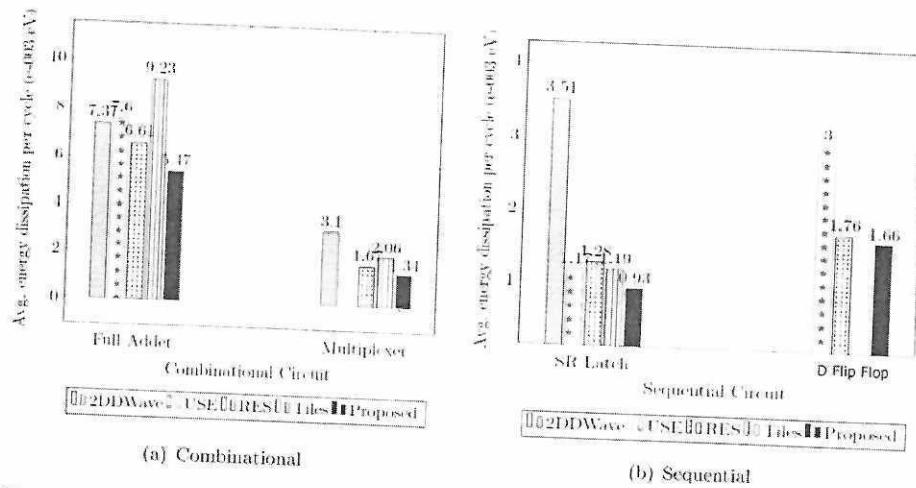
Figure 20. Average energy dissipation per cycle computed using QCADesignerE.

Acknowledgements

Disclosure statement

No potential conflict of interest was reported by the author(s).

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38

A NOVEL DESIGN AND OPTIMIZATION FOR BEAM BRIDGE PIEZOELECTRIC PRESSURE SENSOR

Maibam Sanju Meetei
Department of Electronics and Communication Engineering,
Rajiv Gandhi University, Papum Pare, Arunachal Pradesh, India

Dr. Heisnam Shanjit Singh
Department of Physics, Rajiv Gandhi University, Papum Pare,
Arunachal Pradesh, India

Dr. Aheibam Dinamani Singh
Department of Electronics and Communication Engineering,
National Institute of Technology, Imphal, Manipur, India

Dr. Swanirbhar Majumder
Department of Information and Technology,
Tripura University, Agartala, Tripura, India

ABSTRACT

In this paper, a new approach of mathematical modelling for PZT-5A piezoelectric based bridge structure pressure sensor is presented. For validation of the proposed mathematical model, a 3D model of the sensor is designed and simulated in the COMSOL multiphysics simulator with various parameters of the sensor. Various factors affecting the output voltages and sensitivity of the sensor in the model are examined from two parts-mathematical modelling which enables to analyze the mechanical stress developed on the surface of the sensor and electrostatic modelling which computes various operating modes of the piezoelectric sensor and its output voltage. Transverse mode of operation for the piezoelectric sensor is applied in the bridge structure design. The electrical equivalent circuit of the sensor is discussed. Comparative studies are done between the output values of mathematical modelling and simulated output values. The relationship between the output voltage and various factors affecting the output voltage of the sensor is shown. It is found that the mechanical stresses of the sensor linearly vary with the applied pressures while the output voltages of the sensor are inversely proportional to the applied pressures. Negative voltage are developed on the top surface of the sensor where tensile stress is occurred. The optimization of the sensor structure is also discussed. The sensitivities

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

North Eastern Regional Institute of Science & Technology

(Deemed to be University)
(Under Section 3 of UGC Act 1956, vide notification No.F.9-15/
2002 U.3 dt. 31st May, 2005, MHRD, Govt. of India)
Nirjuli (Itanagar) : Arunachal Pradesh : 791 109

Examination Cell

NOTIFICATION

The Director, NERIST is pleased to declare the result of the under mentioned candidateS to have qualified for the Degree of **Doctor of Philosophy (Ph.D.)** of the North Eastern Regional Institute of Science & Technology. The particulars relating to the Thesis, submitted by the candidates is as under :

Name of the Candidate	Department	Regn No & Date	Roll No	Title of the Thesis	Supervisor / Co-supervisor
Mr RITU ANGU	ELECTRICAL ENGINEERING	51452 23-07-2014	Ph.D/FT/14/EE01	"ENHANCEMENT OF POWER SYSTEM STABILITY OF SYNCHRONOUS MACHINE USING STATE-SPACE TECHNIQUES"	PROF. R.K.MEHTA
Mr NGAHORZA CHIPHANG	AGRICULTURAL ENGINEERING	47200 29-01-2015	Ph.D/FT/15/AE-03	"RESPONSE OF HYDROLOGICAL PROCESSES TO CLIMATE CHANGE IN A GLACIATED RIVER BASIN OF ARUNACHAL PRADESH USING ARCSWAT	DR. ADITI BHADRA
Ms. GRACE NENGZOUZAM	AGRICULTURAL ENGINEERING	51513 31-01-2015	Ph.D/FT/15/AE02	"LONG-TERM FORECASTING OF NET IRRIGATION REQUIREMENT FOR INDIA USING DOWN SCALED WEATHER PREDICTION OUTPUTS"	DR. ARNAB BANDYOPADHYAY
Mr. SINAM AJITKUMAR SINGH	ELECTRONICS & COMMN ENGG	51591001 25-07-2015	Ph.D/FT/15/EC01	"STUDY OF PCG & ECG BASED CARDIOVASCULAR ABNORMALITY"	DR. SWANIRBHAR MAJUMDER
Mr. KHAIDEM KENNEDY SINGH	FORESTRY	51306 25-07-2013	Ph.D/FT/13/FO04	"IN-VITRO SCREENING OF ANTIDIABETIC AND ANTIOXIDENT PROPERTIES OF SELECTED ETHNO MEDICINALLY IMPORTANT PLANTS IN NORTH EAST, INDIA"	DR. S. SURESH KUMAR SINGH PROF. C.L.SHARMA
Mr. NINGOMBAM AJIT KUMAR	ELECTRONICS & COMMN. ENGG.	41304 17-07-2015	Ph.D/FT/15/EC05	"MODELLING AND SIMULATION OF SILICON ON INSULATOR(SOI) AND SILICON ON NOTHING(SON) MOSFETS	DR. A.DINAMANI SINGH

Controller of Examinations

(Dr. Deepak Sharma)
Registrar
Tripura University
25/4/22

NORTH EASTERN REGIONAL INSTITUTE OF SCIENCE & TECHNOLOGY

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled 'DEVELOPMENT OF NEW STEGANOGRAPHY METHODS IN SPATIAL AND TRANSFORM DOMAINS' in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of in the Department of Computer Science & Engineering of the of the NERIST, Nirjuli, is an authentic record of my own work carried out during a period from 2014 to 2019 under the supervision of Prof. (Mrs.) Themrichon Tuithung, Department of Computer Science & Engineering, NIT, Nagaland, and Dr. Swanirbhar Majumder, Department of Information & Technology, Tripura University, Tripura.

I declare that this written submission represents my ideas in my own words and wherever others' ideas or words have been included, I have adequately cited and referenced the sources in the bibliography and has been tested through the standard plagiarism detection software.

The matter presented in the thesis have not been submitted by me for the award of any other degree of this or any other Institute.

Manashee Kalita
Signature of the Candidate
Roll No.: Ph.D(FT)/14/CS/01 (Reg. No.51422)

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

Date : 05 - 10 - 20

(Prof. (Mrs.) T. Tuithung)
Signature of Supervisor

(Dr. Swanirbhar Majumder)
Signature of Co-Supervisor

The PhD viva voce of Manashee Kalita is held today (05 - 10 - 202)

(Prof. (Mrs.) T. Tuithung)
Supervisor

(Dr. Swanirbhar Majumder)
Co-Supervisor

Signature of the Examiner
(Prof. Bhabesh Deka)
Tezpur University

i

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

41

North Eastern Regional Institute of Science & Technology
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[Under Ministry of Education, Govt. of India]
Nirjuli (Itanagar) : Arunachal Pradesh : 791 109 : www.nerist.ac.in

No.Acad./Ph.D./410/2012/Vol.II   Dated: Nirjuli 08.10.2020

NOTICE

In terms of Academic Bye-Laws (3.7.18) the Oral Defense (Viva-Voce) of under mentioned Ph.D. scholars, Department of Electronics & Communication Engineering shall be held in the **Seminar Hall of ET Cell, NERIST** on the date and time as shown below. The Oral defense shall be conducted through Video Conferencing and will be open to all.

Sl.No.	Name of the scholar	Roll No.	Regn. No.	Date and time
1.	Mr. Ningombam Ajit Kumar	Ph.D/(FT)/15/EC/05	413/047	19.10.2020 11.00 A.M. onwards
2.	Mr. Sinam Ajit Kumar Singh	Ph.D(FT)/16/EC/01	516/001	19.10.2020 3.00 P.M. onwards

All are requested to attend the programme.

Sd/-
Dean (Acad)

Copy to :-
1. All Deans, NERIST.
2. All HoD/HoC, NERIST.
3. The Chairman, DPGC, Department of EC, NERIST with a request to inform all DPGC and OEB members.
4. The Chairman, DC, Department of EC, NERIST with a request to inform all DC members.
5. The External Experts [Through the Dean (Academic), NERIST].
6. The CoE, NERIST.
7. Dr.A. Dinamani Singh Supervisor of Mr. Ningombam Ajit Kumar , Assoc. Prof. NIT, Manipur.
8. Dr. Rajesh Kumar, Acting Supervisor of Mr. Ningombam Ajit Kumar, Department of EC , NERIST – for information and necessary action please (with a request to arrange logistic support to the external member as required please).
9. Dr. Swanirbhar Majumder, Supervisor of Mr. Sinam Ajit Kumar Singh, Assoc. Prof. Tripura University.
10. Dr. P.K. Dutta, Acting Supervisor of Mr. Sinam Ajit Kumar Singh, Deptt. of EC. - for information and necessary action please (with a request to arrange logistic support to the external member as required please).
11. Mr. Ningombam Ajit Kumar , Roll No. Ph.D/FT/15/EC/05, Ph.D. Scholar Deptt.of EC, NERIST.
12. Mr. Sinam Ajit Kumar Singh, Roll No. Ph.D/FT/16/EC/01, Ph.D. Scholar Deptt.of EC, NERIST.
13. Incharge ET Cell for information & necessary action please
14. The Director/ The Registrar, NERIST.
15. The Deputy Registrar (Fin), NERIST for information and necessary actions.
16. The Automation Coordinator for information .
17. All Notice Boards.
18. Office Copy

Assistant Registrar (Academic)
08/10/2020

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

42

DEVELOPMENT OF NEW STEGANOGRAPHY METHODS IN SPATIAL AND TRANSFORM DOMAINS

A thesis submitted in partial fulfillment of the requirements for
the degree of Doctor of Philosophy

MANASHEE KALITA

(Roll No.: Ph.D.(FT)/14/CS/01)

(Regn. No: 51422)

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
NORTH EASTERN REGIONAL INSTITUTE OF SCIENCE AND
TECHNOLOGY
(DEEMED TO BE UNIVERSITY u/s 3 OF THE UGC Act, 1956)
NIRJULI (ITANAGAR) -791109
ARUNACHAL PRADESH, INDIA

October 2020

25/4/22

(Dr. Deepak Sharma)
Registrar
Tripura University

त्रिपुरा विश्वविद्यालय
TRIPURA UNIVERSITY
(केंद्रीय विश्वविद्यालय / A Central University)
सूर्यमणिनगर / Suryamaninagar-799022
त्रिपुरा, भारत / Tripura, India.

फोन / Phone: (0381) 237 -9380
फैक्स / Fax: (0381) 237-4802
ईमेल / Email: dean_science@tripurauniv.in
वेबसाईट / Website: www.tripurauniv.ac.in

No.F/TU/COE/Ph.D/10/IT/03/21

Date: 09.04.2021

To
Swarup Nandi
Research Scholar
Department of Information Technology
Tripura University.

Sir,

I am to inform you that you have been granted Ph.D. Registration with effect from **19.03.2021** as per Ph.D. Regulations-2016 for carrying out the research work at this University in accordance with the approved synopsis of your proposed research work.

You are to abide by the usual rules of migration and Tripura University registration if you passed the previous qualifying examination from a University other than Tripura University.

1.	Subject	Information Technology
2.	Title of the proposed thesis	**"A Study of Healthcare Systems Using the Cloud Environment".**
3.	Name of the Supervisor	Dr. Swanirbhar Majumder, Department of I.T., T.U.
4.	Name of the Co-Supervisor	Dr. Madhusudhan Mishra, Department of ECE, NERIST.

This is issued with the approval of the Hon'ble Vice Chancellor, Tripura University.

Sincerely,

09-04-2021
(Prof. R.K. Nath)
Dean,
Faculty of Science
Tripura University

Copy to:

1. The Chairman, BPGS, Department of I.T, T.U
2. Dr. Swanirbhar Majumder, Department of I.T, T.U, Supervisor of the candidate.
3. Dr. Madhusudhan Mishra, Department of ECE, NERIST, Co-Supervisor of the candidate.

25/4/22
(Dr. Deepak Sharma)
Registrar
Tripura University

Multichannel Ordered Contention MAC Protocol For Underwater Wireless Sensor Networks

ALAK ROY[1,*] AND NITYANANDA SARMA[2]

[1]*Department of Information Technology, Tripura University, Agartala, Tripura 799022, India*
[2]*Department of Computer Science & Engineering, Tezpur University, Tezpur, Assam 784028, India*
Corresponding author: alakroy@tripurauniv.in

Recent advancement in hardware and the availability of bandwidth open scope for multichannel communication in underwater wireless sensor networks. Utilizing multiple channels for data and control packets in bursty traffic networks can reduce collisions due to several contending nodes. The paper presents a synchronous reservation-based multichannel ordered contention MAC protocol for deep underwater high data rate bottom monitoring applications to improve the overall network throughput. This protocol is proposed as an enhancement over ordered contention MAC (OCMAC) protocol to deal with bursty traffic by reducing transmission collisions. It does so by enabling nodes to employ multichannel technique along with the scheduling technique of OCMAC. The protocol uses separate channels for channel reservation and data transmission. The throughput performance of the network has been analyzed and validated through simulation. Simulation-based results have shown that MOC-MAC outperforms OCMAC in terms of throughput.

1. INTRODUCTION

In recent years, underwater wireless sensor networks (UWSNs) have attracted attention because of their wide range of applications, including disaster prevention, mine reconnaissance, equipment monitoring and control, environmental monitoring, pollution monitoring, ocean sampling networks, oil and gas field monitoring, assisted navigation, autonomous underwater vehicles, undersea explorations, distributed tactical surveillance and so on [1]. To make these applications capable of working successfully, there is a need to enable cooperative communications among sensor nodes. A UWSN consists of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area [2–4].

Although sharing the similar principles like terrestrial wireless sensor networks (TWSNs), the different transmission medium results in changes in their means of communication from radio to acoustic signals. This renders both networks different in many aspects such as propagation delay, available bandwidth, energy consumption, etc. [5]. The acoustic signal has a propagation speed that is five orders of magnitude lower than radio signal [6]. This means that protocols and algorithms used in TWSNs need to be adapted or redesigned so that they are applicable in acoustic environment. Due to the shared communication medium, an efficient MAC protocol can play an important role to make a judicious decision about when a sensor node can use a common wireless channel and also sort out any disagreement among the neighborly sensor nodes [4, 7].

The following section outlines those underwater channel characteristics that impact MAC protocol design.

One of the most remarkable dissimilarity from radio frequency (RF) networks appears from using acoustic communication in underwater environment. RF wave has an extremely restricted communication range. At high frequencies, the range is less than one meter in fresh seawater [18] because of high attenuation in the underwater channel and due to the effect of absorption. On the other hand, RF wave propagates through conductive salty underwater channel over long distances at low frequencies (30–300 Hz) but at the cost of long antenna size and high transmission power, which make their deployment unpractical.

Instead, UWSN devices use hydrophones as antennas to communicate using acoustic wave. The antennas convert electrical signals into pressure waves. Using acoustic wave

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RPCP-MAC: Receiver preambling with channel polling MAC protocol for underwater wireless sensor networks

Alak Roy[1] | Nityananda Sarma[2]

[1]Department of Information Technology, Tripura University, Tripura, India

[2]Department of Computer Science and Engineering, Tezpur University, Assam, India

Correspondence

Alak Roy, Department of Information Technology, Tripura University, West Tripura, India.
Email: alakroy@tripurauniv.in

Summary

To design a reliable and energy efficient medium access control (MAC) protocol for underwater wireless sensor networks (UWSNs) is an active research area due to its variety of applications. There are many issues associated with underwater acoustic channels including long and variable propagation delay, attenuation, and limited bandwidth which pose significant challenges in the design of MAC protocol. The available sender-initiated asynchronous preamble-based MAC protocols for UWSNs are not reliable and energy-efficient. This is due to the problems caused by transmission of preambles for longer duration and collision of preambles from hidden nodes in sender-initiated preamble-based MAC protocols. To resolve these issues, the paper proposed an asynchronous receiver-initiated preamble-based MAC protocol named Receiver Preambling with Channel Polling MAC (RPCP-MAC) protocol for shallow underwater monitoring applications with high data rates. The protocol is proposed to resolve data packet collision and support reliability in an energy-efficient way without using any transmission schedule. The proposed protocol is based on the following mechanisms. Firstly, receiver preambling mechanism is adopted to reduce idle listening. Secondly, channel polling mechanism is used to determine missing data frame during its sleeping period and to minimize the active time of node and reduces energy wastage. Finally, a back-off mechanism is applied to resolve collision when preambles are received simultaneously. In addition, performance analysis through Markov chain together with its validation with simulation-based studies is reported in the paper. Both the analytical and simulation results have demonstrated the reliability achievable with RPCP-MAC while providing good energy efficiency.

KEYWORDS

energy efficiency, MAC protocol, reliability, RPCP-MAC, underwater sensor networks

1 | INTRODUCTION

In recent years, underwater wireless sensor networks (UWSNs) have attracted attention because of their wide range of applications, including disaster prevention, mine reconnaissance, equipment monitoring and control, environmen-

RPCP-MAC is an asynchronous receiver initiated preamble based MAC protocol for Underwater Wireless Sensor Networks.

A synchronous duty-cycled reservation based MAC protocol for underwater wireless sensor networks

Alak Roy [a,*], Nityananda Sarma [b]

[a] Department of Information Technology, Tripura University, West Tripura, India
[b] Department of Computer Science and Engineering, Tezpur University, Assam, India

ARTICLE INFO

ABSTRACT

To design an energy-efficient Medium Access Control (MAC) protocol for the Underwater Wireless Sensor Networks (UWSNs) is an urgent research issue since depleted batteries cannot be recharged or replaced in the underwater environment. Moreover, the underwater acoustic channels are affected by hindrances such as long propagation delay and limited bandwidth, which appear in the design of the MAC protocol for the UWSNs. The available MAC protocols for the terrestrial wireless sensor networks exhibit low performance in energy efficiency, throughput and reliability in the UWSNs, and cannot be used in the UWSNs directly because of their unique characteristics. This paper proposes a synchronous duty-cycled reservation-based MAC protocol named Ordered Contention MAC (OCMAC) protocol. The basic mechanism of this protocol is to schedule data transmission by transmitters through the scheduling of Ready To Send (RTS) frames. The protocol eliminates the possible collision during data transmission and improves the communication efficiency. The paper analyzes the performance in energy efficiency, throughput and reliability of the protocol by modeling the queuing behavior of OCMAC with a Markov Chain process. Furthermore, the analytical model is validated through a simulation study. The analysis results demonstrated that while providing good throughput and reliability, OCMAC can achieve energy saving.

1. Introduction

In recent years, Underwater Wireless Sensor Networks (UWSNs) have become a rapidly growing research because of its wide range of applications [1], including disaster prevention, mine reconnaissance, equipment monitoring and control, environmental monitoring, pollution monitoring, ocean sampling networks, oil and gas field monitoring, assisted navigation, autonomous underwater vehicles, undersea explorations, distributed tactical surveillance, etc [1,2]. To make these applications capable of working successfully, there is a need to enable the cooperative communications among sensor nodes. In the UWSNs, it is not always feasible to replace or recharge the depleted batteries of sensor nodes that are deployed and unattended in the hostile underwater environment [2,4]. Therefore, energy-efficient communications among the sensor nodes is a must to maximize the networks lifetime, parting other performance factors as less important [5,6]. In such scenarios, a protocol can play an important role in making judicious decisions about when a sensor node can use a common wireless channel and to sort out any disagreement among the sensor nodes [4,7]. The MAC protocol is essential to the final performance of the UWSNs.

Different underwater applications have different requirements on the MAC protocols. In this paper, we aim to design an MAC protocol for deep underwater bottom monitoring applications. This type of applications generates unevenly distributed traffic and have low data rates. For such applications, sensor nodes are usually deployed sparsely at the underwater bottom, having higher depth. This type of applications is not sensitive to the end-to-end delay. Energy efficiency, reliability and throughput are an inherent necessity rather than an additional feature for such applications. The inherent characteristics of the underwater environment, such as long propagation delays, high bit error rates, limited bandwidth, and low data transmission rates, make the provisioning of energy efficiency, reliability and throughput provisioning in such applications an extremely challenging task. Thus, an efficient solution at the MAC layer of the UWSNS protocol stack is required. Given that the provisioning of energy efficiency, reliability and throughput extremely is challenging as an MAC layer problem, we investigate the challenges in our design of an MAC protocol for the deep underwater bottom monitoring applications that rely on the acoustic communication. The acoustic communication has several limitations, such as multi-path, path loss, high delay variance, noise and Doppler-spread, and so on. And, the

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Lung Cancer Detection Using Deep Learning Network: A Comparative Analysis

Susmita Das,
Department of Computer Science,
Ramthakur College
Agartala,India.
susmitadasre@gmail.com

Swanirbhar Majumder,
Department of Information Technology,
Tripura University,
Agartala,India
swanirbhar@ieee.org

Abstract— Deep learning is an emergent and influential method which is used for feature learning and pattern recognition. We provide a comparison between Computer Aided Diagnosis scheme using Deep Learning Technique and traditional Computer Aided Diagnosis scheme in our paper. In this paper, we have compared several deep neural networks for recognition of pulmonary cancer. In our study, we find that Convolutional neural networks are used for pulmonary cancer detection in most of the cases, as compared to other algorithms in deep learning techniques. In conclusion, we address the few difficulties in the implementation of the systems for pulmonary cancer, then we summarise the advantages and disadvantages of the existing algorithms for diagnosis of pulmonary cancer.

Keywords- Pulmonary Cancer Detection, Lung Nodule, Deep Learning Network, Computer Aided Diagnosis scheme, Convolutional neural network.

I. INTRODUCTION

Nowadays, pulmonary cancer is considered as one of the fatal ailment [1]. Every year we have new records of over and above 1.6 million patients with pulmonary cancer. The early detection of lung nodules with Computer-Aided-Diagnosis (CAD) [3] schemes is especially significant for the analysis and recovery of lung cancer patients [2]. Though, classifying huge numbers of CT images is very hard and time consuming for radiologists. Therefore, the automatic recognition of lung nodules is important field for research and significantly enhances the effectiveness of pulmonary nodule detection frameworks.

In order to improve the clinical diagnostic systems for lung cancer, automated detection algorithm is a research domain that is related with representation of computable assessments. Automatic diagnosis of malignant/benign character of pulmonary nodules is typically the most important goals of CAD schemes and it is done on feature extraction in order to decide every time there is analytical indecision and disparity. Conventional CAD systems usually involve a number of image processing steps and then perform categorization job for detection of tumor or abrasion. Performance of traditional CAD systems depends a lot on the intermediary outcomes of the image processing steps for consistent features. In many CAD schemes, additional issues may be integration and selection of extracted features. The malignant/benign character of the training CT images can be can simply identified by the annotator without the need for particular drawing of the tumor margins on the training dataset. There are many automatic diagnosis systems based on traditional systems, as research area based on deep leaning techniques are less explored, so we are presenting our study which concentrates on CAD Schemes based on deep learning techniques.

From our study, we can see that from the perspective of CAD for lung cancer detection, Deep learning techniques have not been that much explored. In this paper, automated detection systems dependent on different types of deep learning architectures are analysed. Lung nodules can be classified as benign or malignant pulmonary nodules with the application of these networks to the CT images with some modification.

In the review paper, our contributions are as written below:

- In this paper, we compare the conventional CAD systems with the CAD methods established on Deep Learning technique.

- We have addressed several the advantages and disadvantages of the existing algorithms for pulmonary cancer detection.

- Several automated detection systems for pulmonary nodules with deep learning architectures are compared for in the paper.

II. TRADITIONAL COMPUTER AIDED DIAGNOSIS SYSTEMS

A CAD method is a research domain for study of the detection of pulmonary nodule and identification of pulmonary cancer, and it incorporates Computed Tomography images as input and based on an algorithm assists radiologists to perform an image analysis and malignant/benign tumor classification. Five important steps of Diagnosis of pulmonary nodules in CAD systems are: Database Acquisition, Preprocessing of Image, Segmentation Operation, Analysis and Classification. In Figure 1, we can see the important steps of a traditional CAD system; the first step is acquisition of CT images from accessible databases like LIDC, LIDC-IDRI, ELCAP [1]. Second step is preprocessing of Lung CT image in order to enhance the image and to remove unnecessary noises. Some of the commonly used preprocessing techniques are Adaptive Median Filter, Alpha-Trimmed Mean Filter, Gaussian Filter [19]. Third step is segmentation of the preprocessed CT image using a standard segmentation technique like thresholding technique, Markov random field, region growing, watershed and histogram based segmentation [22]. The fourth step is analysis, in which during feature extraction, some of the extracted features are for example area, perimeter, eccentricity, centroid, diameter [16]. The fifth

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Self-standing films of tetraindolyl derivative and saponite clay mineral with reversible colour switching properties

Surajit Sarkar [a], Barnali Deb [b], Bapi Dey [a], Sudip Suklabaidya [a], Santanu Chakraborty [c], Debajyoti Bhattacharjee [a], Swapan Majumdar [b] ☒, Yasutaka Suzuki [d], Jun Kawamata [d] ☒, Syed Arshad Hussain [a] ☒

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Highlights

- Synthesis of tetraindolyl derivative.

- Preparation of clay mineral-tetraindolyl hybrid self-standing film.

- Colour switching of hybrid film due to the change in gallery height of clay.

- Colour switching was reversible with a very good stability.

- Such colour switching is suitable for colorimetric sensor, optical switching, optical memory etc.

Abstract

Functional nanosized two-dimensional clay mineral particles are considered as ideal host materials to manipulate the properties of incorporated organic molecules due to their high cation exchange capacity, layer structure and intercalation properties. The interlayer height of clay layers can be manipulated by simultaneous wetting and drying steps. Here, we have studied the chromatic behaviour of an organic dye generated in-situ from 1,4-di-bis-indolylmethane-benzene in the interlayer space of synthetic saponite (SSA). Initially transparent, self-standing organo-clay hybrid films become red upon heating due to aerobic oxidation suggesting in-situ generation of organic dye and increases the planarity of the intercalated organic molecules. Upon swelling the same hybrid film becomes yellow, due to the partial disturbance in the planarity of generated dye via C-C bond rotation. Simultaneous heating and swelling resulted in a reversible colour transition (clearly visible through the naked eye) between red and yellow for at least 30 cycles. This kind of system may have potential applications as a colorimetric sensor and in the field of optics (optical switching and optical memory etc).

Graphical abstract

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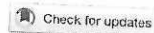
Regular Clocking based Emerging Technique in QCA Targeting Low Power Nano Circuit

Jayanta Pal[a], Amit Kumar Pramanik[b], Mrinal Goswami[c], Apu Kumar Saha[d] and Bibhash Sen[e]

[a]Department of Information Technology, Tripura University, Suryamaninagar, Tripura, India; [b]Dept. Of Computer Science & Engineering, Dumka Engineering College, Jharkhand, India; [c]Department of Systemics, School of Computer Science, UPES, Bidholi, Dehradun, India; [d]Department of Mathematics, National Institute of Technology, Agartala, Tripura, India; [e]Department of Computer Science & Engineering, NIT Durgapur, West, Bengal, India

ABSTRACT

The transistor-based CMOS technology is facing tremendous physical challenges in nano-scale design. The Quantum-dot cellular automata (QCA) have attracted the research focus as aviable alternative to CMOS technology for future designs in the nano-scale. The cell interaction property helps in information propagation in QCA. The three-input majority gate, Inverter gate are the basic building blocks. The fabrication complexity can be optimised with coplanar and clock-based wire crossing techniques. Due to its low power feature, QCA has been experiencing significant power dissipation in its wire crossing and logic-driving cell, which needs special care. Moreover, various challenges to logic synthesis are associated with design automation and integration. Underlying metal wire crossing is another concern in the implementation of a regular clocking circuit. Extensive design proposals in QCA have been studied bypassing regular clocking and ends up with a question of proper fabrication or buildability. This research proposes an emerging technique to develop an efficient, scalable regular clocking scheme incorporating minimal metal wire crossing. The proposed clocking is employed for the cost-effective and power-efficient circuit design in both the sequential and the combinational approach. QCADesigner is used for circuit synthesis, whereas QCAPro and QCADesignerE have been utilised for energy dissipation analysis.

1. Introduction

The gradual reduction in the size of CMOS-based technology has been experiencing some serious challenges as impurity variations, short channel effects, and high in dissipation of leakage power. Quantum-dot cellular automata (QCA) is emerged as one of the encouraging alternatives for beyond CMOS technology (Karim & Walls, 2014) with high device

CONTACT Apu Kumar Saha ✉ apusaha_nita@yahoo.co.in 📧 Department of Mathematics, National Institute of Technology Agartala, Tripura, India

Speaker Identification in Spoken Language Mismatch Condition: An Experimental Study

Joyanta Basu and Swanirbhar Majumder

Abstract This paper describes the impact of spoken language variation in a multilingual speaker identification (SID) system. The development of speech technology applications in low resource languages (LRL) is challenging due to the unavailability of proper speech corpus. This paper illustrates an experimental study of SID on Eastern and Northeastern (E&NE) Indian languages in language mismatch conditions. For this purpose, several experiments are carried out using the LRL data to build speaker identification models. Here, spectral features are explored for investigating the presence of speaker-specific information. Mel frequency cepstral coefficients (MFCCs) and shifted delta cepstral (SDC) are used for representing the spectral information. Gaussian mixture model (GMM) and support vector machine (SVM)-based models are developed to represent the speaker-specific information captured through the spectral features. Apart from that, to build the modern SID i-vectors, time delay neural networks (TDNN), and recurrent neural network with long short-term memory (LSTM-RNN) have been considered. For the evaluation, equal error rate (EER) has been used as a performance matrix of the SID system. Performances of the developed systems are analyzed with native and non-native corpus in terms of speaker identification (SID) accuracy. The best SID performances are observed to be EER 10.52% after the corpus fusion mechanism.

Keywords Low resource language (LRL) · Speaker identification (SID) · Mel frequency cepstral coefficients (MFCCs) · Shifted delta cepstra (SDC) · i-vectors · Linear discriminant analysis (LDA) · Probabilistic linear discriminant analysis (PLDA) · Deep neural network (DNN) · Time delay neural networks (TDNN) · Recurrent neural network (RNN) · Long short-term memory (LSTM)

J. Basu (✉)
CDAC Kolkata, Salt Lake, Sector—V, Kolkata Bidhannagar, Kolkata, India
e-mail: joyanta.basu@cdac.in

S. Majumder
Department of Information Technology, Tripura University, Suryamaninagar, Tripura, India
e-mail: swanirbhar@ieee.org

77

Identification of Seven Low-Resource North-Eastern Languages: An Experimental Study

Joyanta Basu and Swanirbhar Majumder

Abstract This paper describes an experimental study on the identification of seven north-eastern (NE) low-resource languages (LRL) of India namely, Assamese, Bengali, Hindi, Manipuri, Mizo, Nagamese, and Nepali using 55-dimensional hybrid features (HF) and hierarchical technique. However, the development of language identification (LID) systems could be leveraged only with the availability of specially curated speech data in LRL and it is a really challenging task to build a system on such under-resourced languages. We have collected around 42 h of speech data (including 35 h for training and 7 h for testing) for analysis on the above-said seven LRL. The process of designing speech database in LRL has been generic enough to be used for other languages as well. We have compared our proposed methodology with baseline system on collected speech data. From the experimental study, it has been observed that our proposed system is outperformed over baseline system and results are encouraging for researchers in low-resource languages. This initial study unveils the importance of HF for NE-LRL.

Keywords Language identification (LID) · North-Eastern (NE) Low-resource language (LRL) · Hybrid features (HF)

1 Introduction

LID is the problem of identifying the language being spoken from a sample of speech. It is also called as spoken language recognition (SLR). Automatic LID is an integral part of multilingual conversational systems, multilingual speech and speaker

J. Basu (✉)
CDAC, Kolkata, Salt Lake, Sector - V, Kolkata 700091, India
e-mail: joyanta.basu@cdac.in

S. Majumder
Department of Information Technology, Tripura University,
Suryamaninagar 799022, Tripura, India
e-mail: swanirbhar@ieee.org

52

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Multilingual Speech Corpus in Low-Resource Eastern and Northeastern Indian Languages for Speaker and Language Identification

Joyanta Basu[1] · Soma Khan[1] · Rajib Roy[1] · Tapan Kumar Basu[2] · Swanirbhar Majumder[3]

Abstract

Research and development of speech technology applications in low-resource languages (LRL) are challenging due to the non-availability of proper speech corpus. Especially, for most of the Indian languages, the amount and type of data found in different digital sources are sparse and prior works are too few to serve the purpose of large-scale development needs. This paper illustrates the creation process of such an LRL corpus comprising of sixteen rarely studied Eastern and Northeastern (E&NE) Indian languages and presents the data variability with different statistics. Furthermore, several experiments are carried out using the collected LRL corpus to build baseline speaker identification (SID) and language identification (LID) system for acceptance evaluation. For investigating the presence of speaker and language-specific information, spectral features like Mel frequency cepstral coefficients (MFCCs), shifted delta cepstral (SDC), and relative spectral transform-perceptual linear prediction (RASTA-PLP) features are used here. Vector quantization (VQ), Gaussian mixture models (GMMs), support vector machine (SVM), and multilayer perceptron (MLP)-based models are developed to represent the speaker and language-specific information captured through the spectral features. Apart from this, i-vectors, time delay neural networks (TDNN), and recurrent neural network with long short-term memory (LSTM-RNN) method-based SID and LID models are being experimented with to comply with the recent approaches. Performances of the developed systems are analyzed with LRL corpus in terms of SID and LID accuracy. The best SID and LID performances are observed to be 94.49% and 95.69%, respectively, for the baseline systems using LSTM-RNN with MFCC+SDC feature.

✉ Joyanta Basu
joyanta.basu@cdac.in

Extended author information available on the last page of the article

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CHAPTER 25

Identification of two tribal languages of India: An experimental study

Joyanta Basu[a], Theodore Raphael Hrangkhawl[b], Tapan Kumar Basu[c], and Swanirbhar Majumder[d]

[a]CDAC Kolkata, West Bengal, India

[b,d]Department of Information Technology, Tripura University, Suryamaninagar, Tripura, India

[c]Department of Electrical Engineering, IIT, Kharagpur, West Bengal, India

[a]joyanta.basu@cdac.in, [b]theodoreraphuel1@gmail.com, [c]basutk06@rediffmail.com, [d]swanirbhar@ieee.org

Abstract: In the Indian scenario, the inadequacy of digitally available resources of language restricts the expansion of speech technology applications. This paper describes an experimental study of two such low-resource tribal languages (LRTL) of India, Santali, and Hrangkhawl for language identification (LID) purposes. Two different approaches have been taken for the present analysis of 10 hours of speech data. In the first approach, the measure of performance of the LID using the outcome of the acoustic analysis of these two LRTL has been used. On the second approach, we have used a 39-dimensional feature vector and used Vector Quantization (VQ), Gaussian mixture model (GMM), Support Vector Machine (SVM), Multilayer Perceptron (MLP) as classifiers. On collected speech data, we have compared these two proposed approaches. We observed after analysis that the second approach outperforms the first approach and received encouraging results for researchers of LRTL.

Heart Abnormality Classification Using PCG and ECG Recordings

Sinam Ajitkumar Singh[1], Sinam Ashinikumar Singh[2],
Ningthoujam Dinita Devi[3], Swanirbhar Majumder[1]

[1] Tripura University, Department of Information Technology,
India

[2] North Eastern Regional Institute of Science and Technology,
Department of Electronics and Communication Engineering,
India

[3] Regional Institute of Medical Sciences,
Department of Radiation Onclogy,
India

ajit_sinam@yahoo.com, {ashini.sinam, dini.ji2019}@gmail.com,
swanirbhar@ieee.org

Abstract. Both PCG (Phonocardiogram) and Electrocardiogram (ECG) carry helpful features that aid in the fundamental analysis of heart-related disorders. Although they contain varying physical characteristics, some characteristics may predict some parameters better than the other. The research of such electrical and mechanical signals reveals a beneficial topic for any researcher. Hence, the study for automated detection and prediction of an anomaly of the heart using PCG and ECG signal is essential. The proposed method introduced modified preprocessing techniques along with features extraction techniques using both ECG and PCG datasets in tandem based on a different classification approach. The preprocessing of ECG signals comprises of the delineation and elimination of noise and artifacts whereas, the preprocessing of PCG signals includes the removal of unwanted noise and murmurs by applying a band-pass filter. The time-frequency features using PCG signals were extracted based on wavelet decomposition, Homomorphic filtering, Hilbert transforms, and Power spectral density. Using the ECG signals, the QRS based feature extraction method based on the Pan-Tompkins algorithm was performed. The extracted features from PCG and ECG signals were independently trained and tested using different classifiers (SVM, KNN, and Ensemble). Finally, the merged features of both the PCG and ECG signals were again trained and tested. The proposed model was validated using publicly available data-sets 'A' of PhysioNet 2016/ CinC challenges that comprise of both ECG and PCG data-sets. The results show that ECG and PCG signals can efficiently be employed for predicting cardiovascular disorders.

Keywords. Phonocardiogram, electrocardiogram, QRS complex, wavelet decomposition, Hilbert transform, homomorphic envelope, K nearest neighbors, power spectral density, support vector machine, ensemble of classifiers.

1 Introduction

In 1965, medical diagnostic based on artificial intelligence became revolutionized [1]. Hence, many researchers became familiarized with analyzing the medical images [2-4]. During this era, many researchers believed that computer-aided diagnosis could replace humans due to the efficient performance of the predicting model [4].

But, due to the lack of technical methodologies; such as insufficient processing power, absence of advanced image-processing methods and challenges in realizing a digital image, the above the approach was unfit. These methods evolved in the 1980s; then many researchers reported that computer-aided diagnostic could be utilized by the Physicians but not to fully substitute them [5].

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A deep neural network approach for P300 detection-based BCI using single-channel EEG scalogram images

Sinam Ajitkumar Singh[1] · Takhellambam Gautam Meitei[2] · Ningthoujam Dinita Devi[3] · Swanirbhar Majumder[1]

Abstract

Brain–computer interfaces (BCIs) acquire electroencephalogram (EEG) signals and interpret them into a command that helps people with severe motor disabilities using single channel. The goal of BCI is to achieve a prototype that supports disabled people to develop the relevant function. Various studies have been implemented in the literature to achieve a superior design using multi-channel EEG signals. This paper proposed a novel framework for the automatic P300 detection-based BCI model using a single EEG electrode. In the present study, we introduced a denoising approach using the bandpass filter technique followed by the transformation of scalogram images using continuous wavelet transform. The derived images were trained and validated using a deep neural network based on the transfer learning approach. This paper presents a BCI model based on the deep network that delivers higher performance in terms of classification accuracy and bitrate for disabled subjects using a single-channel EEG signal. The proposed P300 based BCI model has the highest average information transfer rates of 13.23 to 26.48 bits/min for disabled subjects. The classification performance has shown that the deep network based on the transfer learning approach can offer comparable performance with other state-of-the-art-method.

Keywords Electroencephalogram · Brain–computer interface · P300 · Continuous wavelet transform · Deep neural network

Introduction

A BCI is a primary communication medium that measured human–brain activities to communicate them with the outside environment. BCIs collect electroencephalogram (EEG) signals, study them, and interpret them into useful data that helps to communicate with external devices that carry relevant messages [1]. The purpose of BCI is to implement a model that helps disabled people to reclaim valuable functions. A study based on BCI includes the estimation of brain

movement, pattern analysis (based on brain activity), development of an adaptive algorithm (for interpretation of brain signals into the system), and development and evaluation of a brain–machine interface system(for the disabled subjects) [2]. This paper presents a non-invasive method for disabled people to analyze brain movement using single-channel EEG signals.

Generally, BCI can categorize into four sections based on signal processing (Neural Network). They are (1) Acquisition of signal using a transducer, (2) preprocessing of the raw input signals, (3) followed by assigning labels to the various stimuli, and (4) transferring the classes to the external devices following a distinct protocol linked with all the devices. The classification of EEG involves feature extraction and the interpretation of these signals into the computer instructions. The BCI model using single-channel EEG signals depends on stimuli, detection response, motor event, and slow cortical potentials.

Most of the studies for analysis of particular EEG signals employed a pattern recognition approach. The machine learning approach outperforms other conventional techniques, as reported in the literature [3–5]. However, neuroscience provides information and experiences about the acquisition

✉ Sinam Ajitkumar Singh
   ajit_sinam@yahoo.com

   Takhellambam Gautam Meitei
   gtm820pm@gmail.com

   Ningthoujam Dinita Devi
   dini.ji2019@gmail.com

   Swanirbhar Majumder
   swanirbhar@ieee.org

[1] Tripura University, Agartala, India

[2] National Chiao Tung University, Hsinchu, Taiwan

[3] Regional Institute of Medical Sciences, Imphal, India

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(Dr. Deepak Sharma)
Registrar
Tripura University

A study on sleep stage classification based on a single-channel EEG signal

7

Sinam Ajitkumar Singh[1], **Sinam Ashinikumar Singh**[2], **Ningthoujam Dinita Devi**[3], **Swanirbhar Majumder**[1]

[1]*Information Technology, Tripura University, Agartala, Tripura, India;* [2]*Electronics & Communication Engineering Department, NERIST, Nirjuli, Arunachal Pradesh, India;* [3]*Radiation Oncology and Radiotherapy, RIMS, Imphal, Manipur, India*

1. Introduction

Sleep comprises approximately 30% of an individual's lifespan. Efficient analysis and diagnosis of cases with sleep-related ailments are crucial and relevant for a healthy environment. For various sleep disorders such as obstructive sleep apnea, sleeplessness, hypersomnia, night terrors, or narcolepsy, precise and adequate analysis is crucial. Sleep abnormality analysis for the clinical platform utilizing polysomnographic (PSG) tools consisting of electroencephalogram (EEG) channel, electromyogram (EMG), and electrooculogram (EOG) is an essential and complicated method requiring various signal processing approaches and expert review. The recorded datasets are usually split into 20- or 30-second epochs before being classified by sleep experts based on Rechtschaffen and Kales (R&K) [1]. These rules classify the sleep stages into six types for an adult: (1) wakefulness (W), (2) nonrapid eye movement 1 (NREM 1), (3) NREM 2, (4) NREM 3, (5) NREM 4, and (6) rapid eye movement (REM). Although R&K classification has become the standard reference, it has certain shortcomings. First, the recording tool is large, causing a "real life" mobile recording complex. Second, the device setup and scoring based on the recording take a longer time and are costly. Therefore, traditional polysomnography (PSG) is unfit for observing the large populations. Besides, the time-consuming feature of PSG is a barrier to encounter the growing interest. Researchers have implemented various automated approaches for efficient analysis of sleep abnormalities based on EEG, EOG, and EMG recordings [2—4]. The sleep stage classification performed by an expert is less than 90% [5]. Traditional computerized classification systems for sleep stages comprise (1) spectral analysis [6]; (2) recurrent neural classifier [7]; (3) quadratic discriminant analysis [8]; (4) sleep scoring software (ASEEGA) [9]; (5) waveform recognition [10]; and (6) decision tree [10].

To obtain accurate performance and analysis based on the different physiologic reports, efficient sleep scoring is acknowledged to be a critical part of the method. In the modern technologic world, the conventional method that usually is practiced is the traditional visual scoring approach, although it needs expert visualization [11]. Sleep analysis using qualitative research yields certain shortcomings that include an expert interpretation that provides contradictory outcomes [12,13]. In the literature, the output obtained by two experts is $83 \pm 3\%$ (average), which is not promising [14].