BIOSURFACTANTS:

A BOON TO HEALTHCARE, AGRICULTURE & ENVIRONMENTAL SUSTAINABILITY

Editors:
Arun Kumar Pradhan
Manoranjan Arakha

Bentham Books

Biosurfactants: A Boon to Healthcare, Agriculture & Environmental Sustainability

Edited by

Arun Kumar Pradhan
Centre for Biotechnology
Siksha 'O' Anusandhan (Deemed to be University)
Bhubaneswar, Odisha-751030
India

&

Manoranjan Arakha
Centre for Biotechnology
Siksha 'O' Anusandhan (Deemed to be University)
Bhubaneswar, Odisha-751030
India

Biosurfactants: A Boon to Healthcare, Agriculture & Environmental Sustainability

Editors: Arun Kumar Pradhan and Manoranjan Arakha

ISBN (Online): 978-981-5196-92-4

ISBN (Print): 978-981-5196-93-1

ISBN (Paperback): 978-981-5196-94-8

First published in 2024.

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.
80 Robinson Road #02-00
Singapore 068898
Singapore
Email: subscriptions@benthamscience.net

BENTHAM SCIENCE

CONTENTS

PREFACE

Biosurfactants are surface-acting molecules isolated from microbes (bacteria and fungi) and plants. The amphipathic nature of biosurfactants makes their application broader. Different types of biosurfactants are isolated and characterized *i.e.* glycolipids, lipopeptides, phospholipids and polymerics. These molecules have emulsifying, wetting, and foaming properties. So biosurfactants are used in pharmaceuticals, cosmetics, food, mining, and petrochemical industries. Research confirms their antimicrobial, anticancer and anti-biofilm formation capacities. They can remove oil from the contaminated soil of oil mines. Biosurfactants can be used in oil spillage aquatic areas to remove oil. They can scavenge heavy metals in contaminated soil and make the environment free from xenobiotics. With the help of nanotechnology, biosurfactants can be used to detect heavy metals in the environment. Nowadays, biosurfactants are used as potential agents in agricultural post-harvest technology. They play an important role in agrochemical industries.

In view of the above discussion, the overarching aim of this book is to discuss major applications of biosurfactants in the fields of healthcare, agriculture and the environment.

The unique features of this book are as follows:

• The book is a contribution of experts from microbiology, cancer biology, pharmaceutical science, nanotechnology, plant biotechnology and environmental sciences.

• The book discusses some novel applications of biosurfactants in the fields of medicine, agriculture and the environment.

The book, in total, comprises 11 chapters written by experts working in the respective aspects of biosurfactants. For instance, Chapter 1 and 2 describe the screening of biosurfactant-producing organisms, the production of biosurfactants and their various applications. Chapter 3 and 4 interpret the application of biosurfactants in the healthcare sector, like various cancer treatments and neurological disorders.

Agricultural applications and food processing with the help of biosurfactants are well explained in chapters 5 and 6. Biosurfactants show vast applications in the environmental cleaning sector. Bioremediation, removal of heavy metal from soil and water by biosurfactants, and removal of oil from contaminated soil by biosurfactants are described in chapters 8, 9, 10 and 11.

We are very much thankful to all the contributing authors for their timely cooperation and support, without which this book would not have taken its final shape. We are also thankful to the series editors for their critical reviews and positive remarks to bring positive developments in the book.

Arun Kumar Pradhan
Centre for Biotechnology
Siksha 'O' Anusandhan (Deemed to be University)
Bhubaneswar, Odisha-751030
India

&

Manoranjan Arakha
Centre for Biotechnology
Siksha 'O' Anusandhan (Deemed to be University)
Bhubaneswar, Odisha-751030
India

List of Contributors

Ananya Kuanar	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Arun Kumar Pradhan	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Arabinda Jena	Fisheries, UNDP (Collaboration with Directorate Fisheries), Cuttack, Odisha-753001, India
Banishree Sahoo	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Bhabani Shankar Das	Centre for Biotechnology, School of Pharmaceutical Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Elina Khatua	Environment and Sustainability Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha-751003, India Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh, 201002, India
Gargi Balabantaray	Department of Immunology and Rheumatology, Institute of Medical Science, Sum Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India
Manisha Mahapatra	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Manoranjan Arakha	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Meena Choudhary	Analytical and Environmental Science Division & Centralized Instrument Facility, CSIR-Central Salt & Marine Chemicals Research Institute, G.B. Marg, Bhavnagar-364002, India Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India
Monali Muduli	Analytical and Environmental Science Division & Centralized Instrument Facility, CSIR-Central Salt & Marine Chemicals Research Institute, G.B. Marg, Bhavnagar-364002, India Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India
Muchalika Satapathy	AIPH University, Bhubaneswar, India
Nilotpala Pradhan	Environment and Sustainability Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha-751003, India Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh, 201002, India
Pratyasha Panda	AIPH University, Bhubaneswar, India
Pradeepta Sekhar Patro	Department of Immunology and Rheumatology, Institute of Medical Science, Sum hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India

Pyari Payal Beura	Department of Biotechnology, Rama Devi Women's University, Vidya Vihar, Bhubaneswar, Odisha-751003, India
Sameer Ranjan Sahoo	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Sanak Ray	Analytical and Environmental Science Division & Centralized Instrument Facility, CSIR-Central Salt & Marine Chemicals Research Institute, G.B. Marg, Bhavnagar-364002, India Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India
Sanjay Kumar Raul	Department of Biotechnology, Rama Devi Women's University, Vidya Vihar, Bhubaneswar, Odisha-751003, India
Sibani Sahoo	Gangadhar Meher University, Sambalpur, India
Soumyashree Rout	Department of Neurology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India
Srikanta Kumar Sahoo	Department of Neurology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India
Swapnashree Satapathy	Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751030, India
Swastika Mallick	Environment and Sustainability Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha-751003, India Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh, 201002, India
Truptirekha Das	Rautara Govt. High School, Binjharpur, Jajapur,, Odisha-755004, India
Twinkle Rout	Department of Surgical Oncology, Institute of Medical Sciences and Sum Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India

CHAPTER 1

Biosurfactants: An Amazing Bioactive Compound

Sameer Ranjan Sahoo[1], **Manisha Mahapatra**[1] and **Arun Kumar Pradhan**[1,*]

[1] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Biosurfactants are organic compounds synthesized by microorganisms such as bacteria, yeasts, or fungi. These compounds exhibit intricate chemical compositions and unique physical properties, often surpassing or rivaling synthetic surfactants. Furthermore, they typically have low toxicity towards freshwater, marine, and terrestrial ecosystems, making them environmentally favorable for various applications. To date, the primary focus of biosurfactant research has centered on enhancing the biodegradation and recovery of oil. These substances have demonstrated their utility in aiding the removal of hazardous contaminants from polluted areas due to their capacity to solubilize and emulsify harmful pesticides. Their versatility as chemical agents renders them suitable for deployment in both biotechnological and industrial applications. This review aims to provide readers with an extensive comprehension of recent advancements in utilizing biosurfactants and the microorganisms responsible for their production. This knowledge encompasses their medical applications, metal remediation technology, and hydrocarbon-related industries.

Keywords: Antimicrobial, Biosurfactants, Bioremediation, Emulsification, Glycolipid, Lipopeptide.

INTRODUCTION

Surfactants are a class of chemicals found in a wide range of fields, such as chemicals, fast-moving consumer goods, pharmaceuticals, and oil/water treatment. Biosurfactants are a family of chemical compounds synthesized by microorganisms, including hydrophilic and hydrophobic moieties. They tend to disperse interfaces between liquid phases (oil/water) of varying degrees of polarity by lowering interfacial and surface tension. Surfactants derived from microorganisms have numerous advantages over synthetic ones, including low toxicity, high biodegradability, multifunctionality, and mild manufacturing conditions.

* **Corresponding author Arun Kumar Pradhan:** Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: arunpradhan@soa.ac.in

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

An *emulsifier* is a substance composed of polymers of polysaccharides, lipopolysaccharides, proteins, lipoproteins, and glycolipids with a low molecular weight, known as a biosurfactant [1 - 3]. The former's molecular components are typically more effective in maintaining oil-in-water emulsions, although they reduce surface tension less than the latter's. It comprises non-interfering amphiphilic and multi-affinity polymers [4].

These compounds, primarily biosynthetically derived as secondary metabolites, play crucial roles in the proliferation and localization of microorganisms. The hydrophobic segment of these molecules comprises long-chain fatty acids, hydroxy fatty acids, or alkyl hydroxy fatty acids. On the other hand, hydrophilic components may include carbohydrates, amino acids, cyclic peptides, phosphates, carboxylic acids, and alcohols. The commercial surfactant market is from petrochemicals, plants, animal fats, and microorganisms. Research indicates that a substantial majority of commercially available surfactant products are petrochemical-based. One of the environmental agencies' transformative challenges involves developing innovative technologies to replace fossil fuel-based products with sustainable, biodegradable, green energy sources.

Numerous microorganisms demonstrate the capacity to utilize diverse substrates, including sugars, oils, alkanes, and various waste materials, for the biosynthesis of biodegradable surfactants [5]. Biosurfactants typically exhibit critical micelle concentrations (CMC) within the 1-200 mg/l range, accompanied by molecular weights ranging from 500 to 1500 Da [6]. Notably, they can rival or surpass the effectiveness of synthetic surfactants due to their distinctive advantages, such as high specificity, biocompatibility, and inherent biodegradability [7]. Biosurfactants represent a category of biodegradable surfactants primarily produced by bacteria and yeast [8-10].

Lipopeptides are mainly produced by Bacillus spp. followed by *Brevibacterium aureum* and *Nocardiopsis alba*. Glycolipids by Pseudomonas, Burkholderia, Mycobacterium, Rhodococcus, Arthrobacter, Nocardia, Gordonia. Some yeasts and fungi such as Starmerella, Yarrowia and Pseudozyma, *Ustilago scitaminea* also found to produce glycolipids. Thiobacillus sp. are found associated with phospholipids production [11].

The adaptability and utility of the molecules have generated attention in industrial and ecological applications such as bioremediation, soil cleansing, better oil recovery, and processing [12]. Emerging commercial applications have been found in chemical, textiles, agricultural, pharmaceuticals, food, and manufacturing industries [10, 13].

Biosurfactants accumulate at the intersection of two immiscible phases or the contact of a liquid and a solid. Lowering surface and interfacial tension minimizes repulsive forces between two distinct phases, allowing for easier mixing and contact. Below are some examples of biosurfactants and their application refer to Table **1**.

Table 1. Some examples of biosurfactants and their applications.

Biosurfactants		**Microorganism**	**Environmental Biotechnology Applications**	**References**
Group	**Class**			
Glycolipids	Rhamnolipids	*Pseudomonas aeruginosa*, Pseudomonas sp.	Improvement of hydrocarbon degradation and dispersion; emulsification of hydrocarbons and vegetable oils; elimination of metals from soil	[17]
	Trehalolipids	*Mycobacterium tuberculosis*, *Rhodococcus erythropolis*, Arthrobacter sp., Nocardia sp., Corynebacterium sp., *Serratia marcescens.*	Increase of hydrocarbon bioavailability	[18]
	Sophorolipids	*Torulopsis bombicola, Torulopsis petrophilum, Torulopsis apicola*, *Candida apicola, Candida bombicola, Candida bogoriensis, Candida lipolytica*	Hydrocarbon recovery from dregs and muds; heavy metal reduction from sediments; oil recovery improvement	[19]

CHAPTER 2

Biosurfactants: Screening, Production and their Applications

Truptirekha Das[1], **Sameer Ranjan Sahoo**[2,*] and **Arun Kumar Pradhan**[2]

[1] *Rautara Govt. High School, Binjharpur, Jajapur, Odisha-755004, India*

[2] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Biosurfactants are commonly recognised as biologically derived surface active agents. The most significant microbes have been studied for the production of glycolipid biosurfactants, including *Pseudomonas aeruginosa, Bacillus subtilis,* and Candida spp. Microbial derived biosurfactants are found commercially superior to chemical derivatives due to their biodegradability, renewability, and good performance under harsh working conditions. It has been found that (isolated) hydrocarbon-degrading bacteria produce far more biosurfactants than that predicted from oil spills. This is because all genomes are regulated in lipid metabolism synthesis. The oil and petroleum sector use biosurfactants as an emulsifier for both recovery and removal from contaminated sites. They also play a role in the removal of heavy metals in metallurgy. In this work, we have provided an overview of the screening of microorganisms that produce biosurfactants, production techniques, and variables that affect the production of biosurfactants. Several analytical approaches for crude metabolite processing are also given. Hence, the importance of biosurfactants in environmental cleaning is simply understood from this review.

Keywords: Antiviral, Biodegradability, Biosurfactants, Metallurgical, Petrochemical industry.

INTRODUCTION

Biosurfactants are microorganism-produced surface active chemicals with critical environmental applications. Biosurfactants are classified into three groups: glycolipids, phospolipids, and lipopeptides. It was observed that glycolipid biosurfactants comprising sugar molecules and hydroxyl fatty acids had hydrophilic and hydrophobic characteristics. The latter has been demonstrated to have the properties of a surfactant, an emulsifier, and a bioactive material. Biological surfactants are often biodegradable, secure, and renewable. They have

* **Corresponding author Sameer Ranjan Sahoo:** Centre for Biotechnology, Siksha *'O'* Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: sahu.samir070@gmail.com

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

the potential to function better than artificial surfactants because of their strong interfacial tension, high surface tension, and critical micelle concentration. They are readily and quickly manufactured.

Biological surfactants function well as detergents, foaming agents, wetting agents, and microemulsifiers [1]. They can function in high pH, salinity, and temperature environments [2].

The critical micelle concentration of surfactants ranges from 5-380 mg/l, and they can generally lower the surface tension of water to 25-40 mN/m. Additionally, it lowers the interfacial tension between oil and water to 1 dyn/cm. Due to its capacity to degrade a variety of substrates, *Pseudomonas aeruginosa* is a perfect microbe for biosurfactant production. For production, economically feasible raw materials like oil waste, soap residues, waste from food firms and vegetable oil refineries are being used. Of all carbon sources, vegetable-based oil has the highest biosurfactant yield [3]. Also, the characteristics of biosurfactants are comparable. Glycolipid biosurfactants, on the other hand, have been identified as potential biosurfactants with a variety of benefits. Environmental cleanup, non-toxicity, and biodegradability are only a few of the benefits. Biosurfactants have a wide range of uses, including medicines, therapies, cosmetics, detergents, agriculture, heavy metal removal, and recovery of oil [4].

Biosurfactant Classification

Synthetically produced biosurfactants are categorised according to their polar groups, which are determined by distinct molecules constituting the hydrophobic (efficient emulsion stabilisers) and hydrophilic (reduce surface and interfacial tension) moieties along with their microbial origin. Amino acids, peptides, mono, and di-polysaccharides are the primary constituents for hydrophilic moiety and saturated or unsaturated fatty acids for hydrophobic moiety [2, 5]. The nutritional environment of the developing bacterium influences the type of surfactant synthesis. Important biosurfactants, as per their types, are listed in Table **1**.

Mechanism of Hydrocarbon Utilization

For early enzymatic catabolism within cells, a wide range of adaptive mechanisms by microbes are followed for collecting and delivering hydrocarbons into the cell [6]. Bacteria are speculated to use a passive process to transfer and digest soluble alkanes dissolved in water. Initially, it was assumed they could only use solubilized hydrocarbons [7]. Until observed, the rate of alkanes destroyed surpassed hydrocarbon solubility in the aqueous phase, indicating the use of an alternative hydrocarbon absorption mechanism by microbes [8]. Several pathways for aliphatic hydrocarbon absorption have been postulated but were ruled out due to the limited solubility of long-chain alkanes in water [9]. The following stages have been discovered to occur during hydrocarbon absorption. a) Little hydrocarbon droplets (micelles) are confined within the cells. b) Cells can encapsulate hydrocarbon within their cells due to direct interaction with the larger hydrocarbon phase. A study revealed that microbes degrading hydrocarbon are designed to flourish in oily environments, that can have a significant effect on biological remediation [10]. Bacteria that break down hydrocarbons produce biosurfactants with a variety of chemical characteristics and molecular sizes. One of the process limitations is the bioavailability of different oil fractions at low temperatures.

Table 1. Biosurfactants type and micro-organism involved.

Microbial Surfactants	Organisms
Glycolipids	*Serratia marcescens, Alcanivorax borkumensis*, Arthrobacter sp., corynebacterium sp., Pseudomonas sp., *Pseudomonas aeruginosa, Serratia rubidea, Torulopsis apicola, T. bombicola, T. petrophilium, Candida apicola, Candida bombicola, Candida bogoriensis, Candida lipolytica, Rhodococcuserythropolis, Nocardia erythropolis*, Mycobacterium sp., *Arthrobacter paraffineus*, Corynebacterium sp.
Fatty Acids (Spiculisporic Acids, Corynomycolic Acids, *etc*.,)	*Candida lepus*, Capnocytophaga sp., *Corynebacterium lepus, Penicillium, spiculisporum, Nocardia erythropolis*
Carbohydrate-lipid-protein	*Pseudomonas fluorescens*
Mannan-lipid-protein	*Candida tropicalis*
Particulate Surfactants	*Pseudomonas marginalis*

Screening of Microorganism

The first step in the selection stage is the isolation of the strains from their natural environments, which are then subjected to screening for the desired product manufacturing in microbial bio-processing. Primary screening is the collection of specified selective methods that permit the identification of isolate-generating targeted metabolites. Ideally, it should be fast, economical, and specific, which is effective for a wide variety of substances with large-scale usability. Screening to find a few suitable ones from a vast number of microbes is time-consuming and labor-intensive. The numerous screening procedures used for bioprocessing biosurfactant-generating microorganisms are explained briefly below.

One effective approach is the hydrocarbon overlay agar test, in which colonies produced on oil are emulsified with halo zones, suggesting potential biosurfactant producers [11]. CTAB agar plate is an appropriate screening procedure for rhamnolipids forming a dark blue halo zone around the colony. This is due to the

CHAPTER 3

Applications of Biosurfactants in Various Cancer Therapies

Twinkle Rout[1], **Muchalika Satapathy**[2], **Pratyasha Panda**[2], **Sibani Sahoo**[3] and **Arun Kumar Pradhan**[4,*]

[1] *Department of Surgical Oncology; Institute of Medical Sciences and Sum Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

[2] *AIPH University, Bhubaneswar, India*

[3] *Gangadhar Meher University, Sambalpur, India*

[4] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Biosurfactants are the naturally-occurring surface-active biomolecules produced by microorganisms having a wide range of applications. Because of their unique characteristics like low toxicity, specificity, biodegradability and relative ease of preparation, these surface active molecules have attracted a wide interest recently. The effective and side-effect-free treatment of cancer remains a top priority for researchers despite various advancements in cancer therapy. To go beyond the drawbacks of chemotherapy, it is necessary to investigate anticancer medications derived from natural sources. Since a wide variety of these compounds have revealed the capacity to elicit cytotoxicity against numerous cancer cell lines, hence modulating cancer growth pathways, biosurfactants have recently come to light as prospective agents for cancer therapy. In this context, microbial biosurfactants offer a potential replacement for existing cancer treatments as well as anti-cancer drug delivery methods. The synthesis, structure, and studies of several cancer cell lines, including breast cancer, cervical cancer, lung cancer, pancreatic cancer, and prostate cancer, are all covered in this chapter, which summarizes the state of the art on microbial surfactants with anti-cancer potential.

Keywords: Anti-cancer, Biosurfactants, Cancer therapy, Surfactin.

INTRODUCTION

Recently, biosurfactants have been amazingly utilized for various applications like greater bioremediation, oil recovery, environmental, food processing and pharmaceutical due to their unique properties such as lower toxicity, higher bio-

* **Corresponding author Arun Kumar Pradhan:** Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: arunpradhan@soa.ac.in

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

degradability, specific action, effectiveness at extreme temperature, PH, salinity, widespread applicability and their unique structures. Biosurfactants can also be used as antimicrobial, antiviral, and anti-adhesive against pathogens [1, 2, 3]. Biosurfactants are the surface-active chemicals made by a variety of microorganisms that are very useful in a wide range of biomedical applications. Glycolipids, glycoproteins, and lipopeptides, among other distinct biosurfactants, which comprise a variety of chemical structures, are anticipated to exhibit a variety of characteristics and physiological activities [4]. This molecule serves as an adjuvant for antigens, an inhibitor of fibrin clot formation, a ligand for binding immunoglobulins, a ligand for gene transfection, and an anti-adhesive biological coating for prosthetic materials.

Chemicals like these undergo interactions with diverse organism's cell membranes and/or the environment because of their surface activity, making them possible cancer treatments or components of drug delivery systems [5]. These are a few surfactants derived from microorganisms, such as rhamnolipids from *Pseudomonas aeruginosa*, surfactants from *Bacillus subtilis*, emulsan from *Acinetobacter calcoaceticus*, and sophorolipid from *Candida bombicola* Table **1**.

Table 1. Classification of biosurfactants on the basis of molecular mass.

<table>
<tr><td rowspan="6">High Molecular Mass</td><td rowspan="5">Polymeric</td><td>Carbohydrate Lipid-protein</td></tr>
<tr><td>Emulsan</td></tr>
<tr><td>Mannan-lipid protein</td></tr>
<tr><td>Biodispersion</td></tr>
<tr><td>Liposan</td></tr>
<tr><td>Particulate</td><td>Vesicles</td></tr>
<tr><td rowspan="12">Low molecular Mass</td><td rowspan="3">Glycolipids</td><td>Sophorolipids</td></tr>
<tr><td>Rhamnolipids</td></tr>
<tr><td>Trehalose lipids</td></tr>
<tr><td rowspan="3">Phospholipids</td><td>Fatty acid</td></tr>
<tr><td>Phospholipids</td></tr>
<tr><td>Corinomiocolic acid</td></tr>
<tr><td rowspan="6">Lipopeptides</td><td>Subtilisin</td></tr>
<tr><td>Lichenysin</td></tr>
<tr><td>Gramicidin</td></tr>
<tr><td>Wisconsin</td></tr>
<tr><td>Peptide lipid</td></tr>
<tr><td>Surfactin</td></tr>
</table>

Both lipopeptide and glycolipid surfactins are well-known biosurfactants that are often utilised in a variety of applications, such as preventing the growth of cancer cells and rupturing cell membranes to trigger apoptosis pathways, which cause the lysis of the cells [5, 6]. During different cancers' developmental stages, biosurfactants have the potential to function as antitumor agents. Biosurfactants significantly reduce the growth of certain tumour types. Particularly, numerous Bacillus genus bacterial species are used to create the biosurfactants surfactin, iturin, and fengycin lipopeptide. Surfactin's amphiphilic nature makes it simple to include into nanoformulations, including liposomes, micelles, micro-emulsions, and polymeric nanoparticles. Using nano-formulations has the benefit of improving surfactin distribution for more effective cancer treatment. A possible platform for reversing multi-drug resistance in cancer chemotherapy may be a surfactin-based nanocarrier (Fig. **1**, Table **2**).

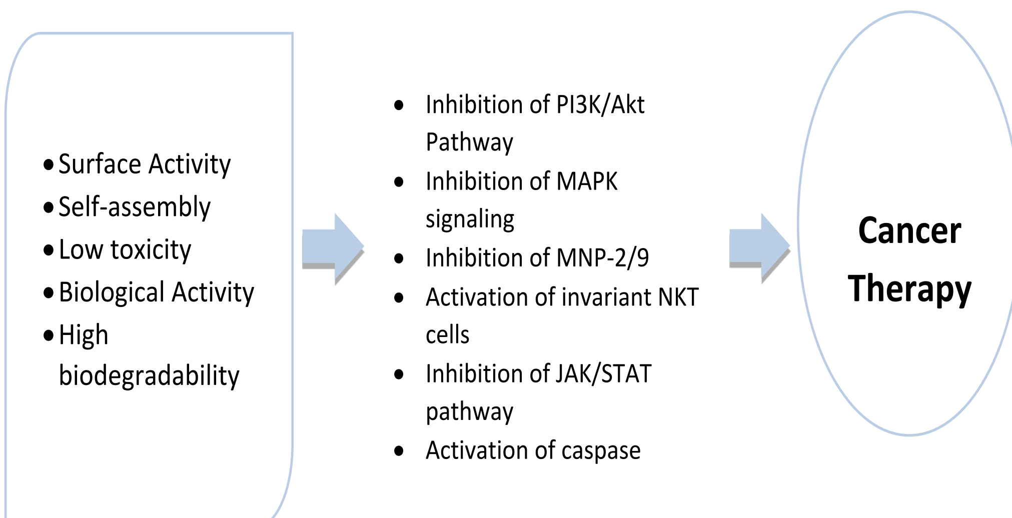

Fig. (1). Function of bio-surfactants targeted with cancer therapy.

Table 2. Activity of biosurfactants in different cancer cell lines.

Biosurfactants	Cell Line	Description	Activity
Mannosylerythritol lipids (MELs)	K562	Leukemia Myelogenous	Growth inhibition & differentiation
Succinoyl trehalose lipids (STLs)	HL60	Promyelocytic leukemia	Growth inhibition & differentiation
	KU812	Basophilic leukemia	Growth inhibition

CHAPTER 4

Forecasting the Parallel Interaction between Biosurfactants and Neurons: A Challenge for Clinicians

Soumyashree Rout[1], **Srikanta Kumar Sahoo**[1,*] and **Arun Kumar Pradhan**[2]

[1] *Department of Neurology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

[2] *Center for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Bacteria that are associated with human health are receiving a growing amount of attention, particularly those that inhabit the body's niches, such as the neural stem, neurons, gastrointestinal tract, skin, vaginal environment, and lungs. Biosurfactants are molecules that are both hydrophobic and hydrophilic, and receive little attention among the secondary metabolites that are released by microorganisms that are associated with human health. Not only do they serve as biosurfactants, but they also have the potential to control the microbiota through their antimicrobial activity and quorum sensing system in the complex human environment. They and the human body as a whole are shielded from microbial and fungal pathogens by these functions. Because of their diverse structures, biological functions, low toxicity, higher biodegradability, and adaptability, biosurfactants are now emerging as promising bioactive molecules. As a result, biosurfactants with antimicrobial activity, which are produced by bacteria that are associated with the human body and are related to everything that humans come into contact with, such as food, beverages, and comestics, are the subject of this comprehensive review.

Keywords: Blood brain barrier, Cytotoxic, Cancer therapy, Neurons, Rhamnolipid.

INTRODUCTION

Biosurfactants (BS) become an excellent alternative to synthetic surfactants because of their low toxicity, pH stability, biodegradability, thermal resistance, and effective critical micelle concentration. Because of its unique surface activity,

* **Corresponding author Srikanta Kumar Sahoo:** Department of Neurology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: drsrikanta25@gmail.com

it has become an extraordinarily unique biomaterial applied to different sectors like food, agriculture, waste treatment, environmental issues, and most importantly human health.

The basic principle of producing biosurfactants is either by excretion or adhesion of microorganisms to cells. The major functional characteristics of biosurfactants are to expand microbial cells on the insoluble substrates by decreasing the surface tension between the two states, and increasing hydrophobic substrates to the maximum for uptake and metabolism. Microbial cells can uptake insoluble hydrocarbons through cleaving hydrocarbons at the interface stage of liquid water-hydrocarbon or solid. Microbial cells can exceed the extension of their adhesion by facilitating cell surface regarding its hydrophobicity through customizing cell surface components by hydrocarbon-degrading bacteria [1, 2, 3]. The type and concentration of biosurfactant production processes are variable and depend upon the different sources like carbon and nitrogen sources, and the amount of lipophilic substrate and nutrients. Various physical and chemical parameters of oxygen, temperature, pH, aeration and agitation speed also influence the production of biosurfactants [2, 3].

The biosurfactants introduce remarkable physio-chemical properties. The composition of biosurfactants makes them more efficient and a candidate for the development of economically viable bioprocess. Due to diverse structural and chemical properties of biosurfactants, their action mechanisms are considered for use as an emulsifier, or a de-emulsifier, with saturating, expanding and foaming properties (Table **1**). Their advantage can also be reserved and they can be used as detergents in different refined manufacturation processes such as petroleum and petrochemicals, organic chemicals, beauty products and pharmaceutical, foodstuffs and refreshments, mining and metallurgy and organic manures [4]. In medical science, biosurfactants appear as a drug delivery system for enhancing the presence of bioavailability of drugs. In addition to this, microbial surfactants possess anti-bacterial, antifungal, and antiviral properties, which make them helpful to cure several diseases [5, 6].

Table 1. Bioemulsifier biosurfactants and their applications.

High Molecular Weight Biosurfactants	Types of Biosurfactants	Source	Property	Applications	Components	References
Polymeric biosurfactant	Emulsan	*Acinetobacter calcoaceticus*	Bioemulsifier	Cosmetics, food, pharmaceutical & petroleum industry	Lipopolysacharides	[25]

(Table 1) cont.....

-	Liposan	*Candidalipolytica*	bioemulsifier	Food & cosmetic industries.	Carbohydrate & protein	[25]
-	Alasan	*Acinetobacter Radioresistens KA53.*	Bioemulsifier & solubilization activity.	Petroleum industry, cosmetic & pharmaceutical	Anionic polysaccharide & a protein.	[25]

The human body is very sensitive to toxic substances which are commonly produced by synthetic surfactants resulting in bad health. As biosurfactant chemical composition is unique and rare, it performs on humans as an anti-microbial, anti-adhesive, anti-immunomodulator, and anti-tumor agent. In the human body, biosurfactant plays an important role in molecular recognition phases like signal transduction, cell differentiation, and immune resistance (Table **2**). The morphology of a membrane protein can be modified by using biosurfactants' anti-adhesive and anti-microbial characteristics which cause disruption of the membrane as well as leakage of the metabolites (Fig. **1**). As a result, decreasing cell adhesion and biofilm formation occur by influencing energy production and converting the lipopolysaccharide system to another stage. BS also stimulates the body for the generation of cationic proteins, lysozyme, and reactive oxygen species (ROS) in response to inflammatory activities. In addition to this, glycosphingolipid (GSL) biosurfactants are fully expressed in the nervous system, comprising up to 12% of the total lipid content of neuronal membranes while in other tissues, it constitutes only 2%. As per a recent review (2016], glucose-6-phosphate, a glucose sugar, is the key factor for the manufacture of biosurfactants carbohydrates *i.e.* found in the hydrophilic part [2].

Table 2. Low molecular weight biosurfactants and their applications in the health area.

Low Molecular Weight Biosurfactants	Types of Biosurfactant	Source	Property	Applications	References
Glycolipids	Rhamnolipids	*Pseudomonas aeruginosa*	Anti-biofilm & antiadhesive agent	Possess significant anti-microbial activity against mycobacterium tuberculosis organisms. (ii) Rhamnolipid opposes several bacterial & yeast strains isolated from trachea oesophageal puncture.	[25, 26, 27]

CHAPTER 5

Application of Biosurfactant in Agriculture

Swapnashree Satapathy[1,*], **Ananya Kuanar**[1] and **Arun Kumar Pradhan**[1]

[1] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: All countries are concerned about meeting the growing demands of the human population in terms of agricultural output in a timely manner. Biosurfactants are substances that bacteria, yeasts and fungus are said to create as green surfactants which are less harmful and environmentally compassionate. Several forms of biosurfactants could be commercialised for use in the pharmaceutical, cosmetics, and food industries. Surface active molecules are frequently utilised in agricultural soil remediation to improve soil quality. In recent years, the chemical compounds have gotten a lot of attention because they're seen as a viable and environmentally benign alternative to traditional remedial solutions. The bio molecules which showed the potential to replace the harsh surfactants currently utilised in the multibillion-dollar pesticide industry. The microbial population is screened for biosurfactant synthesis using traditional methods. The modern civilization is confronted with a number of issues in terms of enforcing environmental protection, implementation and addressing climate change for future generation. As a result, studies on environmental safety and human are being carried out in order to improve the efficiency of sustainable environmental restoration methods. Cosmetics, medicines, food, petroleum, agriculture, textiles and wastewater treatment are just a few of the areas where biosurfactants have been shown to be successful and efficient. Improved plant pathogen management, antibacterial activity, antibiofilm activity, seed protection and fertility, wound healing and dermatological care, drug delivery systems, and anticancer treatments are just a few of the applications for microbial produced biosurfactants. This study emphasizes the widespread utilize of harsh surfactants in the agrochemical industry and agricultural soil. More research is needed to determine the possible relevance of biosurfactants produced from environmental isolates in plant growth improvement and other agricultural applications.

Keywords: Agriculture, Antibiofilm, Antimicrobial activity, Biosurfactant, Plant pathogen, Remediation.

* **Corresponding author Swapnashree Satapathy:** Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: satapathyswapnashree2@gmail.com

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

INTRODUCTION

Biosurfactants are amphiphilic compounds formed on living surfaces, released extracellular non-polar and polar moieties such as microbial cell surfaces or allowed fluid phases to mix while lowering surface and interfacial tension [1]. They have high surface activity, specificity, biodegradability and are naturally benign or least hazardous and may be recycled [2-4]. Pharmaceuticals, cosmetics and personal care items are just a few of the businesses that use them [5]. However, because of their refractory and continuous nature, which is chemically manufactured, most of these substances may pose environmental and toxicological risks. Zhang *et al.* proposed that, biosurfactants are also utilized to increase the steadiness of micro bubble technology, illness detection, molecular imaging, cost-effective water purification, sewage treatment, medication and gene delivery system [6]. Several studies have found that utilizing biosurfactants in the soil remediation process improves agricultural soil health. Pesticides that have collected in agricultural soil can also be broken down with the help of biosurfactants [7-9]. Many researchers have focused on developing more environmentally acceptable strategies for producing various types of biosurfactants from microorganisms as a result of recent biotechnology breakthroughs [10]. There have been reports of surfactin-assisted pesticide biodegradation and glycolipid-assisted chlorinated hydrocarbon degradation, validating the biosurfactant biodegradation accelerator capability. But, *Lactobacillus pentosus* biosurfactant decreased octane hydrocarbon from soil by 58.6 percent to 62.86 percent. *Burkholderia* species, which produce biosurfactants and were identified from oil-contaminated soil, have been discovered to be a viable option for pesticide pollution bioremediation [8].

CLASSIFICATION OF BIOSURFACTANT AND ITS BIOLOGICAL ACTIVITY

Based on microbiological origin as well as their composition, biosurfactants are divided into low molecular weight; glycolipids, lipopeptides (LPs) and phospholipids are of major importance, lipopolysaccharides are high molecular weight biosurfactants. There are various different types of biosurfactant groups, as follows:

1. High and low-molecular-weight biosurfactants include glycolipids, lipopolysaccharides, lipopeptides (LPs) phospholipids. Lipopeptides are anticancer, antibacterial, antiviral, specific toxins, immune-modulators and enzyme inhibitors made up of lipid moieties. According to this the bacterial hydrophobicity, the lipopeptide profile differ substantially between iturin A, strains.This strain is lipopeptide in nature and produced by all *Bacillus subtilis*

strains. Polymixin B and daptomycin both microbial produced LP antibiotics, are the most well-studied LPs. Surfactin (SUR), fengycin and iturin have a wide range of applications and the most well-known LPs, [11].

2. Trehalose lipids derived from Mycobacterium and related bacteria. Glycolipids are the most frequent type of biosurfactant. Sophorolipids derived from yeasts being the most successful in terms of surface-active qualities. Rhamnolipids derived from *Pseudomonas* species. Furthermore, the effects of various types of neurite initiation in PC12 cells and microbial extracellular glycolipids were studied [12]. Differentiations of mouse malignant melanoma cells, growth arrest and death have all been linked to glycolipids [13].

3. Rhamnolipids (Fig. **1**) are amphipathic molecules that include both polar and non-polar moieties, allowing them to interfacial tensions and lower surface. They have antimicrobial properties due to their permeabilizing effect, change bacterial cell hydrophobicity and compromise cell surface charge which causes disruption of the bacterial cell plasma membrane [14]. They can also prevent and inhibit the production of biofilms which are more vulnerable to antimicrobial treatments (Cunha CD *et al.*, 2004).

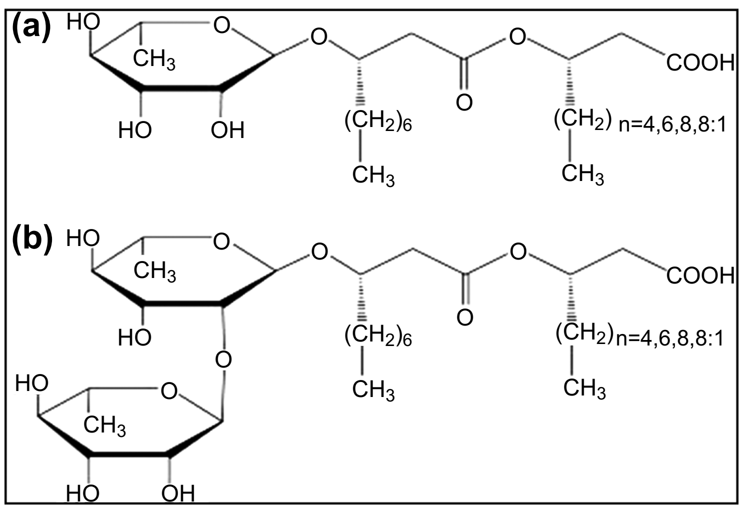

Fig. (1). Mono- and Di-rhamnolipids..

4. Yeasts manufacture sophorolipids. (Fig. **2**) They have a glycosidic connection that connects with two numbers of carbohydrate called sophorose, which has a long-chain hydroxyl fatty acid [15]. Now, it is observed that the spectrum of biosurfactant produced by microorganism. They have extents of bioactivity and quite diverse types to employ highly pure individual of a specific congeners.

CHAPTER 6

Use of Biosurfactants in Food Processing Technology

Gargi Balabantaray[1], **Bhabani Shankar Das**[2] and **Pradeepta Sekhar Patro**[1,*]

[1] *Department of Immunology and Rheumatology, Institute of Medical Science, Sum Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

[2] *Centre for Biotechnology, School of Pharmaceutical Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Biological surfactants are a class of amphipathic biomolecules that contain a diverse range of constituents derived from different biological sources and have been analysed for their ability to lower surface tension. Their distinct properties with cumulative applications have expanded in different fields starting from human health to detergent industry. According to estimates, the global market for biosurfactants will grow from $4.18 billion in 2022 to $6.04 billion by 2029. Biosurfactants outperform artificial surfactants due to their unique attributes. This provides opportunities for commercial utilization of biosurfactants. Thus, the present chapter aims to describe the various biosurfactants present in the market along with their potential application in food industries.

Keywords: Bioemulsifiers, Enhanced oil recovery, Lactic acid bacteria.

INTRODUCTION

Biosurfactants are surface-active amphiphilic biomolecules that are abundantly produced by aerobically growing bacteria, fungi, and yeast. Biosurfactants are made up of a hydrophilic region with polar properties and a hydrophobic region with non-polar properties. The polar region is either anionic or cationic, whereas the non-polar region is either non-ionic or amphoteric, consisting of a hydrophobic chain illustrated in Fig. (**1**). This distinguishing feature of biosurfactants allows them to aggregate and accumulate at the interface of two fluid phases, such as oil in water with two different polarities, lowering interfacial and surface tension and forming emulsions in which hydrocarbons can solubilize. As a result, the monomers can form micelles or aggregate into micellar tubes, bilayers, and vesicles. Biosurfactant production by microorganisms or bacteria

* **Corresponding author Pradeepta Sekhar Patro:** Department of Immunology and Rheumatology, Institute of Medical Science, Sum Hospital, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: patrodrpradeepta@gmail.com

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

depends on fermentation conditions, the environment, and carbon and nitrogen availability [1, 2]. Biosurfactants have large, complex structures, high biodegradability, low toxicity, high surface activity, and extreme stability [2]. There are numerous applications for biosurfactants, from everyday chores like laundry and personal hygiene products to the medical sector, where biosurfactants have antimicrobial, antitumor, and anti-inflammatory properties because of their bioactivity. Biosurfactants are also used as food additives, antioxidant agents, improving the texture of certain foods *etc.*, thus making them potential biomolecules to be used in food industries [3].

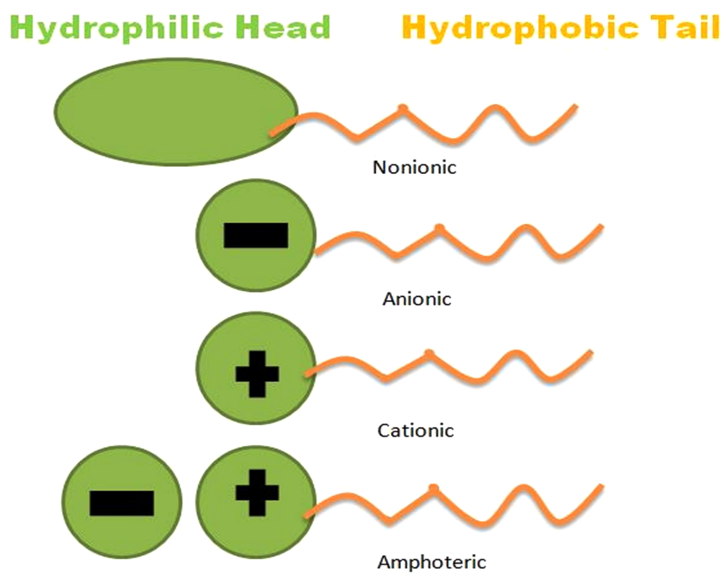

Fig. (1). General structure of a surfactant according to their confirmation.

PROPERTIES OF BIOSURFACTANTS

Biosurfactants have unique and distinguishing properties when compared to synthetic biosurfactants and have sparked widespread commercial interest due to the ever-expanding spectrum of available substances. The following are the distinguishing characteristics of biosurfactants, along with a brief description of each property.

Surface and Interface Activity

Biosurfactants reduce strain and interfacial pressure at lower concentrations, resulting in greater effectiveness and efficiency when compared to conventional surfactants. A lipopeptide surfactant synthesized by *Bacillus subtilis* is able to decrease both surface and interfacial tension of water to 25 mN m^{-1} and water/hexadecane to below 1 mN m^{-1}, respectively [4]. Following the trend, rhamnolipids made by *P. aeruginosa* lowered the surface and interfacial tension of water to 26 mN m^{-1} and water/hexadecane to below 1mN m^{-1}, respectively [5] Biosurfactants are much more capable and effective because their CMC is lower than synthetic surfactants, so less is needed for maximum surface strain reduction [6].

Biodegradability

Compared to synthetic surfactants, microbial compounds are easily degraded and suitable for bioremediation and biosorption [7]. Increasing environmental problems force us to use biosurfactants. Synthetic surfactants pose environmental issues, so biodegradable biosurfactants from marine microorganisms were used to remove phenanthrene from aquatic surfaces [8].

Temperature and pH Tolerance

The lipopeptide from *Bacillus licheniformis* is stable at 75 degrees for 140 hours and within a pH range of 5 to 12 [9, 10]. This is only one example of the wide variety of biosurfactants that may be employed in harsh environments. While conventional surfactants are rendered ineffective at 2% NaCl concentrations, biosurfactants can withstand concentrations of up to 10% salt. Novel microbial items must be separated because industrial procedures involve extremes of heat, pH, and weight.

Low Toxicity

Biosurfactants are low toxic or non-harmful, making them suitable for food, cosmetic, and pharmaceutical industries. A study showed that a chemically-derived surfactant Corexit is 10 times more toxic than rhamnolipids [11]. The toxicity and mutagenicity profile of *P.aeruginosa* biosurfactants was studied and when they were compared to synthetic surfactants, they were found to be nontoxic and non-mutagenic [9, 12].

Emulsion Forming and Breaking

Biosurfactants may destabilize emulsions. An emulsion is a diversified framework that includes one immiscible fluid scattered in 0.1mm-diameter beads [13]. Biosurfactants' minimal stability keeps emulsions stable for years. Liposan can emulsify edible oils without reducing the surface tension. The oil droplets are coated with polymeric surfactants, resulting in stable emulsions [14].

CHAPTER 7

Biosurfactants and Their Application in Remediation of Environmental Contaminants

Meena Choudhary[1,2], **Monali Muduli**[1,2] and **Sanak Ray**[1,2,*]

[1] *Analytical and Environmental Science Division & Centralized Instrument Facility, CSIR-Central Salt & Marine Chemicals Research Institute, G.B. Marg, Bhavnagar-364002, India*

[2] *Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India*

Abstract: The demand for bio-surfactants is growing daily over synthetic surfactants due to their less harmful effects on the environment, biodegradability, and nontoxic effects on public health. Biosurfactants play a significant role in foam generation, emulsification, oil dispersion, and detergency due to their amphipathic structure with the hydrophilic and hydrophobic sites. In recent years, tremendous development in research has resulted in different methods to produce several types of biosurfactants from microorganisms. Several biosurfactants are grown commercially and applied in the pharmaceutical and cosmetic sectors, food, petroleum, and agricultural sectors to mitigate environmental contaminants. The current chapter discusses the potentiality of biosurfactants to degrade environmental pollutants in various fields.

Keywords: Amphipathic, Biosurfactant, Emulsification, Environmental contaminants, Interfacial tension.

INTRODUCTION

Surfactants, surface active agents, are amphipathic molecules with polar and nonpolar structures. They align themselves at the air-water interface in such a way (hydrophobic part in air and hydrophilic part in water) that they would be able to reduce the surface tension. This interfacial tension reduction of surfactants helps them to become effective emulsifiers, cleaning agents, and oil dispersers. Recently, the whole world has been focusing on developing a sustainable society. Thus, surfactants produced by microorganisms have been highlighted more than chemically synthesized surfactants due to their less harmful impact on humans and their environment. The most promising natural surfactants are those derived

* **Corresponding author Sanak Ray:** Analytical and Environmental Science Division & Centralized Instrument Facility, CSIR-Central Salt & Marine Chemicals Research Institute, G.B. Marg, Bhavnagar-364002, India & Academy of Scientific and Innovative Research (AcSIR), Ghaziabad-201002, India; Tel: 91-278-2567760;
E-mail: sanakray@csmcri.res.in

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

from microorganisms, also referred to as “microbial surfactants” or “biosurfactants” [1, 2]. They are surface-acting substances that have the potential to enhance surface-surface interactions by producing micelles from their natural sources, including plants, microorganisms (bacteria, yeast, and archaea), and animals [3].

Biosurfactants adsorb at the interface of the two phases by minimizing surface tensions. They reduce the repulsive force of the two phases and allow them to mix quickly [4].

Amphipathic molecules with both hydrophilic and hydrophobic components typically make up biosurfactants. The hydrophilic chemicals typically consist of amphoteric or positively and negatively charged ions. At the same time, the hydrophobic molecules comprise (water resisting, such as unsaturated or saturated hydrocarbon chains or fatty acids). Similar to their chemical equivalents, biosurfactants can be categorized according to their molecular weight (low or high), critical micelle concentration (C.M.C.), the type of microbe they create, and their action method. The most frequently reported low-molecular-weight substances include phospholipids, glycolipids, and lipopeptides; however, high-molecular-weight biosurfactants comprise polysaccharides and a complex blend of biopolymers [5, 3].

Biosurfactants, one of the latest researched microbially produced/synthesized biomolecules, offer several potential uses. The advantages, like long storage time, biodegradability nature, and feasibility over changing abiotic factors like pH, temperature, and salt concentrations, have made biosurfactants suitable for various applications [2, 5 - 7].

Many microbiological strains of bacteria, fungi, and yeast have been identified for effective biosurfactant generation. The kind of microbe, medium supplements, substrate characteristics, and other internal and external parameters during microbial culture growth all impact the quality and the amount of biosurfactants [8, 9]. The initial stage in the synthesis of biosurfactants is the selection of the microbial strain. However, when nutritional conditions are restricted during the exponential, stationary growth phase, microbial strain synthesizes biosurfactants intracellularly or extracellularly [10]. The source of the microorganisms that degrade a specific pollutant also affects the nature of biosurfactants. This idea probably stems from the fact that an isolated bacterium can utilize a contaminant as a source of energy or a food supply, whereas other bacteria or microorganisms that do not produce surfactants cannot [11].

Bio-surfactants from lower to higher molecular weight can be derived from genera like *Acinetobacter, Pseudomonas, Brevibacterium, Bacillus, Rhodococcus, Clostridium, Leuconostoc, Citrobacter, Thiobacillus, Candida, Corynebacterium, Penicillium, Aspergillus, Ustilago, Saccharomyces, Enterobacter,* and *Lactobacillus* [5, 12, 13].

MECHANISM OF BIOSURFACTANT

Low concentrations of the biosurfactant CMC trigger the mobilization process. In systems involving soil and water and air and water, biosurfactants at such concentrations lower surface and interfacial tension. Interaction between the soil/oil system and biosurfactants increases the contact angle. It decreases the capillary force that holds the soil and oil simultaneously due to reduced interfacial strength. The solubilization method then happens above the biosurfactant CMC. Biosurfactant molecules produce micelles when present in these amounts, greatly enhancing the solubility of oil. In turn, the solubilization process occurs above the biosurfactant CMC. Biosurfactant molecules gather to form micelles at these concentrations, significantly improving the solubility of oil. The hydrophilic ends of biosurfactant molecules are open to the aqueous phase outside, while the hydrophobic ends are connected inside the micelle. As a result, a micelle's inside produced a favorable setting for hydrophobic organic compounds. Solubilization refers to incorporating these molecules into a micelle (Fig. **1**) [14].

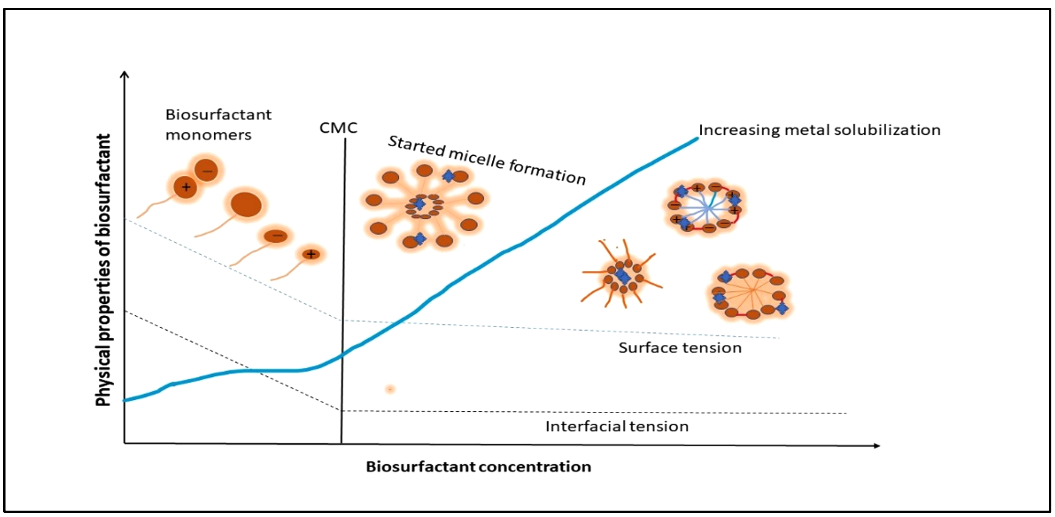

Fig. (1). Mechanism of Biosurfactant.

CHAPTER 8

Biosurfactants: New Insights in Bioengineering and Bioremediation of Crude Oil Contamination

Pyari Payal Beura[1] and **Sanjay Kumar Raul**[1,*]

[1] *Department of Biotechnology, Rama Devi Women's University, Vidya Vihar, Bhubaneswar, Odisha-751003, India*

Abstract: Human activities are the principal source of various kinds of hazardous substances in our environment, which have serious consequencesfor the well-being of the environment and people. Using standard means to lessen, degrade, and eliminate these substances is usually causing harmful effects to environment. Pesticides, crude oil sludge, and polycyclic aromatic hydrocarbons (PAHs) are toxic, mutagenic, and carcinogenic in nature. It has recently been shown to be possible to use microorganisms to breakdown and cleanse contaminated soil and water ecosystems, a process known as bio-reclamation. Biosurfactants, which are amphiphillic chemicals generated by bacteria, fungus, and yeast, have immense potential to lower the surface tension of a liquid as well as tension at the interface between 2 liquids or among a liquid and a solid. Additionally, bio surfactants strongly emulsify hydrophobic substances and create stable emulsions. Bio emulsifiers and biosurfactants are especially useful in a wide range of commercial and scientific applications, including pharmaceuticals, better oil recovery, and pollutant biodegradation. Thus, using biosurfactants to reduce crude oil pollution is an environmentally responsible strategy to developing a sustainable ecosystem.

Keywords: Biosurfactant, Biodegradable, Bioemulsifier, Environment, Pharmaceuticals.

INTRODUCTION

Surfactants are considered to be among the most important groups of chemical products since they are widely utilized in daily life and have several applications in everyday life, the agro industry, or healthcare [1]. At the moment, surfactants are almost entirely synthetic [2]. Recently, there is rising interest in biosurfactants, particularly microbial surfactants. Due to harmlessness and biodegradable characteristics, they are first regarded as environmental friendly. In

* **Corresponding author Sanjay Kumar Raul:** Department of Biotechnology, Rama Devi Women's University, Vidya Vihar, Bhubaneswar, Odisha-751003, India; E-mail: sanjaykumarraul@rdwu.ac.in

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

addition, they have unique physical characteristics that render them essential for their potential application in a range of industrial sectors, ranging from biotechnology to environmental remediation. Finally, they may be synthesized from renewable feedstock and have improved foaming powers, more selectivity, and specialized action in challenging environmental conditions of temperature, pH, and salinity [3].

Secondary metabolites known as biosurfactants (surface active compounds) are physiologically created during the stationary stage of the development of microbial cells. Biosurfactants comprises amphiphilic molecules having hydrophilic and hydrophobic motifs [4]. These compounds are made by microbes living on their surfaces, and they consist of separate polar and non-polar components allowing them to transform into micelles that cluster at the interface of several fluids with varying polarities [5]. They function similarly to chemical surfactants like water and oil in that they are made to lower surface pressure and have the distinctive property of lowering surface and interfacial tension. In contrast to hydrophobic domains, which are frequently made up of long-chain fatty acids, hydrophilic domains are frequently made up of sugars, amino acids, and phosphate chains [4]. Water surface tension (ST) can potentially be decreased from 72 to 35 mN/m by a superior surfactant, and the water/hexadecane interfacial tension (IT) is capable of being decreased from 40 to 1 mN/m [1]. Surfactants enable detergency, emulsification, lubrication, solubilization, and phase dispersion by reducing surface and interfacial tension. Surfactants are a highly important chemical element that are used in a wide variety of goods in very big amounts due to their numerous home and commercial uses [6]. The amount of surfactants that cause micelles form and all further surfactants introduced into the system will form micelles is known as the critical micelle concentration (CMC) in colloidal and surface chemistry. A detergent's CMC is a crucial characteristic (Fig. **1**).

Biological origin and chemical make-up are the main factors used to classify biosurfactants. Biosurfactants are technically essential because they enhance the number of surfactant types available and have distinct surface-active properties in comparison to synthetic surfactants.The major types of biosurfactants include glycolipids, lipoproteins or lipopeptides, phospholipids, fatty acids or natural lipids, polymeric surfactants, and particle surfactants. They are often biodegradable as well, which reduces the possibility of contamination.Recyclable uses for bio surfactants include emulsifiers, flocculating agents, demulsifiers, adhesives, detergents, and as amethod used in the tertiary recovery process of oil. All of these characteristics are used by bio systems in an environment. Numerous environmental uses of biosurfactants include the transfer of crude oil, increased oil recovery, and bioremediation of oil spills. Additional uses for biosurfactants include the food, cosmetics, and healthcare sectors as well as the cleansing of harmful compounds with both industrial and agricultural origins (Fig. **2**) [8]. Therefore, biosurfactants are a natural alternative to chemically produced surfactants and are chosen for a variety of industrial applications in the bioremediation, healthcare, cosmetics, oil, and food processing industries.

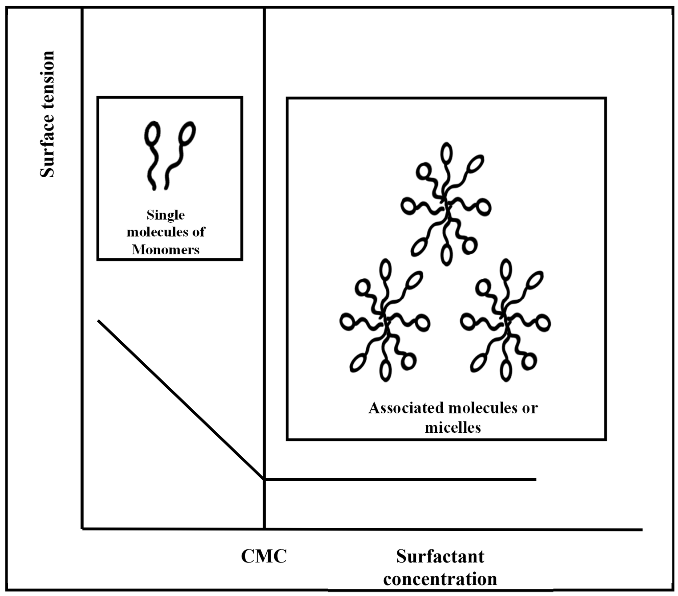

Fig. (1). CMC (critical micelle concentration) as a function of chemical or natural surfactant concentration [7].

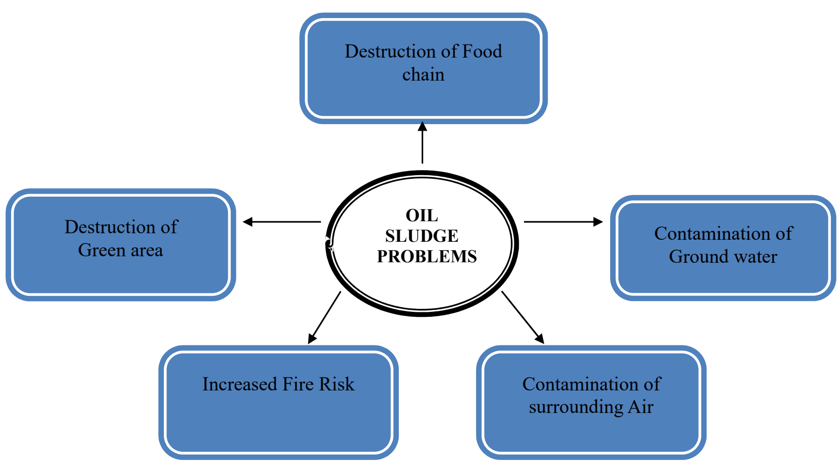

Fig. (2). Various impact of oily sludge.

CHAPTER 9

A Review of Biosurfactant-Mediated Synthesis of Nanoparticles for Environmental Applications

Elina Khatua[1,2], **Swastika Mallick**[1,2] and **Nilotpala Pradhan**[1,2,*]

[1] *Environment and Sustainability Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha-751030, India*

[2] *Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh-201002, India*

Abstract: The potential of surfactants has been harnessed to fulfill human purposes for a long time. Biosurfactants are one of the promising bioactive molecules, produced by microorganisms, and subjected to intense research due to their chemical structure, diverse applications, and eco-friendly nature. Nanobiotechnology is an emerging scientific domain, encompassing various sectors like agriculture, medicine, bioremediation, food technology, *etc.* The discovery of biosurfactant coated nanoparticles has marked a breakthrough in the field of scientific research due to its cost-effectiveness and low toxicity nature. The present review emphasizes the role of discovered biosurfactants in nanoparticle synthesis and its application in the broad arena of nanotechnology and environment concerning issues.

Keywords: Biosurfactants, Glycolipids, Lipopeptides, Micro-emulsion, Nanoparticles, Surface active molecules.

INTRODUCTION

Anthropogenic activities are indiscriminately discharging industrial and household effluents into the environment. These effluents contain many chemicals which are toxic when they exceed a particular concentration. Some of these are not toxic but alter the relative concentration of species in a particular ecosystem causing havoc. One of such commodity is synthetic detergent, specifically phosphate detergent which has played a critical role in the eutrophication of inland lakes and ponds. These have caused the depletion of aquatic life and the destruction of the environment. Similarly, oil spillage is another such cause of environmental destruction. It is important to assess the biodegradable nature of

* **Corresponding author Nilotpala Pradhan:** Environment and Sustainability Department, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, Odisha-751030, India & Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh-201002, India; E-mail: npradhan@immt.res.in

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

commodity substances and search for future alternatives to save the environment. Microorganisms with high biodiversity are promising candidates for bioremediation. They are also known for the production of biosurfactants [1]. Biosurfactants are surface-active substances produced as secondary metabolites by a range of microbes, including bacteria, yeast, and fungi. The structural diversity of biosurfactants renders them useful in industries and the environment through biotechnological research and developments [2]. Bacteria manufacture surfactants for adsorbing, emulsifying, and solubilizing water-immiscible materials while taking such material as a source of food. For example, bacteria exposed to crude oil spillage area manages to disperse and emulsify the oil [1]. The biocompatibility, eco-friendly, and nontoxic nature of biosurfactants is due to their composition, which is made up of sugars, lipids, and proteins. The utility of biosurfactants as a greener, safer, and natural alternative to chemical surfactants, including synthesis of nanomaterials, has attracted the attention of scientists in the last decade [3].

Biosurfactants are amphiphilic surface-active compounds of microbial origin, carrying a hydrophilic head and hydrophobic tail [4]. Alcohol, carbohydrates, phosphates, carboxylic acid, and amino acids or peptides make up the hydrophilic parts of the head group, whereas branched, linear, hydroxylated, saturated, or unsaturated fatty acids make up the hydrophobic tail [5, 6]. They are produced primarily in aqueous media by aerophilic bacteria using either carbohydrates or hydrocarbons, fats, and oils as carbon sources [4]. They are better than synthetic surfactants as they are biodegradable, non-toxic, specific, and tolerant of higher temperatures, pH, and ionic strengths [7]. Production of biosurfactants is influenced by carbon and nitrogen supplies, as well as environmental variables such as pH, temperature, oxygen, and agitation rate during bacterial growth [6, 8].

CLASSIFICATION OF BIOSURFACTANTS

Biosurfactants are mostly produced from bacteria, fungi, and, yeast [9, 10]. Humans and plants also produce biosurfactants [11]. Dominating genera of bacteria reported for biosurfactant productions include *Pseudomonas, Bacillus,* and *Acinetobacter* [12]. Among yeasts' significant genera are *Torulopsis, Pseudozyma*, *Saccharomyces, Rhodotorula,* and *Kluyveromyces* [13 - 15]. Similarly, *Aspergillus, Ustilago, Fusarium, Trichoderma, and Penicillium* are well-reported biosurfactant-producing fungal genera in research publications [16]. Several species of fungi, yeast, and bacteria that produce biosurfactants are listed in Table **2**. The vast structural diversity allows different systems to classify microbial biosurfactants. According to their molecular weight, biosurfactants are divided into two categories: those with low molecular weights, like glycolipids, and those with large molecular weights, like lipopolysaccharides. According to the charge, low molecular weight biosurfactants are classified into non-ionic, anionic, cationic, and amphoteric biosurfactants. Another common method of classification is the categorization according to their chemical structure, such as glycolipids, lipopeptides, and proteins [17].

Classification Based on Molecular Weight

Biosurfactants are divided into two groups based on their molecular weights: low molecular weight biosurfactants and high molecular weight biosurfactants [18].

Low Molecular Weight Biosurfactants

These compounds generally include glycolipids, lipopeptides, rhamnolipids, trehalolipids, and sophorolipids; out of which glycolipids are the best studied to date [19]. These substances often exhibit lower surface and interfacial tension at air/water interfaces [4].

High Molecular Weight Biosurfactants

This group of compounds includes emulsan, alasan, polysaccharides, protein complexes, and liposan, collectively called bioemulsans [20], which stabilizes oil-in-water emulsion [21, 22]. At low concentrations, they act as highly efficient emulsifiers and exhibit substrate specificity [23]. These bio emulsifiers are of special interest in the cosmetic, food, or pharmaceutical sector, owing to their stable potential for emulsion [24].

Classification Based on Chemical Composition

Biosurfactants are classified into the following types according to their chemical composition [25].

Glycolipids

Glycolipids are made up of long-chain aliphatic or hydroxyl fatty acids and carbohydrates that are joined together by ester or ether groups [26]. The best-known glycolipids include rhamnolipids, trehalolipids, mannosylerithritol lipids, and sophorolipids [27, 28]. The carbohydrate part is constituted by mono/ di/tri or tetra saccharides, which include glucose, mannose, galactose, rhamnose, galactose sulfate, and glucuronic acid, depending upon the type of glycolipid [19].

Lipopeptides and Lipoproteins

These classes of biosurfactants include a large number of cyclic lipopeptides, which are composed of lipid groups attached to the polypeptide chain. They

CHAPTER 10

Nanoliposome Mediated Heavy Metal Detection

Banishree Sahoo[1,*] and **Manoranjan Arakha**[1]

[1] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: The bulk of metal ions are carcinogens that significantly harm human health by producing free radicals. Therefore, the need for quick and accurate metal ion detection has been a matter of concern. However, the most dangerous metal ions are cadmium, arsenic, mercury chromium, and lead. Heavy metals are indestructible. Instead, they interact with living things directly or indirectly *via* the food chain. Metal ions have the potential to directly disrupt metabolic processes or to change into more hazardous forms inside the body. Nanotechnology is known as an emerging field that has been utilized for heavy metal analysis and removal from intricate matrices. Numerous methods based on nanomaterials have been developed for the analysis of heavy metals, including electrochemical, colorimetric, fluorescent, and biosensing technologies. As a result, in recent decades, there has been significant growth in the quest for more systematic nano-vesicular systems, like nanoliposomes, with elevated biocompatibility properties and directed releases. Additionally, nanoliposome have various applications such as drug delivery in the pharmaceutical industry, storage of food mainly cheeses, and dairy products for a long time in the food industry and cosmetics industry.

Keywords: Biocompatible, Drug delivery, Heavy metals, Nanotechnology, Nanoliposome.

INTRODUCTION

The world is in a disquieting condition, as industrialization increases the number of toxic metals in the environment. Metals are highly electrically conductive compounds that voluntarily give up one or more of their electrons to form cations. Heavy metal(loid)s are released into the surroundings through effluents from different industries such as paper, textile, tannery, mining, and pulp [1]. Heavy metals accumulate in birds, animals and human bodies over time. These heavy metals are characterized as "a group of toxic metals and metalloids associated with pollution and toxicity, having a density greater than 6 Mgm^{-3} and an atomic weight greater than that of iron" [2]. Out of 35 existing metals that are of concern

* **Corresponding author Banishree Sahoo:** Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India; E-mail: sahoo.banishree1@gmail.com

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

to us due to residential or occupational exposure, 23 are categorized as "heavy metals". The heavy metals are tellurium, antimony, bismuth, thallium, tin, arsenic, gold, cerium, lead, cadmium, cobalt, copper, iron, vanadium, chromium, gallium, mercury, nickel, platinum, silver, manganese, uranium, zinc, *etc*. Surprisingly, significant concentrations of any of these metals can cause subtle toxicity, despite the fact that little amounts of them are ubiquitous in our environment and diet, which has been demonstrated to be helpful to health. Surprisingly, significant concentrations of any of these metals can cause subtle toxicity, despite the fact that little amounts of them are ubiquitous in our environment and diet, which has been demonstrated to be helpful to health [3]. However, the deposition of higher concentrations of heavy metals accumulates in the soil, sediment, and water and from the contaminated area plants and animals absorbed the minerals, thus accumulating inside the body and entering into the food chains [4]. These heavy metals are assimilated and aggregated in different organs of the body and they can cross the blood-brain barrier and produce adverse effects on human health. Arsenic is transported *via* aquaglyceroporins, whereas cadmium enters *via* calcium channels [5]. Lead can enter the body *via* a divalent metal transporter or a calcium channel. Mercury utilizes a similar transporter through which it enters the cell. These metals can cause a wide range of disorders by damaging cellular enzymes, causing cardiovascular disease, DNA damage, obstructing protein synthesis routes and affecting the neurons and neurotransmitters [6]. Thus, identifying heavy metals that are major pollutants of the environment, such as mercury, cadmium, lead, arsenic, and chromium is very critical for protecting and preserving the environment and avoiding their adverse consequences on living organisms. Despite the direct toxicity, heavy metals are non-biodegradable in nature and are kept for a prolonged period of time [7].

Conventional methods for detecting heavy metals include neutron activation analysis [8], microprobes, atomic absorption spectroscopy [9], energy dispersive X-ray fluorescence [10], inductively coupled plasma atomic/optical emission spectrometry [11], X-ray fluorescence spectrometry [12] and flame atomic absorption spectrometry [13]. Although they can typically attain acceptable detection sensitivity, they are unavoidably constrained by high costs, heavy equipment, complex operation and lab use only. Ion exchange [11], precipitation, oxidation, membrane filtration and reverse osmosis [14] are all conventional strategies for heavy metal removal from wastewater. Hence these traditional approaches are limited to the laboratory, hence low-cost, simple, and quick analytical techniques that may be carried out *in situ* are required for broad and large-scale testing of heavy metals. Hence claimed that appropriate sensing techniques should be sensitive, inexpensive, user-friendly, specific, equipment-free, quick and resilient, and deliverable to end-users (the ASSURED criteria)

[14]. Their efficiency, however, is limited due to the drawbacks of high pH sensitivity, sludge contamination and corrosiveness [15].

Numerous electrolytic sensing techniques have been explored for the application in the detection of toxic contaminates throughout the few last decades.

Electrochemical sensing techniques employ the interaction between chemistry and electricity by monitoring output signals such as current, charge, frequency, potential, phase, *etc*. at the electrolyte-electrode interface. Electrochemical strategies are categorised into potentiostatic and potentiometric techniques. Potentiostatic electrochemical techniques regulate charge transfer at the electrolyte electrode interface by detecting species reduction/oxidation and analysing the observed current. Potentiometric approaches can be employed to identify analytes using zero current, with the voltage reported across the membrane being driven by an electromotive force and being directly proportional to the difference in sample concentration on either side of the membrane [16 - 20]. Both types of electrochemical sensors are used to detect quick, rapid and cost-effective heavy metals. Electrochemical detection methods are very sensitive, accurate, easy to handle and optimizable and can be used in the microlitre range. Since these sensor techniques are very costly and a lot of samples are required for the processing and high-end equipment. Hence recent focus on the simple material sensor which is rapid, sensitive, easy to handle and accurate [21].

Recent breakthroughs in nanotechnology, as well as new possibilities for nanomaterial production, have aided in the design and development of enhanced sensing techniques and portable gadgets. Nanotechnology is the use of multidisciplinary techniques that integrate chemistry, physics, biology and engineering principles to create nanoscale devices [22]. With the advancement of applications of nanotechnology, nanomaterials for heavy metal detection and removal have been delicately designed and fabricated offering numerous advantages over other traditional methods.

NANOPARTICLES MEDIATED HEAVY METAL DETECTION

Nanotechnology has made tremendous achievements and developments over the last few eras. Nanoparticles are classified as materials with at least one dimension smaller than 100 nm. They are classified into different classes based on types of material, dimension, *etc* [23]. Nanoparticles, particularly metal nanoparticles provide significant advantages in the realm of electrochemical sensing. Metallic nanoparticles can support the mass-transport rate and give quick electron transfer, the two of which increase the awareness of the cathodes used [24]. In this section, we will discuss the utilization of various sorts of metallic nanoparticles for the detection of most heavy metals.

CHAPTER 11

Omics Perspectives Regarding Biosurfactant Biosynthesis and the Suitability of Site Bioremediation and Developments

Arabinda Jena[1,*] and **Sameer Ranjan Sahoo**[2]

[1] *Fisheries, UNDP (Collaboration with Directorate Fisheries), Cuttack, Odisha-753001, India*

[2] *Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha-751003, India*

Abstract: Modern compounds are called biosurfactants. Their application(s) interfere with day-to-day activities of human beings. The economics of production place a significant restriction on the broad applicability of biosurfactant(s). There can be many ways to overcome this. This study primarily focuses on current technical advancements in biosurfactant research. One of the innovations is the application of metabolomic and sequence-based omics approaches, which have evolved into a high-throughput essential tool for the detection of biosurfactant producers. Many bacteria produce ethanol, microbial lipids, polyhydroxyalkanoates, and other value-added compounds in addition to biosurfactants. The use of metabolic engineering techniques can further address restrictions while also improving the overall process's economics. The yield of biosurfactants is increased by the tailoring technique, which enables variation in the composition of the congeners produced. By enhancing their bioavailability or water solubility, bio-based surfactants have demonstrated promising effects in reducing pollution in terrestrial and aquatic habitats. Due to the expanding market for biosurfactants, this investigation identified technologically feasible developments in biosurfactant research that might help researchers create more trustworthy and secure technologies.

Keywords: Biosurfactants, Bioremediation, Metabolomics, Metagenomics, Metabolic engineering.

INTRODUCTION

Nearly all everyday chores include surfactants, which are chemicals or petroleum-based substances having tension-active characteristics [1, 2]. Microbial

* **Corresponding author Arabinda Jena:** Fisheries, UNDP (Collaboration with Directorate Fisheries), Cuttack, Odisha-753001, India; E-mail: arabindajena1994@gmail.com

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

surfactants have drawn the attention of researchers due to environmental concerns and the advantages microbial surfactants offer over synthetic ones, such as their biodegradability, low toxicity, stability in a variety of temperatures and pH levels, and salt stability [3 - 5]. As a result, biosurfactants are now widely used in a range of disciplines, including the environment, food, and biomedicine [6, 7].

The global market for commercial biosurfactants is expected to develop at a 5.6% CAGR from 2017 to 2022, reaching $5.52 billion [8]. In 2016, the market for biosurfactants was valued at $30.64 billion, and by 2021, it is anticipated to reach $39.86 billion. In 2023, the biosurfactant market earned US$ 1.8 billion in sales, with an 8% growth to US$ 2.6 billion projected in 2023. This yielded 540 kilotonnes of biosurfactants [9].

The market for these compounds is still undeveloped despite growing interest in biosurfactants due to the economics of manufacture and the availability of less-priced raw ingredients [10]. Other established methods for identifying effective biosurfactant makers from certain environmental niches require work and time, including the blue agar plate test, drop collapse assay, hemolytic assay, oil spreading assay, surface tension measurement, and emulsification assay [11 - 13]. Therefore, it is crucial to employ high throughput omics techniques in the study of biosurfactants. Depending on the sample under examination, the omics approach might be classed as metagenomics, metatranscriptomics, metaproteomics, or metabolomics. Total macro- and micro-molecules, as well as DNA, RNA, and proteins, are all present (Fig. **1**). These methods yield astonishing amounts of information on an organism's genetic makeup, metabolic profile, and functionally active portion [14, 15].

Metabolomic studies have been carried out to examine the effects of biosurfactants on the bioremediation of petroleum-contaminated wastelands [16]. This demonstrated the design strategy's effectiveness in reducing the abiotic stress on the plants. The *Rhodococcus* sp. I2R strain was grown in 22 different settings, and the metabolomic approach discovered more than 30 different functional groups, including glycolipids. Herpes simplex virus and human coronavirus were both resistant to the antiviral and anticancer effects of the active component [17]. Moreover, new biosurfactants have been discovered using metagenomic methods [18]. With advanced genomic analysis it became economical along with improvements in next-generation [19]. This approach was used to identify the relevant biomolecules by comparing the protein-coding sequences' sequence homology to the reference database. A variety of technologies have been developed to aid in the identification of secondary metabolites of interest. Anti-SMASH (the antibiotic and secondary metabolite analysis shell) is one such tool that uses sequencing data to annotate and detect gene clusters. The *Serratia* *marcescens* Db11 genes associated with biosurfactants have been found using the anti-SMASH tool [20].

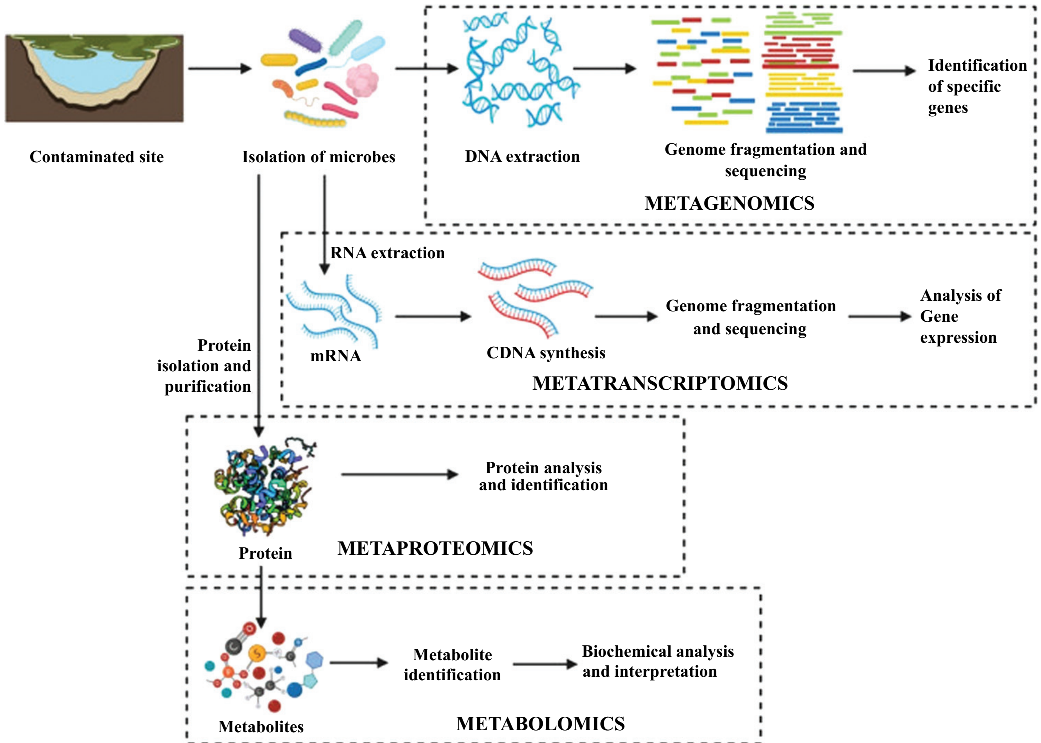

Fig. (1). Biosurfactant study using omics techniques.

Aside from that, there are limitations on the type and the amount of biosurfactants that can be produced for various uses that have been greatly enhanced by tailoring and engineering approaches. In some investigations, biosurfactant producers that weren't local to the area were created by modifying their genomes [21, 22]. Low Rhamnolipid levels were seen in *Pseudomonas aeruginosa* strain ATCC 9027, but with the addition of the rhlAB-R operon-containing plasmid, the Rhamnolipid titer increased to levels comparable to strain *Pseudomonas aeruginosa* PAO1. The ATCC 9027 strain also failed to make di Rhamnolipid because genetic changes were made to produce mono rhamnolipids [21].

In terms of market acceptance and economic viability, the use of these methodologies has profoundly impacted and enhanced biosurfactant research. This article went into detail about how biosurfactants are produced alongside other key industrial goods like bioplastics. It has been discussed how to find the sources of biosurfactants using metabolomics and next-generation sequencing

SUBJECT INDEX

Arun Kumar Pradhan and Manoranjan Arakha (Eds.)

C

D

E

F

G

H

I

J

L

M

N

O

P

R

S

T

V

W

Z

"Biosurfactants: A Boon to Health Care, Agriculture, and Environmental Sustainability" unveils the transformative potential of biosurfactants in diverse fields. This compelling book delves into their applications, illustrating how these natural compounds can revolutionize healthcare, agriculture, and environmental practices. A must-read for those seeking sustainable solutions in these crucial sectors.

Assist. Prof. Dr. Sandeep Panda
Gujarat Biotechnology University
India

Arun Kumar Pradhan

Prof. Arun Kumar Pradhan is an Assistant Professor at the Centre for Biotechnology, School of Pharmaceutical Sciences, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India. He received a Ph.D. degree in 2016 from the Department of Environment & Sustainability, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, India. His area of interest is microbial biosurfactants and their various biotechnological applications like effect of biosurfactant on cancer cells, study of biofilm inhibitory capacity of biosurfactants, nanoparticle approach (liposome) of heavy metal detection etc. Currently, he is working on green synthesis of various nanoparticles and clinical applications of biosurfactants to cure different disorders.

Manoranjan Arakha

Prof. Manoranjan Arakha is an Assistant Professor at the Centre for Biotechnology, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha, India. He received doctorate in life sciences from National Institute of Technology Rourkela, India, in 2017, and subsequently pursued post-doctoral research on bio-nano interface from the University College Dublin, Ireland. His research interests include green synthesis of different metal nanoparticles and moderate their physico-chemical parameters for antimicrobial and cytotoxic properties. For antimicrobials, he is mainly interested in nanoformulation effective against biofilm forming and antimicrobial peptide-resistant bacteria. Another aspect of his research includes nano-liposome mediated heavy metal detection.