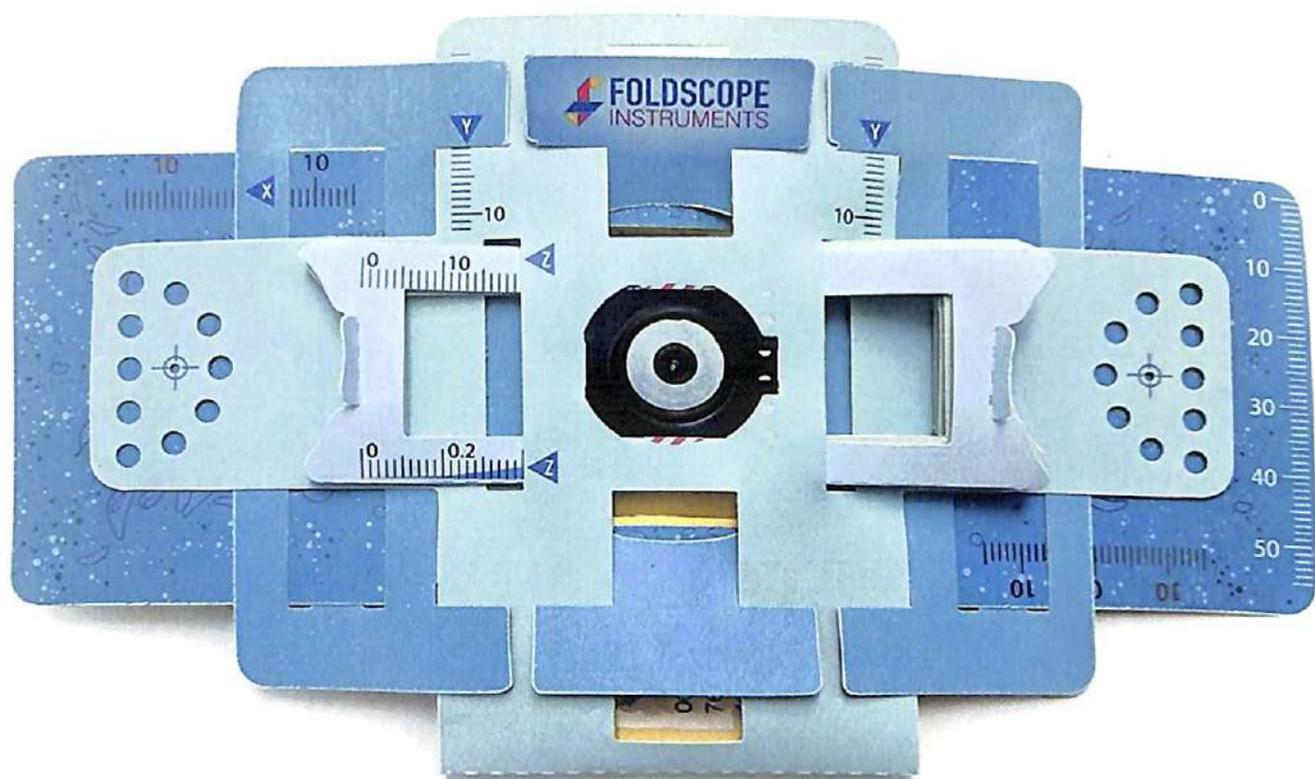


FOLDSCOPE AND ITS APPLICATIONS



CHIEF EDITOR
DR. ARUN DEV SHARMA

Foldscope and its Applications

EDITOR-IN-CHIEF

Dr. Arun Dev Sharma

ISBN No: 978-93-85835-68-1



**Published By:
National Press Associates, New Delhi**

Foldscope and its Applications

EDITOR-IN-CHIEF

Dr. Arun Dev Sharma

Editors

Dr. Gayatri Gurjar
Dr. Ch Tulasi Mastanamma
Dr. Indu Sharma
Dr. Shobha Ajeet Waghmode
Dr. SG Kulkarni
Dr. Bharathi Prakash
Dr. Dharmesh Harwani
Dr. Mousmisaikia
Dr. Mahipal Singh Shekhawat
Dr. Anupmaharshal W
Dr. KG Sabarinathan
Dr. M. Gomathy
Dr. KG Sabarinathan

© 2019. National Press Associates, New Delhi

All rights reserved 2019. No part of this book may be reproduced or Transmitted in any form or by any means of electronic or mechanical including photocopy, recording or any information stored in a retrieval system, without the prior written permission of the publisher.

ISBN No: 978-93-85835-68-1

Price: 800/-

The Responsibility for the facts or opinions expressed in the papers are entirely of the Authors. Neither the College nor the Publisher is responsible for the same.

Printed in India

National Press Associates

Admin Office: C-24, Ground Floor, Panchsheel Vihar, Malviya Nagar, New Delhi-110017, India

Regional Office: #79, Guru Angad Dev Nagar, Flower Enclave, Ludhiana (PB), India.

Branch Office: C-104, Anuroop Soceity, Vartak Nagar, Thane (West)-400606, Maharashtra, India

Email: info@npajournals.org www.npajournals.org

PREFACE

A Foldscope, a low-cost science tool, is an optical microscope that can be assembled from simple components, including a sheet of paper and a lens. It was developed by Dr. Manu Prakash and designed to cost less than US\$1 to build. It is part of the "frugal science" movement which aims to make cheap and easy tools available for scientific use in the developing world. The Department of Biotechnology (DBT), Government of India and the Prakash Lab at Stanford University, USA signed an agreement to bring the Foldscope to India to encourage curiosity in science. It is being used as a teaching tool for the students in biology, chemistry, physics and many other streams. Keeping these facts in the background, the editors and authors of the book have tried to compile their research and review outlook about Foldscope usage and its various applications. The aim of this book is to facilitate the adoption of Foldscope as an educational and research tool by students, teachers, scholars, scientists and the general people. Many authors who are also Project Investigators and recipients of the Foldscope research grant acknowledge Department of Biotechnology, Government of India. The authors hope that this book will not only provide pleasant reading but also practical knowledge which can be utilized by the user of this book in the area of Foldscope microscopy.

EDITOR IN CHIEF

Dr Arun Dev Sharma

*FISCA, FPASc, FSAWR, HOD,
Associate Prof, PG Dept of Biotechnology,
Lyallpur Khalsa College, Jalandhar, 144001, Punjab, India*

CONTENTS

APPLICATION OF THE FOLDSCOPE TO IDENTIFY, CHARACTERIZE INDIGENOUS SPECIES AND GENERATE A DNA BARCODE DATABASE <i>Anupma Harshal W, Sagarika Vivek Damle, Sharon K., Anand Sharma</i>	1	BIOFILM PRODUCING ORGANISMS AND THEIR ANTIBIOTIC RESISTANCE: A FOLDSCOPE APPROACH <i>Indu Sharma, Gayatri Gogoi, Parijat Hazarika</i>	87
FOLDSCOPE: AN EFFICIENT PORTABLE TOOL FOR PLANT BIOLOGISTS, EDUCATION AND SOCIETY <i>Arun Dev Sharma, Priya Nischal</i>	12	FOLDSCOPE AS A RESEARCH TOOL AND ITS APPLICATIONS <i>Jayateertha R Diwan, Kashappa Chikkanaragund</i>	95
PUBLIC PARTICIPATION IN MITIGATING WATER BORNE DISEASES USING FOLDSCOPE AS A TOOL IN TRIBAL REGION OF DAKSHINA KANNADA <i>Bharathi Prakash, G D Khedkar, S P Jeevan, K.E. Prakash, Vaniprabhu</i>	18	STANDARDIZATION OF FOLDSCOPE IN COMPARISON WITH A MICROSCOPE TO IDENTIFY E. COLI FOR FURTHER USE IN FIELD SETTINGS <i>Jeyakumar Angeline, Swapnil Godbharle, Bibek Raj Giri, Juana Hatwik</i>	101
FOLDSCOPE AS A STUDY TOOL FOR POLLEN GRAINS <i>Ch. Raghmani Singh, Y. Sunitibala Devi</i>	24	FOLDSCOPE: A PRIMARY TOOL FOR DETECTION OF BIOACTIVE COMPOUNDS IN PLANT CELLS <i>Kuldeep D. Shekhaliya, Jigna G. Tank, Rohan V. Pandya</i>	105
FOLDSCOPE: AN EDUCATIONAL CUM RESEARCH TOOL USED IN IDENTIFICATION OF MICROORGANISMS FROM WASTE WATER <i>Dharmendra Rathod</i>	29	STUDY OF MORPHOLOGY, HISTOLOGY, POWDER CHARACTERISTIC OF SOME DRUG BY USING FOLDSCOPE AS A RESEARCH TOOL <i>Juvatkar PV, Dr. Kale M. K., Khan NI, Gorde N, Waghulde S, Gokhale S</i>	117
FOLDSCOPE VIEW OF FLORAL AND FAUNAL DIVERSITY IN THE THAR DESERT OF RAJASTHAN <i>Dharmesh Harwani, Jyotsna Begani, Sweta Barupal, Jyoti Lakhani</i>	32	FOLDSCOPE AS A TOOL TO SCREEN PARASITIC INFECTIONS IN WILD ANIMALS OF TAMIL NADU <i>M. Palanivelrajan, K. Manoj Dhanraj, C. Sreekumar, K. Senthilkumar</i>	128
FOLDSCOPE AS A TOOL TO CREATE AWARENESS ABOUT HYGIENE AND INVOLVEMENT OF MICROBES AMONG STREET FOOD VENDORS AND CONSUMERS <i>Tulasi Mastanamma, Hima Bindu, Sunitha Das</i>	39	FOLIAR MICROMORPHOLOGICAL ANALYSIS OF <i>OXALIS CORNICULATA</i> L. USING FOLDSCOPE <i>Mahipal S. Shekhawat, Manokari M., Priyadharashini S., Cokul Raj M., Kannan N</i>	135
FOLDSCOPIES AS USER-FRIENDLY TOOL ON BONE MARROW STEM CELLS <i>Dr. A. Mangala Gowri</i>	48	AN EXPERIMENTAL INVESTIGATION ON THE QUALITY OF AIR AND GROWTH OF MICROORGANISM IN VARIOUS CONSTRUCTION MATERIALS AT VARIOUS CONDITIONS AND IN VARIOUS COOKING VESSELS <i>E. Muthu Kumaran, Manikannan Mathayan</i>	143
SCREENING FOR THE PRESENCE OF MICROBES IN VEGETABLE AND WATER SAMPLES FROM TWO DISTRICTS OF MANIPUR, INDIA, USING FOLDSCOPE <i>Pukhrambam Grihanjali Devi, Indira Yumnam, N. Romabati Devi</i>	55	VERSATILITY OF THE PAPER MICROSCOPE: <i>FOLDSCOPE</i> , MIRACLE MICROSCOPE <i>Moirangthem Bhubaneshwari Devi, Dhananjay Singh Chingangbam</i>	147
STUDY OF ZEBRAFISH EMBRYOGENESIS USING FOLDSCOPE <i>Gayathri N., Priti Dubey, Nitin Wasnik</i>	60	MICROSCOPIC CHARACTERIZATION OF BOTANICALS HAVING ANTI-MALARIAL PROPERTIES USED BY THE TRIBAL COMMUNITIES OF ASSAM <i>Pranab Borah and Mousmi Saikia</i>	154
A GLIMPSE INTO THE PLANT WORLD THROUGH FOLDSCOPE <i>Madhavi G Kanade, Gayatri S Gurjar</i>	65	✓ A FOLDSCOPIIC STUDY OF ARSENIC RESISTANCE BACTERIA IN GROUNDWATER SAMPLES OF LAKHIMPUR, ASSAM (INDIA) <i>Mridul Buragohain</i>	163
FOLDSCOPE AND PHYLOSOPHERE MICROORGANISMS <i>Gomathy, M, Sabarinathan, K.G, Subramaniam, K.S, Kalaiyarasi, VandJeyshree M</i>	76	FOLDSCOPE: LOW COST PAPER MICROSCOPE FOR ENVIRONMENTAL MONITORING <i>Munmi Gogoi, Dr. Dilip Saikia</i>	169
CERVICAL CANCER & IT'S DIAGNOSIS BY FOLDSCOPE <i>Hari Lakshmi Chikkala, K. Vijaya Rachel</i>	82	CAPTURING DIVERSE, IMPRESSIVE IMAGES USING FOLDSCOPE <i>Prarthana.J, Narayana</i>	175

FOLDSCOPE: A NEW AGE EXPLORATORY EDUCATIONAL TOOL

Lalit Mohan, Keshav Goyal, Shaubhik Anand, Muskan Mittal, Shrabani Snigdha, Tavleen Bajwa, Kusum R Gupta, Rakesh Kumar Gupta and Prerna Diwan

188

EXPLORATION OF ARBUSCULAR MYCORRHIZAL FUNGI (AMF) IN THE RHIZOSPHERE OF FIVE VARIETIES OF *COCOS NUCIFERA* L. DURING SUMMER SEASON IN POLLACHI TALUK, COIMBATORE DISTRICT, TAMILNADU, INDIA

Nivedha. D, R. Gokilavani and H. Rehanabanu

194

A COMPARATIVE STUDY ON USE OF FOLDSCOPE AND COMPOUND FOLDSCOPE FOR BIOLOGICAL SAMPLE THE OBSERVATION

S. T. V. Raghavamma

201

FOLDSCOPE: AN INNOVATIVE TOOL TO STUDY AGRICULTURALLY IMPORTANT MICROBES.

Sabarinathan K. G, M. Gomathy, D. Arun Kumar and R. Kannan

206

FOLDSCOPE: A VERSATILE TOOL TO STUDY THE PUPPET MASTERS OF RHIZOSPHERIC AND AQUATIC MICROBIOME

Satish V. Patil, Bhavana V. Mohite

212

DETECTION AND DIAGNOSIS OF FISH PATHOGENS USING FOLDSCOPE ON FRESHWATER FISHES IN THE WATER BODIES OF THE CHIRANG DISTRICT OF ASSAM, INDIA

Sewali Pathak

219

DIAGNOSIS OF NATURE'S KIDNEY WITH THE AID OF FOLDSCOPE

ShamimRahman

225

GREEN SYNTHETIC APPROACH CORESHELL NANOMATERIALS: AS AN ANTIMICROBIAL AGENT.

ShobhaA. Waghmode

231

MAPPING MICROSCOPIC BIODIVERSITY IN AQUATIC ECOSYSTEMS USING PAPER MICROSCOPE 'FOLDSCOPE'

Maya Murdeshwar, SujataDeshpande, Siddhi Parab, Jennifer Tellis

238

MICROSTRUCTURAL EXAMINATION OF WASTE E- WASTE REINFORCED POLYMER MATRIX COMPOSITE BY NOVEL MICROSCOPY

Swanand Gajanan Kulkarni

252

A FOLDSCOPIIC STUDY OF ARSENIC RESISTANCE BACTERIA IN GROUNDWATER SAMPLES OF LAKHIMPUR, ASSAM (INDIA)

Mridul Buragohain

Department of Chemistry, Lakhimpur Girls' College, North Lakhimpur, Assam, India

Abstract

Arsenic pollution in our ecosystem is nowadays a severe risk effecting to human population. Millions of people across the globe unknowingly depends on arsenic contaminated groundwater for drinking purpose and facing serious health hazards. The groundwater is known to be contaminated from different xenobiotic and anthropogenic sources leading to fatal diseases as cancer and skin lesions. Arsenic in the form of arsenate (IV) and arsenite As (III) is toxic in water sources. Presence of microbial biome such as *E. coli*, *Pseudomonas*, and *Actinobacter* helps to reduce the arsenic in ground water. Microscope provides a beneficial instrument for visualization of bacteria. Instead of that, Foldscope- an origami based low cost paper fold microscope provides to visualize such bacteria in water samples at instant. This study mainly focused on the application of Foldscope for investigating gram stained and arsenic resistance bacteria of different ground water sources, where foldscopic images were obtained.

Keywords: groundwater, gram stained and arsenic resistance bacteria, foldscopic view, etc.

Introduction

Rising of urbanization, industrial pollution, burning of fossil fuels elevated the range of arsenic in the biosphere. Concentration of arsenic is found to be high in rainfall thus troubles to groundwater. In Asian countries including India arsenic polluted groundwater is being used for drinking and irrigation¹. Estimation of fifty million populations in Bangladesh depends on arsenic contaminated tube wells and suffering from severe chronic diseases including cancer². Dissolution of Fe, Mn oxyhydroxide, NaHCO_3 , DOC and high pH are the main factor of As mobilization in ground water³. Elevated form of arsenic in water sources results in a stress livelihood to a society including poverty and a drop of agricultural products⁴. Volcanic eruption and hydrothermal sources cause a major role in arsenic contamination to the environment⁵. In most districts of West Bengal(India), it was reported that water used for drinking and agricultural purpose were elevatedly affected by arsenic. A positive correlation of arsenic concentration between soil and water was also seen⁶. To equalized the arsenic contamination, arsenic resistance gene of bacterial species are found to remain associated with ars operon. These moiety are As(III) genes responsive regulation on (ArsR), As(III) efflux permease (ArsB or ACR3) that expel As (III) from the cell⁷. Bas1 and Bas2 two bacterial strains isolated that can convert the toxin As (III) to non toxic As (V) and is reported to be used in bioremediation process⁸. *Bacillus* species BARI was also isolated from arsenic polluted groundwater which reported to be resistant to arsenic and also resistance to other Cu, Cd, Ni, Hg, Zn heavy metals.⁹ *Pseudomonas*, *Bacillus*, *Psychrobacter*, *Enterobacter*, *Vibrio* show a elevated resistance capacity for As with a minimum inhibitory concentration from 2-200Mm¹⁰. A study in Hetao plain, Inner Mongolia reflected the presence of *Pseudomonas* and *Acinetobacter* in a dominated pause of both high and low As groundwater¹¹. High As resistant bacterial strains- *Actinobacteria*, *Microbacterium*, *Pseudomonas* and *Rhizobium* were localized in ground water of West Bengal (India) showing minimum inhibitory concentration of about > 10 mM¹². Arsenate reductase activity is seen to be influenced by *Agrobacterium*, *Achromobacter*, *Rhizobium*, *Ochrobactrum* starins isolated from arsenic contaminated groundwater of West Bengal (India)¹³.

Arsenic release in environments occurs due to weathering of rocks, minerals (arsenopyrite) and anthropogenic sources. Mobilization of arsenic in ecosystem is influenced by hydrogeochemical reactions, and redox reactions carried by potential micro biomes. Elevated form of arsenic is found with high concentration of Fe oxide and pyrites⁴. Sulphate and iron reduction isolates *Deltaproteobacteria*, *Nitrospirae* were found positive in arsenic mobilization¹⁴. Phosphatase and siderophores play a crucial role in release of As (V) and As (III) is reduced by arsenate reductase to mobilize arsenic in groundwater¹³. Oxalic acid assemblance and As (V) reductase of *Brevundimonas*, *Flavobacterium*, *Rhodococcus*, *Methyloversatilis*, *Methylotener*, *Pseudomonas* and *Polaromonas*, *Brevundimonas*, *Acinetobacter*, *Bosea*, *Bacillus*, *Brevundimonas*, a lead to mobilized arsenic in wide range¹⁵.

Caulobacter Herbaspirillum, Pseudomonas, Staphylococcus, Ralstonia, Rhizobiales, Rhodococcus, Undibacterium found to use the carbon source and grow chemolithotrophically enhancing the arsenic mobilization in groundwater¹⁶. PO_4^{3-} , SO_4^{2-} , HCO_3^- , carbonate dissolution and Fe-oxyhydroxides important factor of reduction influences mobilization of arsenic¹⁷. Arsenic contamination in groundwater is geogenic and may triggered by Fe (III) oxides and sulphide oxidation¹⁸.

Increasing of anthropogenic and xenobiotic activities by human, arsenic contamination in groundwater is now in elevated form. Infectious health hazards is a stressed for human population that depends mainly on natural water sources. Arsenicosis- nearby incurable disease includes skin lesions, cancer in lungs, liver, urine and kidney is nowadays a serious issue to humans¹⁹. Mee lines symptom is mostly occurable in fingernails due to arsenic toxicity resulting in various cardiovascular diseases. Diabetes and pregnancy outcomes such as child mortality is an another cause factor of arsenic toxicity in drinking water. High arsenic exposure to drinking water also leads to chronic respiratory problems such as cough, breathing problem etc. Contaminated arsenic water used for irrigation purpose is passed to our nutritional crops. Cattles feeding on arsenic polluted water sources face a vulnerable death.

Materials and Methods

A. Profile of the study area

Lakhimpur district (Fig. 1) lies on the North East corner of Assam and at the North Bank of the mighty river Brahmaputra. The district lies between 27.597° Northern latitude and 94.737° Eastern longitude and covers an area of 2277 Sq km out of which 2257 Sq km is rural and 20 sq km is urban. It is bounded on the North by Siang and Papumpare District of Arunachal Pradesh and on the East by Dhemaji District and Subansiri River. The river Brahmaputra along with Majuli district stands on the southern side and Gahpur sub division of Biswanath district is on the West. The area is characterized by a temperature range of 24°C-33°C and with an average humidity of 82%. The annual rainfall of the district is 1551.3 mm per year²³.

B. About Foldscope

A Foldscope is an optical microscope (Fig. 2) which is very easy and affordable for mankind. The Foldscope was developed by a team led by Manu Prakash and his student Jim Cybulski from Stanford University, USA²⁰. It is a part of the "frugal science" movement which aims to make cheap and easy tools available for scientific use in the developing world²¹. It can be assembled from a punched sheet of cardstock, a spherical glass lens, a light emitting diode and a diffuser panel, along with a watch battery that powers the LED²². The idea of creating a low-cost microscope using simple parts struck to Manu Prakash in 2011, when he was having a scientific visit to a field station in Thailand. There, he observed that though expensive microscopes were available in the station, people seldomly used them and were afraid of or apprehended that this costly equipment might go bad or broken by their mistakes or mishandlings. It made Manu Prakash think to create a cheap, affordable and versatile device which was sturdy enough to be used in field conditions and people should not have a hitch to use it. He also thought to supply the Foldscope in form of an easy to assemble kit so that people can assemble it themselves. Foldscope can be assembled from a punched sheet of cardstock, a spherical glass lens, a light emitting diode and a diffuser panel, along with a watch battery that powers the LED²². Once assembled, the Foldscope is about the size of a bookmark. Its weighs about 8 grams and comes in a kit with multiple lenses that provide magnification from 140X to 2,000X. The kit also includes magnets that can be stuck onto the Foldscope to attach it to a smart phone, which allow the user to take pictures of the magnification²¹.

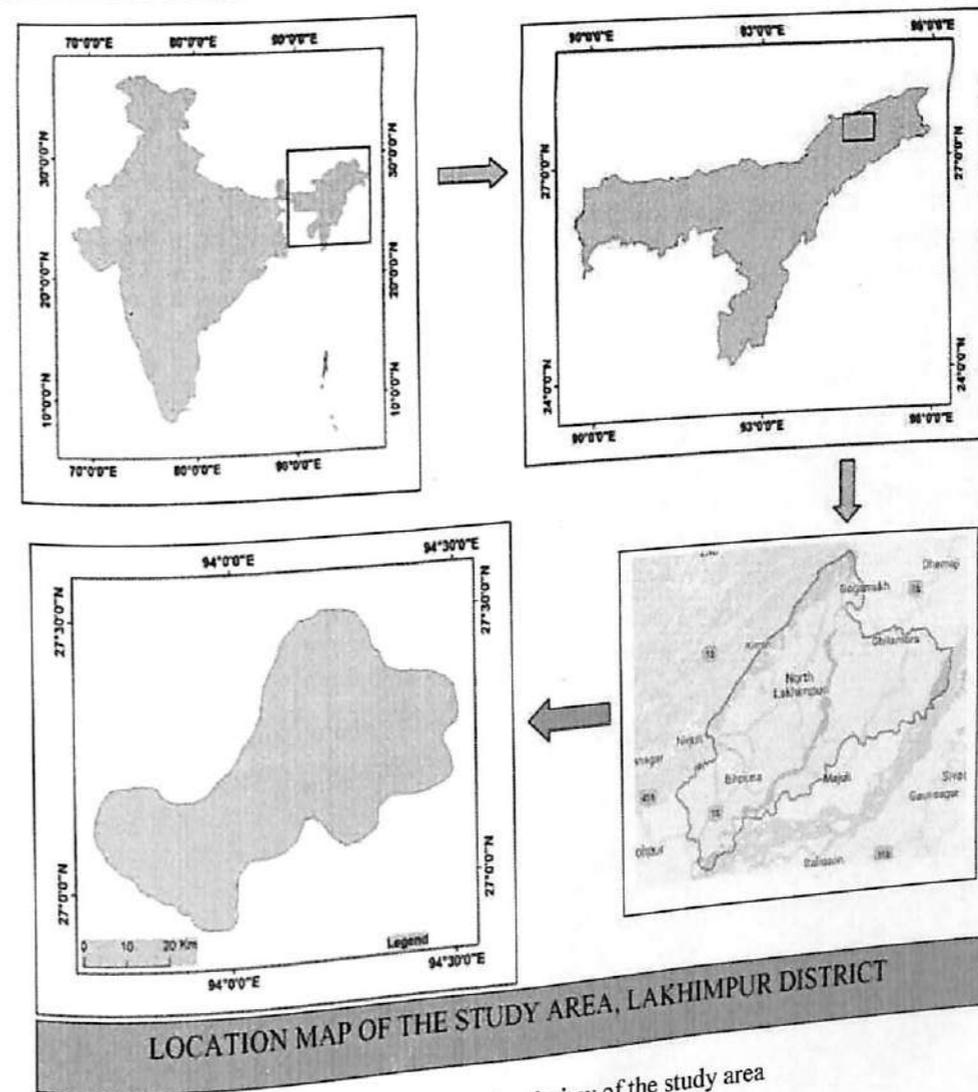


Fig. 1: A cross sectional view of the study area

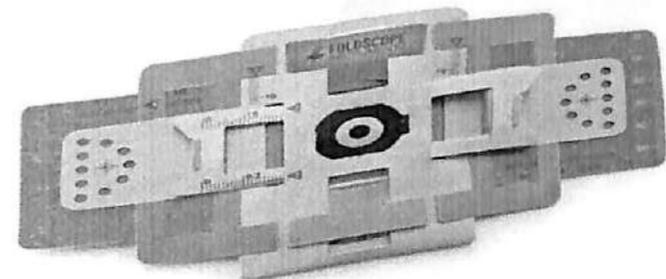


Fig. 2: Front view of Foldscope

C. Sample Collection and Gram's staining

Water samples were collected from groundwater of different locality of Lakhimpur district, Assam. The samples were smeared in sterilized slides and further processed for gram staining.

D. Estimation of Arsenic concentration in watersamples

Arsenic concentration in the water samples was analyzed by atomic absorption spectrophotometer (model-'240AA by Agilent Technologies').

E. Isolation of arsenic resistance bacteria

About 1ml water samples were spread on nutrient agar plates that contain 5mM As (V), 1mM As (III), for the isolation of arsenic-resistant bacteria. After 24 h of incubation at 37 °C the growth of bacteria was observed. Individual colonies were picked and streaked on fresh nutrient agar medium and discrete colonies were picked up and were preserved at 4°C on nutrient agar slants.

Results

A. Isolation of bacteria

A total of 10th bacterial strains were isolated from water samples based on their abilities to grow in the presence of 5mM As (V), 1mM As (III) in the medium. The cultures showing substantial growth were transferred to fresh medium. After three more transfers, discrete colonies were picked up and were preserved at 4 °C on nutrient agar slants. Out of 10th isolates, among one of them GB-18 was (0.86 ± 0.04) highest growth found on acetate minimal medium supplement with arsenate and arsenite in one week incubation periods. This isolate was chosen for further study.

B. Foldscopic images of Isolated of bacteria

Foldscopic view of Gram staining (+ ve & - ve) and Arsenic resistance bacteria are given in figure 3 and 4.

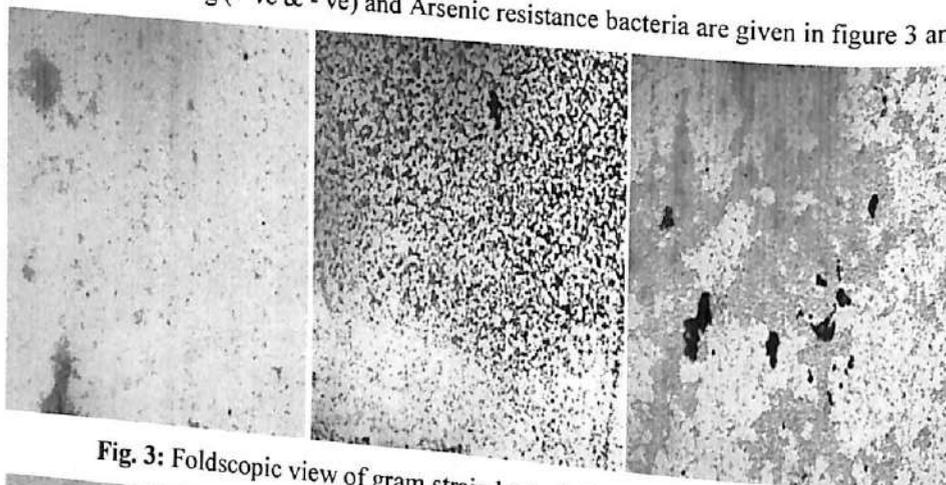


Fig. 3: Foldscopic view of gram stain bacteria in groundwater samples

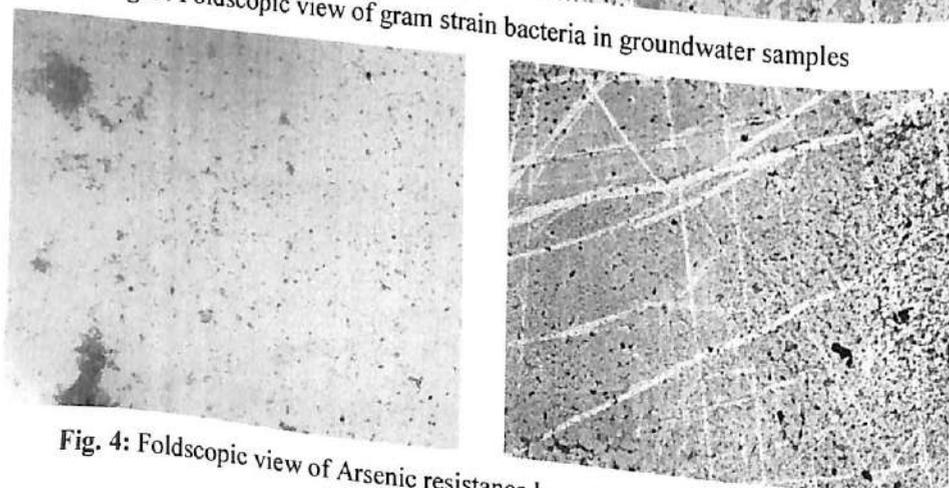


Fig. 4: Foldscopic view of Arsenic resistance bacteria in groundwater samples

Conclusion

Foldscope is a brilliant innovation. It paves ways for other such innovations for replacement of costly scientific instruments. Scientists like Manu Prakash have shown that simple and affordable scientific devices can be designed, was fabricated for the use of common masses and can be made available in the remotest part of the world for scientific exploration which is very very easy, useful and affordable for all mankind. Application of this low-cost microscopy technology to a different domain of microscopic study would help people to better understanding microscopic world around us including microorganisms and micro-structure.

The present study shows a marvelous view regarding the easy handling of Foldscope. The comparative microscopic (10X) and foldscopic view (140X) marks no difference in visualization of the samples. The study reported that uses of Foldscope are one of the cheapest and easiest technology in visualization of bacteria present in water samples. Foldscope is an advanced technology developed in microscopic world that will help the people to understand the microscopic world troublesly.

Acknowledgement

This research was supported by a grant from Department of Bio Technology (DBT), Govt. of India, New Delhi in the form of Major Research Project vide no. BT/IN/INDO-US/FOLDSCOPE/39/2015, dated 20th March, 2018.

References

- Chakrabarti, D, Singh S.K, Rashid Md. H, Rahman M.M, (2017): Arsenic: Occurrence in groundwater, Encyclopedia of Environmental Health, Elsevier <https://doi.org/10.1016/B978-0-12-409548-9.10634-7>
- Ahmad S.A, Khan M.H, Haque M, (2018): Arsenic contamination in groundwater in Bangladesh: implications and challenges for healthcare policy, Risk Management and Healthcare Policy, pp 251-261; <https://doi.org/10.2147/RMHP.S153188>.
- Anwar M.H, Akai J, Komaki K, Terao H, Yoshioka T, Ishizuka T, Safiullah S, Kato K (2003): Geochemical occurrence of arsenic in groundwater of Bangladesh: sources and mobilization process (2003), Journal of Geochemical Exploration, Elsevier, pp 109-131 [https://doi.org/10.1016/S0375-6742\(02\)00273-X](https://doi.org/10.1016/S0375-6742(02)00273-X).
- Shankar S, Shankar U, Shikha (2014): Arsenic contamination of Groundwater : A review of sources, prevalence, health risks and strategies for Mitigation, The Scientific World Journal, <https://doi.org/10.1155/2014/304524>.
- Dhuldhaj U.P, Yadav I.C, Singh S, Sharma N.K, (2013): Microbial Interactions in the Arsenic Cycle: Adoptive Strategies and Applications in Environmental Management, Review of Environmental Contamination and Toxicology, https://doi.org/10.1007/978-1-4614-5882-1_1.
- Shrivastava A, Barla A, Yadav H, Bose S (2014): Arsenic contamination in shallow groundwater and agricultural soil of Chakdaha block, West Bengal, India, Frontiers in Environmental Science, <https://doi.org/10.3389/fenvs.2014.00050>.
- Yang H.C, Rosen B.P, (2015): New Mechanisms of bacterial arsenic resistance, Biomedical Journal, pp 5-13, <https://doi.org/10.1016/j.bj.2015.08.003>.
- Biswas R, Sarkar A, (2018): Characterization of arsenite-oxidizing bacteria to decipher their role in arsenic bioremediation, Preparative Biochemistry and Biotechnology, <https://doi.org/10.1080/10826068.2018.1476883>
- Biswas R, Majhi A.K, Sarkar A (2019): The role of arsenate reducing bacteria for their prospective application in arsenic contaminated groundwater aquifer system, Biocatalysis and Agricultural Biotechnology, Elsevier, <https://doi.org/10.1016/j.bcab.2019.101218>
- Liao V H, Chu Y et.al. (2011): Arsenite-oxidizing and arsenate-reducing bacteria associated with arsenic rich groundwater in Taiwan, Elsevier, <https://doi.org/10.1016/j.jconhyd.2010.12.003>
- Wang Y, Lil P et.al. (2016): Microbial community of high arsenic groundwater in agricultural irrigation area of Hetao plain, Inner Mongolia, Frontiers in Microbiology, <https://doi.org/10.3389/fmicb.2016.01917>
- Paul D, Poddar S, Sar P (2014): Characterization of arsenite-oxidizing bacteria isolated from arsenic-contaminated groundwater of West Bengal, Journal of Environmental Science and Health, <https://doi.org/10.1080/10934529.2014.937162>
- Sarkar A, Kazy S. K, Sar P (2013): Characterization of arsenic resistant bacteria from arsenic rich groundwater of West Bengal, India, Ecotoxicology, <https://doi.org/10.1007/s10646-012-1031-z>
- R.E Danczak, M D Johnston, C Kenah, M Slattery, M J Wilkins (2019): Capability for arsenic mobilization in groundwater is distributed across broad phylogenetic lineages, Plos one, <https://doi.org/10.1371/journal.pone.0221694>.
- D Paul, S K Kazy, A K Gupta, T Pal, P Sar (2015): Diversity, Metabolic Properties and Arsenic Mobilization Potential of Indigenous Bacteria in Arsenic Contaminated Groundwater of West Bengal, India, Plos one, <https://doi.org/10.1371/journal.pone.0118735>.

16. G Soma, S Pinaki (2013): Identification and characterization of metabolic properties of bacterial populations recovered from arsenic contaminated ground water of North East India (Assam), *Water research*, Elsevier, pp 6992-7005, <https://doi.org/10.1016/j.watres.2013.08.044>.
17. S Bhowmick, B Nath et.al. (2012): Arsenic mobilization in the aquifers of three physiographic settings of West Bengal, India: Understanding geogenic and anthropogenic influences, *Journal of Hazardous Materials*, Elsevier, <https://doi.org/10.1016/j.jhazmat.2012.07.014>.
18. H Indika, V Meththika et.al. (2016): Natural Arsenic in Global Groundwaters: Distribution and Geochemical Triggers for Mobilization, *Current Pollution Reports*, Springer, <https://doi.org/10.1007/s40726-016-0028-2>.
19. Shankar S, Shanker U, Shikha (2014): Arsenic Contamination of Groundwater: A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation, *The Scientific World Journal*, <https://doi.org/10.1155/2014/304524>.
20. Coxworth, Ben, "Folding paper microscope could reduce deaths from malaria". *Gizmag*. Retrieved 13 March 2014.
21. "A Microscope to Save the World". *The New Yorker*. Retrieved 2015-12-22.
22. Mathews, Lee (11 March 2014): "Foldscope is a 50-cent paper microscope that magnifies up to 2000 times". *Geek.com*. Retrieved 13 March 2014.
23. Statistical Hand book, Assam (2017) Directorate of Economics and Statistics, Govt. of Assam, Guwahati-28



Published By

NATIONAL PRESS ASSOCIATES

PUBLISHERS AND DISTRIBUTORS OF INDIAN AND INTERNATIONAL JOURNALS

ADMIN OFFICE C-24, GROUND FLOOR, PANCHSHEEL VIHAR, MALVIA NAGAR,
NEW DELHI- 110017 (INDIA)

REGIONAL OFFICE 79, GURU ANGAD DEV NAGAR, FLOWER ENCLAVE, DUGRI,
LUDHIANA-141013 (PUNJAB), INDIA

BRANCH OFFICE C-104, ANUROOP SOCIETY, VARTAK NAGAR, THANE (WEST) -
400606, MUMBAI, MAHARASHTRA (INDIA)

E-MAIL: info@npajournals.org

Website: www.npajournals.org

ISBN 978-93-85835-68-1



9 789385 835681 >