3.3.1 Number of research papers published per teacher in the Journals notified on UGC CARE list during the last five years (2022-23)

Title of paper	Name of the author/s	Department of the teacher	Name of journal	Calendar Year of publication	ISSN number	Link to the recognition in UGC		
						Link to website of the Journal	Link to article / paper / abstract of the	Is it listed in UGC Care list
Problems Faced by Readymade Garments Workers in Ballari District , Karnataka	Gangadhara K	Commerce	International Journal of Research and Analytical Review (IJRAR)	Apr-23	E-2348-1269, P-2349-5138	http://www.ijrar.org	https://ijrar.org/download.php?file=IJRAR23B1710.pdf	Yes

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Smt. Allum Sumangalamma Memorial
College for Women, Ballari.

IQAC, Co-ordinator
Smt. Allum Sumangalamma Memorial
College for Women, Ballari-583103

PRINCIPAL
Smt. A.S.M. College for Women
BALLARI-583 103

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Problems Faced By Readymade Garments Workers In Ballari District, Karnataka.

1.*Gangadhara. K **2. ** Dr. Meghavath Govind Naik**

1.***Research Scholar** in Commerce, Department of Development Studies, Kannada University, Vidyaranya, Hampi.

2. ****Research Guide**, Department of Development Studies, Kannada University, Vidyaranya, Hampi. And Associate Professor in Department of Commerce, Vijayanagara College, Hosapete. Karnataka, India

Abstract: Workers in the readymade garment industry are mostly employed as helpers and laborers in home industries. It is impossible to estimate the number of workers in this business because they primarily operate in unorganized or unregistered sectors. Although there are workers in several sectors in Ballari district, for the purpose of the study, so researcher has considered only the workers of the readymade garment industry have been selected for the research study. Thus, it may be claimed that those employed in the ready-made clothing sector have relocated to urban regions in search of work, where they are subjected to economic and social exploitation through the use of more labor and lower pay. It can be said that the workers of the readymade garment industry are subjected to economic and social exploitation. The workers in this industry have a low monthly income and are below the poverty line, whose standard of living is low. Although the workers are partners in the economic development of the industry, they are not getting adequate reward for their work. Even if the workers work in different units of the same enterprise, the wages are not the same. One entity differs from another entity. In order to overcome the inequality of workers, it is necessary for the labor unions and the government to provide adequate employment protection and social security to the domestic workers. There is no doubt that India will become a developed country only then. As their work is more monotonous or repetitive work, they inevitably work to support their families. The working environment in which they are doing is so lacking in basic facilities and due to the use of many chemicals they are prone to many occupational diseases or problems. Searching of readymade garment industry workers in different units of Ballari district. To know their problems, a study is undertaken to suggest suitable measures to overcome the problems, create awareness about the Government schemes and help in getting them.

Key Words: RMG Workers, Wage Discrimination, Social and Economic Problems, Risk factors.

I. Introduction:

Our country is a developing country where employment is an important source of subsistence economy. Its contribution to the country's economy is also seen to be significant. There are many types of unorganized sector out of which readymade garment industry is one in which many men and women are employed. Although there are more workers in the unorganized sector than in the organized sector, they are not unorganized as per the name and do not come under the legal framework. So they are deprived of many facilities. They are facing many discriminations like gender discrimination, caste discrimination, wage discrimination, job discrimination etc. in workplaces. Equal pay for equal work is limited to what is mentioned in labor laws. This study has gained importance in examining the social and economic conditions of the three sectors of workers namely daily wage basis, contract basis and permanent basis workers as mentioned above as well as the conditions at their workplaces.

Karnataka State is at the forefront of development in the industrial sector and in 2019-20 the share of this sector in the income of the state reached 21.3 percent. But it fell to 19.8 percent in 2020-21 due to Covid-19. Textile industry is the main industry as cotton production is very high in the state. In many parts of the state handloom, power loom and ready-made garments sector are developing at a high rate in the state. There are cotton mills in Bangalore, Davangere, Gadag, Hubli, Gokak, Ballari, Nanjangud, Belgaum, Bagalkote, Raichur, Ilakallu, Gudegudda. Karnataka is the readymade garment manufacturing capital of the country with readymade garments production worth $1.56 billion. Readymade garments are being exported from Karnataka state to America, Italy, Germany, England, Hong Kong, Canada, Australia and Western Europe.

One such mean of research for readymade garments Ballari's ready-made garments, jeans, has a history of hundreds of years. This has been achieved through the hard work of thousands of families. As cotton, the raw material required for jeans, is grown more in Ballari district, jeans manufacturing is at a very high level here. Ballari Jeans has put its stamp on the international map. Today, Ballari is known as Jeans Nadu even before it was called as Borderland.

There are more than 1000 jeans manufacturing units in Ballari. There are two units in the manufacturing of jeans namely spare parts unit and assemble unit. In the accessories section, cutting the cloth separately according to the size, i.e. the leg part of a pant, the packet part and so on. Ready-made garments are made by adding all the accessories in the assembled units. There are 800 units that make these accessories and 200 assembly units. Recently, after 5 decades of production of most jeans clothes, not only in our state, but also in foreign states and foreign countries, the state government and the central government hope to make many industrial units in Kuditini to make jeans fair in Ballari. Ballari is the jeans hub but there is no doubt that Ballari is on the rise. There are many workers in these units.

Utilization of goods and services is essential in production. Economists divide the factors of production into four categories namely land, labor, capital and entrepreneurship. "The laborers who are employed in different types of industries are called 'Industrial Laborers'. But cottage industries are not considered industrial workers in India. Only those working in organized large and medium industries are included in this group. All workers covered by the Industrial Factories Act are treated as organized workers, while workers in cottage industry and contract work are treated as unorganized workers".

1. Review of Literature:

Research always starts with a question and a problem. Its basic objective is to find an answer to a question through the application of the scientific method. Literature, research papers, articles, books related to the study can help the current research study perfectly and meaningfully.

"Health Hazard and Occupational Safety Challenges for Unorganized Sector Works in India" written by **Mohammad Shams Muktar and Dr. Preeti R. Gatmre (2021)** states that it is common for workers in the unorganized sector to fall prey to many health problems. The government instituted many health policies and programs in urban and rural areas of India which include government hospital, community health centers, sub-centers and primary health centers. They are National Health Mission, National Mental Health Programme, Asha, Ayushman Bharat, National Rural Health Mission and National Urban Health Mission, all launched by the Union Ministry of Health and Family Welfare. found in their study that it is the combination of all organized activities that ensure the welfare and well-being of all employees working in the unorganized sector.

The article **"Working and Living Conditions of Workers in Unorganized Sector-A Review of Literature"** by **PrasanaKumar Shetty and Surbhikapoor (2014)** provides information about the living conditions of workers in the unorganized sector. He undertook an in-depth study of the working and living conditions of the workers in the unorganized sector. Unorganized sector is popularly known as the insecure sector, where most of the people feel that there is no regular source of income and work throughout the year. The article echoes the general plight of poor relations between employers and employees, discrimination at work, sexual harassment, poor health/medical care and denial, terminal benefits, torture and poor working conditions. Workers in almost all sectors of the sector suggest that more research is needed in this area to suggest practical solutions to existing problems and on issues such as social security and the positive impact of unions and labor laws on workers.

Nitika Diwakar and Tafpikku Ahmed (2014) have done a study on **"Problems and Challenges Faced by the Unorganized Sectors: An Indian Perspective".** Unorganized sector workers are defined as working in small scale industries. The unorganized sector has less capital and fewer workers at home or less. It is often not consistent. Out of the total population of India, there are only 46.5 crore workers, out of which only 2.8 crore are in the organized sector and 43.7 crore are in the unorganized sector, according to the report of National Sample Survey Institute 2009-10. They do not have any specific framework. The workers are mostly

illiterate and without any knowledge of the laws they are forced to work long hours and low wages given by the employers.

Lilipet S, Jain T and Joseph B (2017); In their study **"Health Problems Among Garment Factory Workers – A Narrative Literature Review"** the objective of this study was to identify the pattern and prevalence of major health problems among garment factory workers. Working for long periods of time without rest, absence of personal protective equipment and inadequate provision of ergonomic facilities at the workplace lead to major health related problems among workers. Workers of repetitive nature are prone to physical, mental and nutritional health problems. Respiratory problems, cardiovascular diseases, gastrointestinal diseases, gynecological diseases, nervous disorders, mental disorders and nutritional deficiencies are common health risks. Sidda therefore opined that it is necessary to organize specific programs aimed at preventing muscular and skeletal disorders for garment workers.

2. Objectives of the Study

1. To know the problems faced by the workers of readymade garment industry.
2. To know the social security programs undertaken by the governments for the welfare of workers.

3. Results and Discussion:

Industrial workers in general and garment workers in particular are facing several occupational problems. While some are exposed to work that requires intense concentration, such as cutting, sewing, and finishing, which can result in headaches and blurred vision, others are exposed to more physically demanding tasks and experience muscle aches from prolonged sitting or standing. They primarily have health issues including shoulder discomfort, hip pain, etc. as a result of using their hands for extended periods of time while performing repetitive activities. The information available indicates that women are more likely than men to experience depression or mental health issues as a result of juggling work and housework. As it is very important for the study to know the problems of the workers, the information provided by the workers, the information provided by the workers in the study is described in Table 1 below.

Table: 01

Description of occupational problems of workers in readymade garment industry in Bellary district

Health Problems	Daily wage workers		Contract workers		Permanent workers		Total		Total (%)
	Male	Female	Male	Female	Male	Female	Male	Female	
Allergy	16 (25.00)	19 (13.67)	16 (19.57)	13 (23.21)	11 (17.74)	0 (0.00)	43 (20.77)	32 (15.69)	75 (0.18)
Eye Pain	6 (9.38)	27 (19.67)	14 (17.28)	15 (26.79)	9 (14.52)	2 (22.22)	29 (14.01)	44 (21.57)	73 (0.17)
Body Pain	21 (32.81)	31 (22.30)	22 (27.16)	17 (30.36)	19 (30.65)	3 (33.33)	62 (29.95)	51 (25.00)	113 (0.27)
Difficulty in Breathing	15 (23.44)	19 (13.67)	9 (11.11)	9 (16.07)	12 (19.35)	2 (22.22)	36 (17.39)	30 (14.71)	66 (0.16)
Tiredness	3 (4.69)	16 (11.51)	11 (13.58)	2 (3.57)	7 (11.29)	2 (22.22)	21 (10.14)	20 (9.80)	41 (0.09)

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Cough	0 (0.00)	9 (6.47)	6 (7.41)	0 (0.00)	2 (3.23)	0 (0.00)	8 (3.86)	9 (4.41)	17 (0.04)
Other	0 (0.00)	7 (5.04)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	7 (3.43)	7 (0.03)
None of the above	3 (4.69)	11 (7.91)	3 (3.70)	0 (0.00)	2 (3.23)	0 (0.00)	8 (3.86)	11 (5.39)	19 (0.04)
Total	**64 (100)**	**139 (100)**	**81 (100)**	**56 (100)**	**62 (100)**	**9 (100)**	**20 7 (100)**	**204 (100)**	**411 (100)**

Table 1 reveals that the health problems faced by the 411 workers selected for the study at the place of work or by nature of work. Looking at the figures in the table, a total of 411 male and female workers in the entire sector have health problems. Allergy 0.18%, Eye pain 0.17%, Migraine 0.27%, Breathing problem 0.16%, Fatigue 0.09%, Cough 0.04%, Other 0.03%, None 0.04%. . There are no respondents other than the number of daily wage earners who are facing other problems. Women are no exception. Generally speaking, readymade garment workers are more likely to work sitting and standing on the same side, so they have more eyestrain and eye strain in hemming and stitching. A large number of people who face problems like allergies are those who dye their clothes and use chemicals. Its information is depicted in diagram 1.

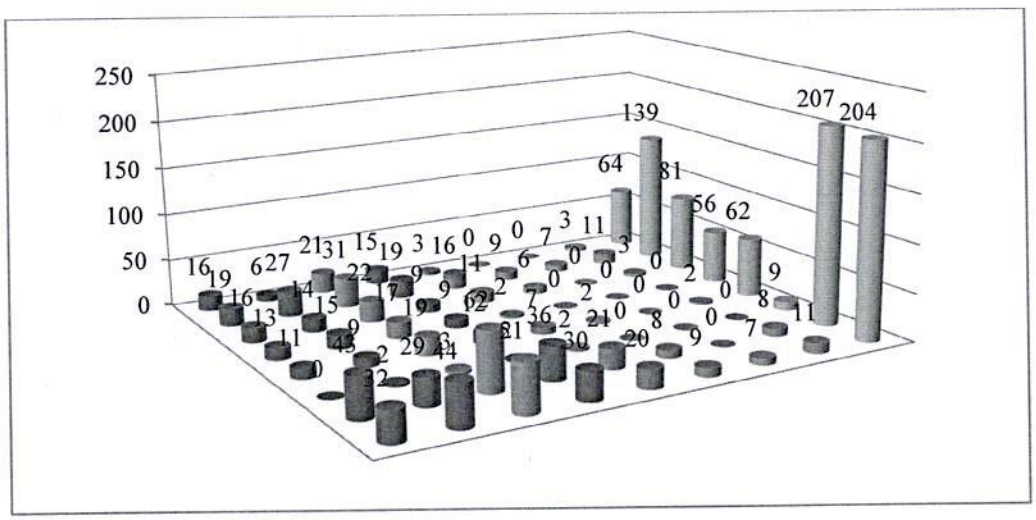

Figure 1: Description of occupational problems of workers in RMG

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4. Problems of Workers in Readymade Garment Industry in Ballari

1. Overtime duty: - Bellary has a high demand for readymade garments such as jeans garments. Apart from our country, these are also exported to foreign countries. So this industry is always profitable. As there is a huge demand especially during the festive season, the employers give overtime work to the workers as they produce more for their profit.
2. Lack of transport system: - Majority of people in Bellary is living in villages. They have to travel far away from their place of residence as there is a ready-made garment unit in the urban area. Employers do not provide transport arrangements for any type of workers. Go through government buses or autos.
3. Wage Discrimination: - Wage discrimination is an unsolved problem across India. Garment workers are no exception. As there are many types of jobs, low pay for low work, high pay for high work or high pay for skilled work. For example, low skilled jobs like threading, buttoning, labelling etc. One of them has not come but another can do that job. But some skilful things like cutting cloth etc. can be done only by experienced people. Because their work is indispensable, they are paid more. Similarly, women worked equally as men and were paid less. It is decided that the male is a wage earner and the female is a wage earner.
4. Delay in payment of wages: - Livelihood of workers depends on readymade work. Their wages or wages are low and the cost of daily necessities is high, making it difficult for them to make ends meet. When entrepreneurs delay in paying wages, they resort to debt. Very high interest has to be paid.
5. Job insecurity: - Although the readymade garment industry seems to be always in demand, sometimes there is no work. Because there is always a change in the styles of clothes. People always want new style of clothes. This made the garments less expensive when they were made in the old style without more advanced machines. Only when all of them are sold do the entrepreneurs start making new clothes. As a result, workers have to face insecurity without job stability.
6. Scolding with unspoken words: - Ready-made garment workers do not have any respect as they do menial work. If you don't do the right work or come to work a little late, they scold you with unspoken words regardless of whether you are male or female. As the laborers are in the habit of swearing all the time, they have assimilated excuses regardless of whether they are deaf or work is inevitable.
7. Lack of toilet facilities for women: - Readymade garments units are in many nooks and crannies or in small spaces so they do not have toilet facilities. If they are men, they go outside somewhere. But women are not able to go out and are blocking those going home. Due to this many health problems are faced.
8. Dermatological problem due to excessive use of chemicals: - In readymade clothes especially jeans clothes which have many colors A chemical material is used. Moreover, there are many stages in the manufacture of ready-made garments and some stages require the use of chemicals. Workers working in this stage may suffer from various types of allergies or skin diseases.
9. Physical and Mental stress: - Readymade garment manufacturers not only make the workers work longer hours to get more profit, they have to work more in less time without any kind of freedom, but if they do not work properly, the workers are subjected to a lot of physical and mental stress.
10. Absence of proper medical facility: - Although the garment workers suffer from many allergies, they are not provided with medical facilities by the workers. Due to the high cost in private hospitals, one cannot afford them and has to go to the government hospital. Many people are succumbing to diseases without proper medical facilities.
11. Children are not provided with higher or better educational facilities: - The workers of the readymade garment industry are unable to provide education in better or better schools as they struggle to meet their daily or essential supplies due to their low wages. Their children are not able to pursue higher studies and half of their children drop out of school and join other small jobs.
12. Without any kind of insurance facility: - Many government facilities like insurance facility, health facility, provident fund and ESI. are deprived of It is an unorganized unit and due to lack of stability in their work and non-fixed monthly payments.
13. Not getting the membership of labor union: - Although there are many labor unions, not knowing its existence or presence is a major reason for not getting membership of the labor union. Deprived of the benefits of a trade union.

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5. Conclusion:

In some cases, unorganized workers know about government schemes but do not know where to contact and whom to contact. Therefore, the National Social Security Council, a part of the government, and the NGOs (Non-Governmental Organizations) should come forward to provide information to the unorganized workers to avail the benefits of these schemes.

Although the contribution of the readymade garment industry in the Indian economy is immense, the workers working in this industry face many problems such as wage problems, health problems, etc. As this sector is mostly cottage industry and unorganized sector, there is no legal framework for the workers in this sector. There is no regular relationship between the employer and the employed as the workers in the readymade garment industry mostly work under contract workers. As the workers in this sector are highly illiterate, they are subjected to many forms of exploitation, but without knowing the labor laws that fight against them, they inevitably work for a living.

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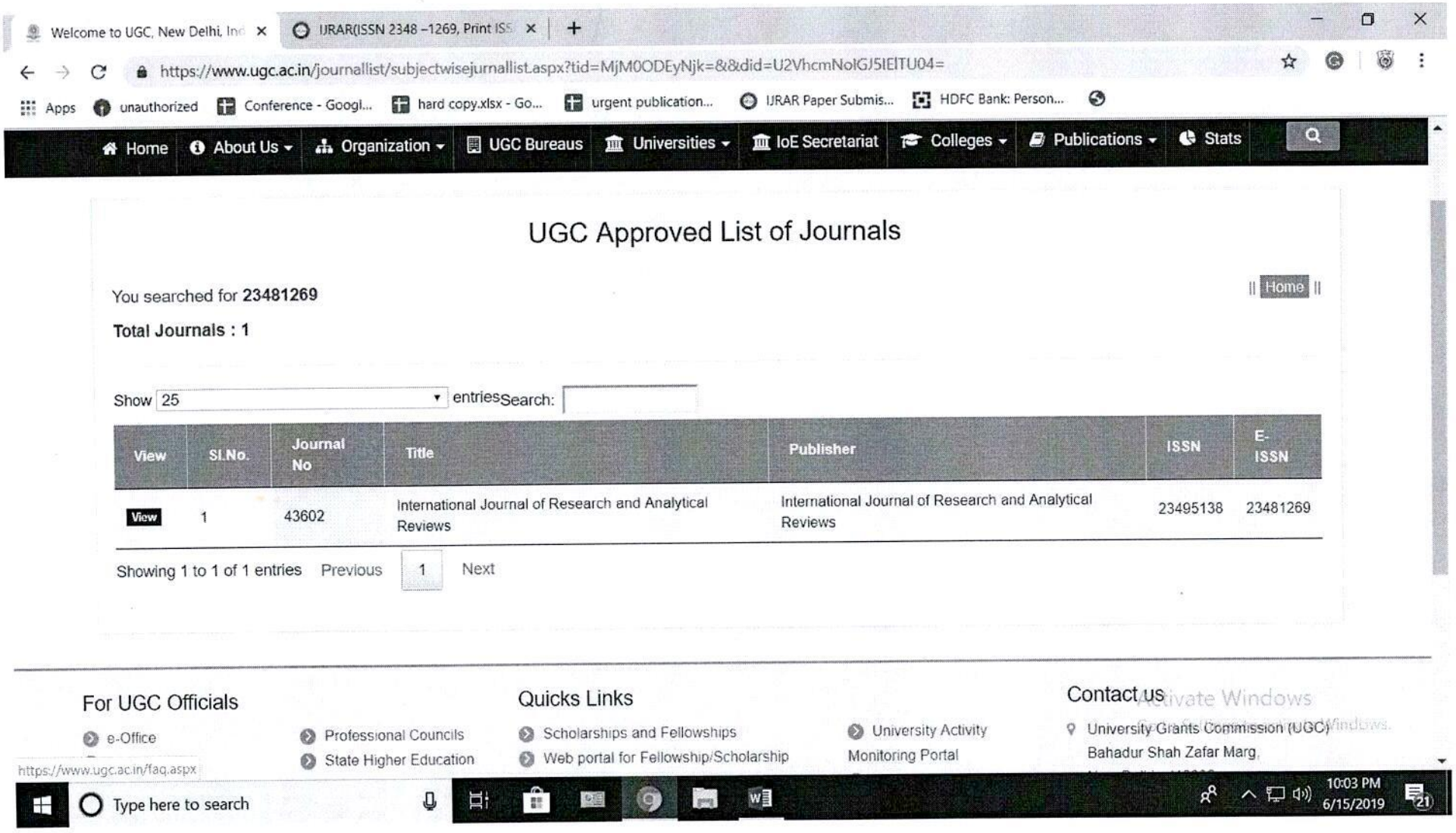
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Information Technology Impact on Banking Industry in India	Dr.Anupama K	Commerce	Muktha Shabd	Jan.2022	ISSN-2347-3150	**https://shabdbooks.com**	https://app.box.com/s/msh78ege1afohr1dc7isiky2gwwm1l6t	Yes

Director,
Research Development Council,
Smt. Allum Sumangalamma Memorial
College for Women, Ballari.

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Smt. Allum Sumangalamma Memorial
College for Women, Ballari-583103

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INFORMATION TECHNOLOGY IMPACT ON BANKING INDUSTRY IN INDIA

*Dr. Sadyojathappa S
**Anupama K

Abstract

The Banking industry in India is rapidly progressing with increased customer base and due to newly improved and innovative facilities offered by technology. As the coin has two faces likewise technology also has its two sides on Indian banking Sector-the positive and the negative side. The risks are high, though it can be minimized and Technology will be the backbone of Indian Banking Industry in upcoming time. Banking atmosphere has to turn into highly competitive currently. IT states to the gaining, dealing out, storing and broadcasting of all forms of material using computer knowledge and telecommunication systems. These technologies are used for the input, storing, dealing out, and communication of information. The basic essential of Information Technology (IT) in the banking sector are meeting internal requirements, effective in data handling, extending customer services, creative support for new product development, end-user development of the nontechnical staff. Emerging trends of information technology in the banking sector are Outsourcing, Combination, Distinguishing Edge, IT as Income Centre, Flourishing in Down Market. Tests faced by Indian banking scenario in India are Meet customer prospects on service and capability offered by the bank, Customer retaining, Dealing the spread and sustain the functioning profit, Recollecting the present market share in the industry and the enlightening the same, Accomplishment from another group of actors in the banking industry.

Key words: Banking Industry, Emerging Trends and Information Technology

Introduction

Banking industry is a backbone of Indian financial system and it is afflicted by many challenging forces. One such force is revolution of information technology. In today's era, technology support is very important for the successful functioning of the banking sector. Without IT and communication we cannot think about the success of banking industry, it has enlarged the role of banking sector in Indian economy. For creating an efficient banking system, which can respond adequately to the needs of growing economy, technology has a key role to play. In past 10 years, banks in India have invested heavily in the technology such as Tele banking, mobile banking, net banking, ATMs, credit cards, debit cards, electronic payment systems and data warehousing and data mining solutions, to bring improvements in quality of customer services and the fast processing of banking operation. Heavy investments in IT have been made by the banks in the expectation of improvement in their performance. But important in the performance depends upon, differences in the deployment, use and effectiveness of IT.

*Dr. Sadyojathappa S, Associate Professor, Vijayanagara Sri Krishnadevaraya University, Ballari-583105
**Anupama K, Research Scholar, Department of Developmental Studies, Kannada University Hampi, Vijayanagara District, Karnataka

Information technology in banking sector refers to the use of sophisticated information and communication technologies together with computer science to enable banks to offer better services to its customers in a secure, reliable and affordable manner and sustain competitive advantage over other banks. The significance of technology is greatly felt in the financial sector in view of the competitive advantage for banks resulting in the efficient customer service.

Information Technology revolution is of entirely changing the way financial business is done and has considerably widened the range of products and increased the expected demands of the customers. Financial sector reforms and banking sector reforms are the part and parcel of economic reforms, which strengthen the economic reforms. IT Act of 2000 gave new dimension to the Indian financial sector. IT has created transformation in banking sector: banking structure, business process, work culture and human resource development. It affected the productivity, profitability and efficiency of the banks to a large extent. Strengthening the financial sector and improving the functioning of financial market have been the core objective of the financial sector reforms. It was in June 1999 that an IT revolution actually appeared in the Indian financial institutions specially banking sector when the world of IT seemed too wide open with introduction of Indian Financial Net. This Indian Financial Net included a wide area satellite based network, which used Very Small Aperture Terminals Technology. The Reserve Bank of India jointly set it up with the Institute for Development and Research in Banking Technology. The Indian Financial Network initially comprised only the public sector banks but was later on opened up for participation by other categories of members including foreign banks as well. It was the payment system, which was the first segment of banking system, benefited a lot from the introduction of the new technology.

Transformation of Indian Banking

Indian banking has undergone a total transformation over the last decade. Moving seamlessly from a manual, scale-constrained environment to a technological leading position, it has been a miracle. Such a transformation takes place in such a short span of time with such a low cost.

Entry of technology in Indian banking industry can be traced back during the 1990s, the banking sector witnessed various liberalization measure. One of the major objectives of Indian banking sector reforms was to encourage operational self-sufficiency, flexibility and competition in the system and to increase the banking standards in India to the international best practices. With the ease of licensing norms, new private and foreign banks emerged-equipped with latest technology. Deregulation has opened up new opportunities to banks to increase revenues by diversifying into investment banking, insurance, credit cards, mortgage financing, depository services etc. The role of banking is redefined from a mere intermediary to service provider of various financial services under one roof acting like a financial supermarket.

Evolution of Information Technology in Banking

- MICR based cheque processing

- Arrival of card based payments
- Electronic Clearing Services
- RTGS/NEFT
- Cheque Truncation System (CTS) or Image-based Clearing System (ICS)
- Core Banking Solutions (CBS)
- Automated Teller Machine (ATMs)
- Phone and Tele Banking
- Internet and Mobile Banking

Recent IT Trends of Indian banks

The banking industry is going through a period of rapid change to meet competition, challenges of technology and the demand of end user. Clearly technology is a key differentiator in the performance of banks. Banks need to look at innovation not just for product but for process also.

Today, technology is not only changing the environment but also the relationship with customers. Technology has not broken barriers but has also brought about superior products and channels. This has brought customer relationship into greater focus. It is also viewed as an instrument of cost reduction and effective communication with people and institutions associated with the banking business. The RBI has assigned priority to the up gradation of technological infrastructure in financial system. Technology has opened new products and services, new market and efficient delivery channels for banking industry. IT also provides the framework for banking industry to meet challenges in the present competitive environment. IT enables to cut the cost of global fund transfer.

The Banking industry has been taking advantage of the following technology Products

Electronic Payment and Settlement System – The most common media of receipts and payment through banks are negotiable instruments like cheques. These instruments could be used in place of cash. The inter bank cheques could be realized through clearing house systems. Initially there was a manual system of clearing but the growing volume of banking transaction emerged into the necessity of automating the clearing process.

Use of MICR Technology – MICR overcomes the limitation of clearing the cheques within banking hours and thus enables the customer to get the credit quickly. These are machine – readable codes added at the bottom of every cheque leaf which helped in bank and branch-wise sorting of cheques for smooth delivery to the respective banks on whom they are drawn. This no doubt helped in speeding up the clearing process, but physical delivery of cheques continued even under this partial automation.

CTS (Cheque Truncation System) – Truncation means stopping the flow of the physical cheques issued by a drawer to the drawee branch. The physical instrument is truncated at some point on route to the drawee branch and an electronic image of the cheque is sent to the

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drawee branch along with the relevant information like the MICR fields, date of presentation, presenting banks etc. This would eliminate the need to move the physical instruments across branches, except in exceptional circumstances, resulting in an effective reduction in the time required for payment of cheques, the associated cost of transit and delays in processing etc., thus speeding up the process of collection or realization of cheques.

Electronic Clearing Services (ECS) – The ECS was the first version of "Electronic Payments" in India. It is a mode of electronic funds transfer from one bank account to another bank account using the mechanism of clearing house. It is very useful in case of bulk transfers from one account to many accounts or vice-versa. The beneficiary has to maintain an account with the one of the bank at ECS Centre.

There are two types of ECS (Electronic Clearing Service)

ECS – Credit – ECS Credit clearing operates on the principle of 'single debit multiple credits' and is used for transactions like payment of salary, dividend, pension, interest etc.

ECS – Debit – ECS Debit clearing service operates on the principle of 'single credit multiple debits' and is used by utility service providers for collection of electricity bills, telephone bills and other charges and also by banks for collections of principle and interest repayments.

Electronic Fund Transfer (EFT) – EFT was a nationwide retail electronic funds transfer mechanism between the networked branches of banks. NEFT provided for integration with the Structured Financial Messaging Solution (SFMS) of the Indian Financial Network (INFINET). The NEFT uses SFMS for EFT message creation and transmission from the branch to the bank's gateway and to the NEFT Centre, thereby considerably enhancing the security in the transfer of funds.

Real Time Gross Settlement (RTGS) – RTGS system is a funds transfer mechanism where transfer of money takes place from one bank to another on a 'real time' and on 'gross basis'. This is the fastest possible money transfer system through the banking channel. Settlement in 'real time' means payment transaction is not subjected to any waiting period. The transactions are settled as soon as they are processed. "Gross settlement" means the transaction is settled on one to one basis without bunching with any other transaction.

Core Banking Solutions (CBS) – Computerization of bank branches had started with installation of simple computers to automate the functioning of branches, especially at high traffic branches. Core Banking Solutions is the networking of the branches of a bank, so as to enable the customers to operate their accounts from any bank branch, regardless of which branch he opened the account with. The networking of branches under CBS enables centralized data management and aids in the implementation of internet and mobile banking. Besides, CBS helps in bringing the complete operations of banks under a single technological platform.

Development of Distribution Channels – The major and upcoming channels of distribution in the banking industry, besides branches are ATMs, internet banking, mobile and telephone banking and card based delivery systems.

Automated Teller Machine (ATM) – ATMs are perhaps most revolutionary aspect of virtual banking. The facility to use ATM is provided through plastic cards with magnetic strip containing information about the customer as well as the bank. In today's world ATM are the most useful tool to ensure the concept of "Any Time Banking" and "Any Where Banking".

Phone Banking – Customers can now dial up the banks designed telephone number and he by dialing his ID number will be able to get connectivity to bank's designated computer. By using Automatic voice recorder (AVR) for simple queries and transactions and manned phone terminals for complicated queries and transactions, the customer can actually do entire non-cash relating banking on telephone: Anywhere, Anytime.

Tele Banking – It is another innovation, which provided the facility of 24 hour banking to the customer. Tele-banking is based on the voice processing facility available on bank computers. The caller usually a customer calls the bank anytime and can enquire balance in his account or other transaction history.

Internet Banking – Internet banking enables a customer to do banking transactions through the bank's website on the internet. It is system of accessing accounts and general information on bank products and services through a computer while sitting in its office or home. This is also called virtual banking.

Mobile Banking – Mobile banking facility is an extension of internet banking. Mobile banking is a service provided by a bank or other financial institution that allows its customers to conduct financial transactions remotely using a mobile device. Unlike the related internet banking it uses software, usually called an App, provided by the financial institution for the purpose. Mobile banking is usually available on a 24 hour basis. Some financial institutions have restrictions on which accounts may be accessed through mobile banking, as well as a limit on the amount that can be transacted. Transactions through mobile banking may include obtaining account balances and lists of latest transactions, electronic bill payments, and fund transfers between a customer's or another's accounts.

Emerging Trends of Information Technology in Banking Sector

1). Outsourcing: Banking business process outsourcing or banking BPO is a highly specialized sourcing strategy used by banks and lending institutions to support the business acquisition and account servicing activities associated with customer lending lifecycle.

2). Integration: integration is a phenomenon in which financial markets in neighbouring, regional and/or global economies are closely linked together. ... Because of financial market imperfections, financial integration in neighbouring, regional and/or global economies is therefore imperfect.

3). Distinctive Edge: banking entity, owned by a state or nationally chartered BANK, with an international business scope. Edge Act banks are authorized to operate interstate branches,

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accept DEPOSITS from offshore sources, invest in foreign securities and projects, and grant foreign LOANS.

4). Prospering in Down Market: to commercial products, services, etc, that are cheap, have little prestige. The market condition in which the values of safeties are falling and extensive gloom causes the undesirable sentiment to be self-sustaining .

5). Leading to Downsizing: Downsizing is the eternal decrease of a company's labor power through the removal of unproductive workers or divisions. Downsizing is a mutual administrative exercise, usually connected with economic downturns and fading businesses.

6). Getting Competitive Intelligence: Competitive intelligence is the performance of gathering and examining actionable info about participants and the marketplace to form a business strategy. It is effective when a business has a comprehensive plentiful representation of the marketplace so that it may anticipate and respond to tests and problems before they arise.

Positive impact of technology on banking sector

- The biggest revolution came in banks is Digitization.
- Banking process is faster than before and more reliable. Maintenance and retrieval of documents and records have become much faster and easier.
- Computerized banking also improves the core banking system. With CBS (core banking system) all branches have access to common centralized data and are interconnected.
- With the innovation of MICR cheque processing system, the processing of cheques becomes more faster and efficient h than before.
- USSD (Unstructured supplementary service data) was launched by Government, so people with no internet-connectivity too can access their bank accounts without visiting the branch.
- With increasing internet reach, Internet Banking was developed and now offered by almost every bank. Through this, every transaction details and inquiries can be performed online without visiting the bank.
- It offered more transparency in transactions.
- The scope of frauds in banks is being minimized through the use of passwords, double authentication in online banking.
- Technology also leads to competition among the banks which eventually provides better services to people.
- With introduction of mobile banking, one can access their bank from anywhere-anytime. Everything is one quick tap away.
- To facilitates better services, Banks have introduced Automated Banking Services Solution like Cash Deposit Machine, Cheque Deposit Machine, Passbook Printing Machine through these service have become easier.

Digital Payments

In line with earlier years, large value credit transfers through RTGS dominated the overall digital payments landscape in the year 2020-21, accounting for 80.8 per cent of the total value of digital transactions. In terms of volume

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Digital Payments

Item	2018-19		2019-20		2020-21	
	Volume (in lakh)	**Value (in crore)**	**Volume (in lakh)**	**Value (in crore)**	**Volume (in lakhs)**	**Value (in crore)**
Payment system						
Credit transfers						
1.Large Value Credit Transfers - RTGS	1366	135688187	1507	131156475	1592	105599849
2.Credit Transfers	118481	26090471	206506	28562857	317852	33522150
AePS (Fund Transfers)	11	501	10	469	11	623
ECS Cr	54	13235	18	5145	-	-
IMPS	17529	1590257	25792	2337541	32783	2941500
NACH Cr	8834	729673	11290	1043212	16450	1232714
NEFT	23189	22793608	27445	22945580	30928	25130910
UPI	53915	876971	125186	2131730	223307	4103658
3.Debit transfers						
BHIM Aadhaar Pay	68	815	91	1303	161	2580
ECS Dr	9	1260	1	39	-	-
NACH Dr	4830	522461	7340	718166	9630	868906
4.Card Payments						
Credit Cards	17626	603413	21773	730894	17641	630414
Debit cards	44143	593475	50611	703920	40146	661385
5.Prepaid Payment Instruments	46072	213323	53318	215558	49392	197695
Total Digital Payments (1+2+3+4+5)	232601	163713425	341239	162089411	437064	141483892

Source: Report on Trend and Progress of Banking in India 2020-21

However, credit transfers via multiple channels such as the Unified Payments Interface (UPI), National Electronic Funds Transfer (NEFT) and Immediate Payment Service (IMPS) were the leaders. In case of card payments, the value of debit card transactions registered a growth of 35.6 per cent as against 21.1 per cent for credit cards

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Negative impact of technology on banking sector :

- The biggest negative impact of technology is loss of Jobs as automation has replaced number of jobs in banking sector.
- Through technology comes the threat of Cyber Attack, a loophole in the system, millions of data can be lost in the blink of an eye.
- These technologies consumes less time, it also sometimes makes people careless- which causes loss of personal details as happened last year in 2016,many debit cards details of big banks were compromised.

Conclusion:

Information Technology offers enormous potential and various opportunities to the Indian Banking sector. It provides cost-effective, rapid and systematic provision of services to the customer. The efficient use of technology has facilitated accurate and timely management of the increased transaction volumes of banks which comes with larger customer base. Indian banking industry is greatly benefiting from IT revolution all over the world.

The Indian banks lag far behind the international banks in providing online banking. In fact, this is not possible without creating sufficient infrastructure or presence of sufficient number of users. Technology is going to hold the keys to future of banking. So banks should try to find out the trigger of change. Indian Banks need to focus on swift and continued infusion of technology

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3.3.1 Number of research papers published per teacher in the Journals notified on UGC CARE list during the last five years (2020-21)

Title of paper	Name of the author/s	Department of the teacher	Name of journal	Calendar Year of publication	ISSN number	Link to the recognition in UGC		
						Link to website of the Journal	Link to article / paper / abstract of the article	Is it listed in UGC Care list
Photocatalytic degradation of solochrome balck under UV light on cobalt doped titanium dioxide photocatalysts.	r. A.M. Kalamn	Physics	Journal of Engineering Sciences	Jul-20	0377-9254	www.jespublication.com	https://jespublication.com/upload/2020-1107121.pdf	Yes
Microwave-Assisted Synthesis of Copper Nanoparticles : Influence of Copper Nanoparticles Morphology on the Antimicrobial Acivity	P J Bindu	Chemistry	Jounal of Materials NanoScience	Aug-20	2394-0867	http://pubs.iscience.in/jmns	https://pubs.thesciencein.org/journal/index.php/jmns/article/view/223	Yes

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Research Development Council,
Smt. Allum Sumangalamma Memorial
College for Women, Ballari.

IQAC, Co-ordinator
Smt. Allum Sumangalamma Memorial
College for Women, Ballari-583103

PRINCIPAL
Smt. A.S.M. College for Women
BALLARI-583 103

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PHOTOCATALYTIC DEGRADATION OF SOLOCHROME BLACK UNDER UV LIGHT ON COBALT DOPED TITANIUM DIOXIDE PHOTOCATALYSTS

A M Kalamma[1*], T Subba Rao[1] Ambreensaba Mulla[2], Shirajahammad.M. Hunagund[3], Mohammed Afzal[2]

[1]*Department of Physics, Shri Krishnadevaraya University Ananthapuramu-515003 Andhra Pradesh (AP), India*

[2]*Department of Physics, SECAB's A.R.S.I Degree College for Women, Vijayapur-586101 Karnataka, India*

[3]*Department of physics, SECAB's I.E.T College, Vijayapur-586101 Karnataka, India*

[*]Corresponding Author - email: **amkalamma@rediffmail.com**

Abstract - In the present investigation well-crystalline cobalt doped TiO_2 nanoparticles (NPs) were prepared by hydrothermal process. The structural, morphological, optical and compositional properties of as prepared samples have been characterized by X-ray diffraction (XRD),field emission scanning electron microscopy (FESEM), UV-Vis spectrophotometry and energy dispersive X-ray spectroscopy (EDS) .XRD analysis reveals that the prepared samples were nanocrystalline and had anatase phase. The average size of crystallites using Scherrer's formula was found to be 7.07nm and 5.73nm for TiO_2 and Co-TiO_2 NPs respectively. FESEM analysis shows the NPs were spherical shape with an average size of about 10nm to 20nm.EDS analysis confirms the chemical compositions of the NPs having Ti and O elements. UV-Vis measurement shows increase in optical band gap due to cobalt doping. The photocatalytic activity was evaluated by monitoring the degradation of Solochrome Black [Eriochrome Black T (EBT)] under UV-light illumination. The photocatalytic degradation results for Solochrome dye were 61.4 % and 78.3 % for TiO_2 NPs and Co-TiO_2 NPs respectively under UV irradiation for 110 minutes. Thus increase in photocatalytic degradation when doped with Co.

Keywords- Hydrothermal synthesis, Photocatalytic degradation, TiO_2 NPs, Co-TiO_2 NPs.

INTRODUCTION

Natural colors is one of the significant gatherings of poisons broadly utilized in material, plastic, medication and numerous different businesses, while the unsafe impacts of natural colors in waste water have been a significant concern and now a significant danger in the earth because of the considerable contamination issues brought about by them. These businesses depleted enormous amount of high substance shading effluents, which are commonly increasingly harmful and impervious to devastation by traditional techniques. An essential basis in the utilization of these colors is that they should be profoundly collected in water and stable in light during washing. The gathering of these colors in the water bodies causes eutrophication, decreases the reoxygenation limit and makes serious harm to the aquatic living beings by impeding the invasion of daylight [1]. They must also be resistant to microbial attack. Therefore, they are not readily degradable and are typically not removed from water by wastewater treatment systems and conventional methods like adsorption, ultra filtration, chemical and electrochemical methods [2]. The predominance of photocatalytic degradation by nanoparticles in wastewater treatment is because of its favourable circumstances over the regular techniques, for example, snappy oxidation, no development of polycyclic items and oxidation of toxins. It is a compelling and quick strategy in the expulsion of contaminations from waste water [3]. In the recent years, numerous metal oxides including TiO_2 [4], ZnO [5], and other oxides have attracted growing attentions for photodegradation of organic dyes; TiO_2 is of specific interests because of its ease and high strength. In any case, TiO_2 has been increased momentous consideration as a photocatalyst in corruption of natural poisons. Because of the properties of hostile to oxidation long haul strength, non-harmfulness, solid redox capacity, it has been broadly utilized in the field of photocatality. TiO_2 being a semiconductor with a huge band gap i.e, 3.2, 3.02 and 2.96eV for anatase, rutile and brookite phases individually. As TiO_2 particles, get lighted by photons with vitality more noteworthy than the band width of TiO_2, the valence band electrons will be travelled to the band of conduction which leave gaps in the valence band.

Presently electron gap sets could take an interest into a wide range of substance responses on TiO_2 surface and that at last debases all the toxins in the arrangement. This response prompts recombination of electrons and openings rapidly; in the long run TiO_2's photocatalytic movement incredibly diminishes. To acquire higher photocatalytic action, one usually utilized technique is doping metal and/or non metal particles into the TiO_2's crystal lattice. In photocatalysts, vitality of the episode pillar ought to be equivalent to this boundary that can energize the electron and move to conduction band. By considering the band gap of anatase stage, it is considered as a photocatalyst under UV illumination. As per the examinations, daylight on Earth's surface is around 52 to 55% infrared (over 700 nm), 42 to 43% visible (400 to 700 nm), and 3 to 5% bright (under 400 nm) [6]. Along these lines, planning of photocatalysts with energizing vitality in obvious range or changing the necessary vitality for energizing the electrons can be valuable for utilizing the daylight so as to cleansing of water. While vitality change and capacity is the large test in the modernized world, over these issue is significant for the improvement of synergist and electrochemical innovation [7-10]. Doping is one of the most common methods to change the required energy for exciting of electrons in photocatalysts [11]. Doping can decrease or increase this energy; this change depends on type of photocatalyst and dopants [12]. Vu et al [13-17] incorporating exceptionally dynamic photocatalytic TiO_2 nano tubes by aqueous treatment in the base medium utilizing the commercial powder of TiO_2 as Ti source. In this work, Co was used as dopants in TiO_2 nanostructures and the products were characterized and analysed their photocatalytic solochrome dye degradation under UV light.

2. MATERIALS AND METHODS

2.1 CHEMICALS

Titanium (IV) n butoxide (TNB) wt 99% liquid analytical grade, Cobalt nitrate hexahydrate [Co $(NO_3)_2.6H_2O$] and EDTA (di-sodium salt dehydrate) were purchased from Alfa Aesar Chemicals, India. De-ionized water (DW) was used in the preparation of all solutions.

2.2 SYNTHESIS OF TIO_2 AND CO DOPED TIO_2 NANOPARTICLES

TiO_2 NPs were synthesized using hydrothermal method [18]. 30ml of 0.1M of E.D.T.A ($C_{10}H_{14}N_2Na_2O_8.2H_2O$) was prepared by dispersing 0.56gm of E.D.T.A in 15ml of de-ionised water (DW) with a continuous stirring with the aid of magnetic stirrer for 10 minutes later adding 15ml of DW and 1ml of Titanium (IV) n butoxide was added drop wise with continuous stirring for 30 minutes. The colloidal solution was then transferred to a 50ml Teflon-lined stainless steel auto clave, the autoclave was sealed and placed in an oven at 180^0C for 3hours, then the autoclave was allowed to cool down to room temperature. Under ambient conditions, the reactant mixture was centrifuged to collect the product; the product was washed continuously with DW several times to remove the organic molecules bonded to the surface of the product. The final product was dried in an oven at100^0C for one hour. Same procedure is adopted for Cobalt doped TiO_2 nanoparticles by adding 5ml of 0 .1M [Co $(NO_3)_2.6H_2O$] to the solution, then the prepared sample is used for photodegradation application.

PHOTOCATALYTIC EXPERIMENTS

The photo catalytic reactor is a Pyrex-glass cell with 1.0 L capacity. A 10 W Lamp (Philips) as the UV light source (365 nm) was set in a quartz light holder which immersed in the photo reactor cell. Prior to passing light, the solution was allowed stirred in dark for 60 minutes to accomplish adsorption–desorption balance between the color and photo catalyst. The cell was loaded up with 1mg/L of color arrangement and 1 x 10^{-5} M of the photo catalyst. Magnetic stirrer was used to introduce fresh air bubbles into the suspension using a pump. Dye degradation was inspected by taking 4 mL of the suspension at 10 minutes light time spans. Finally, the rate of degradation was determined from the change in absorbance of Dye solution. Prior to the estimation, the resultant solution was centrifuged for 10min at 5000 rpm to remove any turbidity. Kinetic data were evaluated using Microsoft Excel 2010 program.

2.3 CHARACTERIZATION TECHNIQUES:

2.3.1 UV-VIS SPECTROSCOPY

UV-Vis absorbance spectra in the wavelength range 200-800nm was measured using UV-Vis spectrophotometer (model: SPECORD 200+ Analytikjena)

2.3.2 XRD

The crystal structure of the powder sample at a scanning rate of 0.02^0 per second in the scattering angle range of 20^0 to 80^0 with the use of Cu K_α radiation of wavelength $1.54060A^0$ were analysed by XRD (model: Rigaku pro analytical) Peak analysis was carried out using PCPDFWIN software.

2.3.4 The surface morphology and nano size nature of the samples at an operating voltage 5kV were examined using FE-SEM (model: Xford-EDX system IE 250 X Max 80).

2.3.5 EDS Elemental compositions were analysed using EDS (model: FEI Quanta 200 F).

2.3.6 ZETA POTENTIAL

The zeta potential was based on the surface charge of the particles relative to the local environment of the prepared particle. This electrostatic potential of shear plane of the particle was carried out in ultrasonicated dispersion of 0.01 g/100 mL in DMSO in room temperature using the Horiba SZ-100 nanoparticle analyzer.

3. RESULTS AND DISCUSSIONS

3.1 OPTICAL PROPERTIES:

3.1.1 UV-VIS SPECTROSCOPY;

UV-Vis Spectra were recorded for TiO_2 NPs and Co-TiO_2 NPs in ethanol solvent at room temperature and graphs are shown in Fig 1(a). From the curves it is seen that the absorption maxima (λmax) for TiO_2 NPs and Co-TiO_2 NPs were seen at 341 nm and 370.8 nm separately which is a preliminary indication for the presence of TiO_2 material. The band gap of both the samples were estimated utilizing the absorption information with the assistance of (K–M) transformation method [19].Band gap energy of the semiconductor was estimated using the optical absorption coefficient (α) and is expressed by equation

$$\alpha = \frac{A(h\nu - E_g)^{1/n}}{h\nu} \qquad (1)$$

Where, hν is energy of photon, E_g is the band gap energy, A is a constant depends on the transition probability and depends on the nature of the transition for allowed direct transition (n= ½), for allowed indirect transition (n=2). In the present cases for an indirect gap, the value of n is 2 for TiO_2 NPs and Co-TiO_2 NPs. Using Tauc's plot the estimated E_g values were found to be 3.07eV and 3.95 eV respectively.

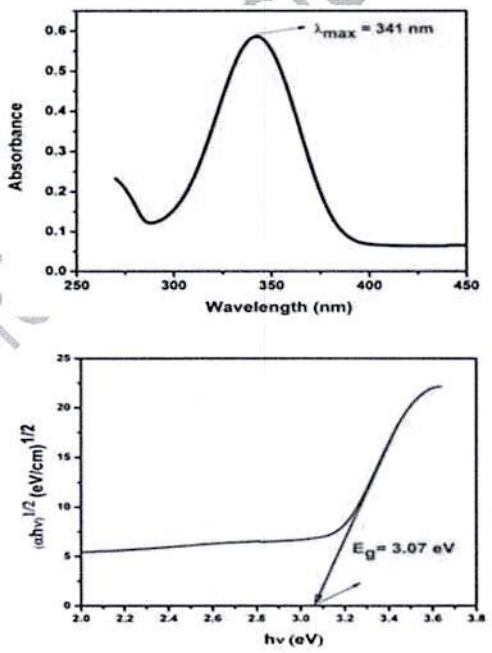
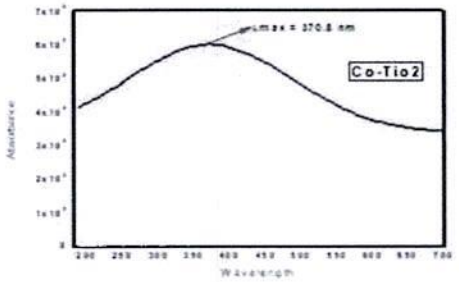


Fig (1) a: UV and Tauc's plot for TiO



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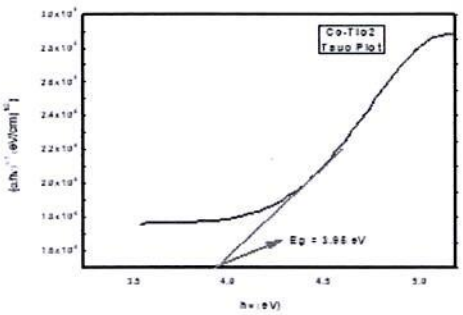

Fig 1(b): UV and Tauc's plot for Co -TiO_2

3.2 STRUCTURAL PROPERTIES:

XRD analysis was carried out to verify the presence of nano crystalline and phase formation. Fig 3 (a and b) shows XRD patterns for TiO_2 and Co-TiO_2 powders respectively it is observed that the presence of strong and sharp peaks; it reveals the formation of the well crystallized samples. From the Fig 3 (a) it is observed that the Bragg's reflection at 2Θ = 25.3429, 37.8769, 47.9727, 54.0791, 62.7467, 75.1348 and 82.6813 can be indexed to (101), (004), (200), (211), (204), (215) and (224) crystal planes respectively. The comparison of 2Θ values in observed Fig 3(a) XRD patterns with those from the standard Joint Committee on Powder Diffraction Standards (JCPDS) data no. 89.4921 confirms the formation of the TiO_2 having anatase phase and tetragonal crystal structure. Fig 3(b) shows the XRD patterns for Co-TiO_2 powders, it is observed that the Bragg's reflection at 2Θ=25.3669, 37.7705, 48.0267, 54.1788, 62.749, 75.1144 and 82.8806 can be indexed to (220), (311), (002), (060), (402), (650) and (660) crystal planes respectively. The comparison of 2Θ values in observed Fig 3(b) XRD patterns with those from the standard Joint Committee On Powder Diffraction Standards (JCPDS) data no. 35.0793 confirms the formation of the Co-TiO_2 having anatase phase and orthorhombic crystal structure. The Scherer's equation [20] is used to estimate an average crystalline size by determining the full width at half maximum (FWHM) of the most intense reflection plane and this equation is given by

$$D \approx \frac{0.9\lambda}{\beta \cos\theta} \qquad (2)$$

Where D is an average crystalline size, λ is the wavelength of X-ray used (1.50406 x 10^{-10} m), Θ is the Bragg's angle in radian and β is the full width at half maximum of the most intense reflection in radian. In our case, the most intense peak for TiO_2 and Co-TiO_2 were found to be (101) and (006) plane and the estimated average crystalline size is 7.07nm and 5.73nm respectively

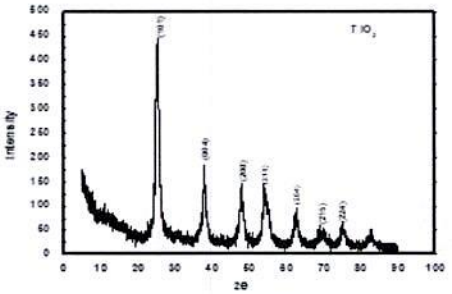

Fig 3 (a) XRD graph for TiO_2

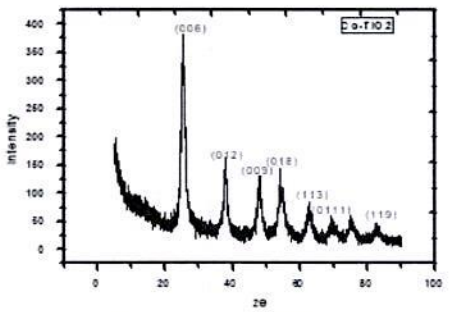

Fig 3 (b) XRD graph for Co-TiO_2

3.3 MORPHOLOGY, SIZE DISTRIBUTION AND ELEMENTAL ANALYSIS

FE-SEM analysis was used to examine the surface morphology and nano size nature of the samples. Fig 4 (a) and Fig 4 (b) shows the particles are having the spherical cluster with average size of about 10 nm to 20 nm. EDS was examined to investigate the chemical composition in $CoTiO_2$ NPs Fig 4 (c) and Fig 4 (d) represents the EDS spectrum for TiO_2 NPs and Co-TiO_2 NPs, hence EDS spectrum confirms the presence of elements i.e. Ti and O, in addition small quantities of element C was observed since it is residue of oil contaminants. The weight percentage (%) and atomic weight percentage (%) Co-TiO_2 NPs are shown inset of Fig 4 (c) and Fig 4 (d)

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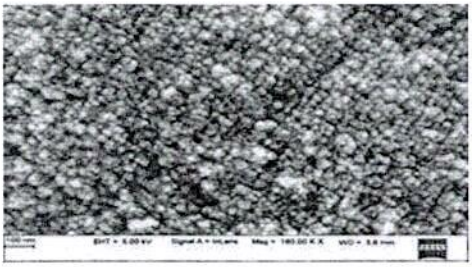
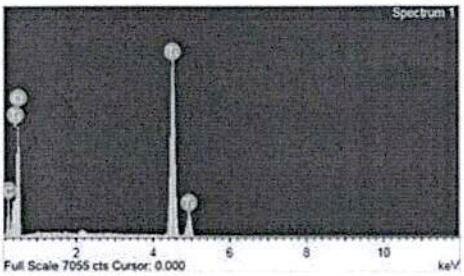


Fig 4(a) FE- SEM image of TiO_2



Element	Weight %	Atom %
O k	61.19	55.18
Ti k	57.22	17.23
C k	22.97	27.59

Fig 4(c) EDS spectrum of TiO_2 NPs inset corresponding weight % and atomic % of element

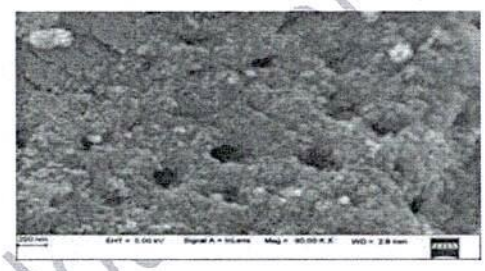
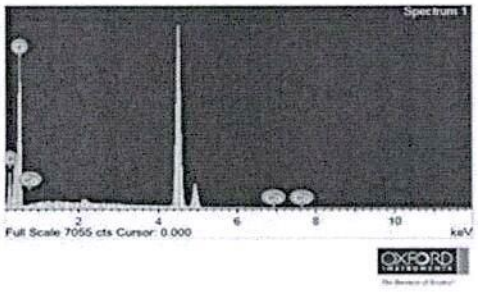


Fig 4(b) FE- SEM image of Co-TiO_2

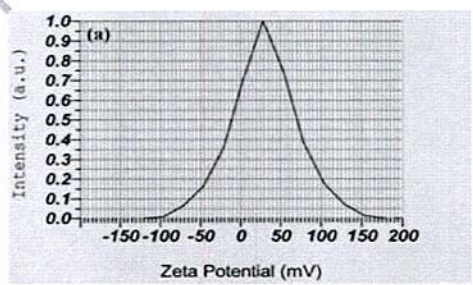


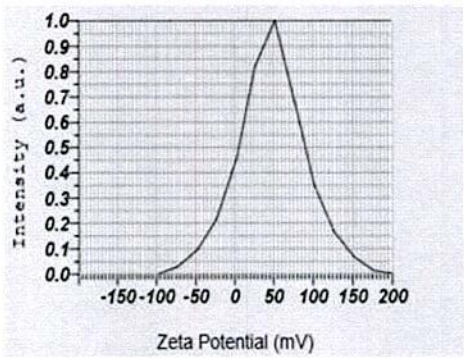
Element	Weight %	Atom %
O	33.77	66.56
Co	0.29	0.16
C	12.68	33.28

Fig 4(d) EDS spectrum of Co-TiO_2 NPs inset corresponding weight % and atomic % of elements

ZETA POTENTIAL STUDY

The zeta potential with a positive value of 30 mV with electrophoretic mobility 0.000061 cm^2/Vs and with positive value of 47.6 mV with electrophoretic mobility 0.000097 cm^2/Vs suspension was obtained for the $TiO_2$and Co-TiO_2 NPs respectively in DMSO and the zeta potential graphs shown in the Fig (5), which clearly shows a stable dispersion without particle settlement. Furthermore, the study of prepared suspension corroborates with general criteria of zeta potential (ξ) value 30 mV with positive or negative sign for better stability.





(b)

Fig. 5: Zeta potential evaluation of
(a) TiO_2NPs and (b) Co-TiO_2 NPs in DMSO solvent.

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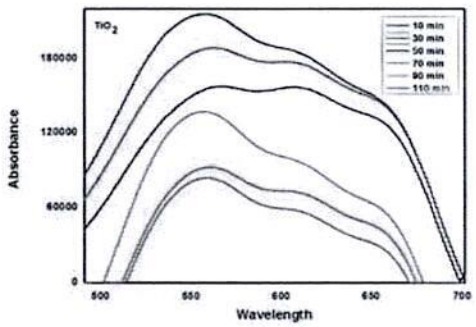
PHOTODEGRADATION PROCESS:

(a)



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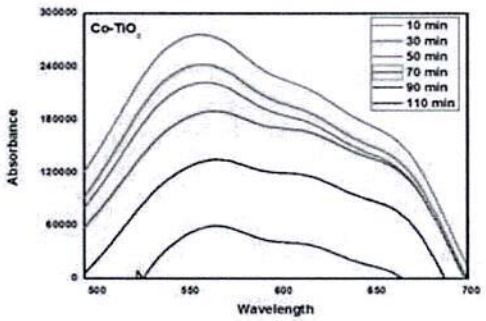

Fig. 6: Photo degradation evaluation of (a) TiO_2 NPs and (b) Co-TiO_2 NPs in solochrome dye solution.

EVALUATION OF PHOTO CATALYTIC ACTIVITY

To assess the photo catalytic activity of TiO_2 NPs, the photo catalytic degradation of solochrome color was performed under UV illumination. The photo catalytic degradation was assessed by estimating the absorbance at customary time stretches. Strikingly, it was seen that the relative absorption intensity constantly diminished as the UV brightening presentation time expanded, altogether demonstrating that solochrome dye degradation viably on the outside of TiO_2 photo catalyst [Fig. 6(a) and Fig 6(b)]. This is on the grounds that, under light, profoundly oxidizing hydroxyl and oxy radicals are shaped by the semiconducting metal oxides like TiO_2, Co-TiO_2 etc. via generation of electron–hole pairs, which break the large organic materials into less harmful small organic materials. The obtained degradation was 61.4 %, 78.3 % within 110 min for TiO_2 and Co-TiO_2 [21].It reveals that after doping with Co percentage of degradation was increased. The Solochrome degradation percentage was calculated as:

$$\text{Degradation rate } (\%) = \frac{A_0 - A}{A_0} \times 10 \quad (3)$$

In order to compare the photo catalytic efficiency of prepared TiO_2 NPs with commercially available photo catalyst such as, TiO_2 & Co-TiO_2 experiments have been done at a fixed solochrome dye concentration for 110 min.

CONCLUSION

Eco friendly hydrothermal route was used for the synthesis of TiO_2 and Co doped TiO_2 nanoparticles and was confirmed by various characterization techniques. The TiO_2 and Co-TiO_2 are having particle size about 10 to 20 nm. Further studied Solochrome dye was degraded under UV light using TiO_2 and Co doped TiO_2 nanoparticles. Among doped TiO_2, the maximum degradation efficiency was found to be 61.4 % for TiO_2 and 78.3 % for Co-TiO_2. From this we can conclude that Co-TiO_2 Shows enhanced photocatalytic activity than bare TiO2.

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Integrated Science

Journal of Materials NanoScience

Microwave-assisted synthesis of copper nanoparticles: influence of copper nanoparticles morphology on the antimicrobial activity

T. R. Ravikumar Naik,*[1] S. A. Shivashankar,[1] P. J. Bindu[2]

[1]Centre for Nano Science and Engineering, Indian Institute of Science, Bangalore, India. [2]Department of Organic Chemistry, Indian Institute of Science, Bangalore, India

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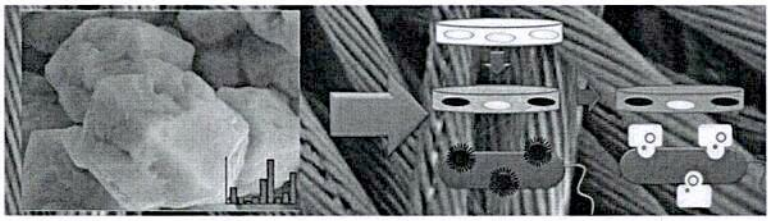
ABSTRACT



Among the several transition metals known to mankind, the synthesis of Cu has remained a major challenge owing to their instinctive oxidative power under ambient conditions. Microwave assisted synthesis of copper nanoparticles (CuNPs) using different types of copper-β-diketonates complexes and glycine as reducing agent. The morphology, size, and structural properties of obtained nanoparticles were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), and UV-visible spectroscopy (UV-VIS) techniques. The results of FE-SEM exhibited that the CuNPs of various shapes and size, depended upon the type of copper-β-diketonates complexes used. Furthermore, all the CuNPs exhibited good antimicrobial activity against both, Gram-positive and Gram-negative bacteria. The result shows that, the cubic CuNPs derived from $Cu(acac)_2$ demonstrated a better antibacterial activity against both bacterial strains.

Keywords: Cu nanoparticles, Microwave-irradiation, Antifungal activity

INTRODUCTION

Metal nanoparticles have been received much attention due to their unique optical, electrical, biomedical and catalytic properties.[1] The size, shape and surface morphology of the particles were crucial in tuning these properties of nanosized metal particles. There are many synthesis methods have been developed to prepare metal nanoparticles including, chemical, physical and biological methods.[2] Among these, microwave-assisted synthesis of metal nanoparticles is the simplest and environment friendly method.[3-5]

On the other hand, copper nanoparticles are the most preferred target for microwave-assisted methods due to their diverse applications like, catalysis, electronics, optics, medicine, photonics, and antimicrobial agent.[6] Several synthesis techniques for CuNPs with controlled size and shape have been reported, including vacuum vapor deposition, radiation, microemulsion, laser ablation, super critical techniques and sonochemical.7 One of the main limitations of these approaches, is the use of toxic chemicals and harmful by-products produced during the process. As a consequence, microwave-assisted synthesis have been used by researchers for the synthesis of various metallic nanoparticles. Microwave-assisted synthesis is appealing because it can dramatically reduce reaction time, improve product yield, and enhance material properties when compared to conventional synthesis routes.[7,8] Among the different metallic nanoparticles, CuNPs exhibit good antibacterial activity.[9,10] Very recently, the mechanism of antibacterial activity of CuNPs was reported and

*Corresponding Author: Dr. T. R. Ravikumar Naik

Address: Centre for Nano Science and Engineering, Indian Institute of Science, Bangalore, India

Tel: +91 9900792675

*E-mail: naikravi7@gmail.com

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the CuNPs are known to be very effective against bacteria.[11] CuNPs are preferred to silver nanoparticles because of lower cost of copper than silver, easier mixing with polymers, and relatively more physic-chemical stability.[9,10]

In this work, we reported a facile microwave-assisted method for the synthesis of CuNPs by using different copper metal beta diketonates and reducing agent. The synthesized CuNPs were characterized by UV–visible spectrophotometer, energy dispersive X-ray spectra (EDS), field emission scanning electron microscopy (FE-SEM), Fourier transform infrared spectroscopy (FTIR), X-ray diffraction crystallography (XRD), and the antimicrobial activity of CuNPs was evaluated.

EXPERIMENTAL

Materials and equipment

All the chemicals used in the present study are of AR grade. Whenever analytical grade chemicals were not available, laboratory grade chemicals were purified and used. We have employed metal β-diketonates as precursor materails,[12,13] which possess low moisture sensitivity and are thus less susceptible to hydrolysis, rendering them superior to metal alkoxides and halides often used in metal/metal oxide synthesis. The metal–oxygen bond present in β-diketonates complexes makes them appropriate precursors for the synthesis of metal/metal oxide nanoparticles. The metal complexes, Cu (II) β-diketonates like, $Cu(acac)_2$, $Cu(maa)_2$, $Cu(eaa)_2$ and $Cu(tbob)_2$, were synthesized and purified in-house.[14-16] ^{1}H- NMR spectra were obtained using a 400 MHz on a Bruker spectrometer (chemical shifts in δ ppm). Mass spectra were recorded using a micro spray Q-TOF MS ES Mass spectrometer.

Synthesis of Cu(β-diketonates)$_2$ Complexes.

To a solution of 6 g copper(II) chloride dihydrate ($CuCl_2.2H_2O$) in 4 mL of distilled water in a 500-mL beaker, add dropwise over a period of 30 minutes a solution of 7.5 mL of β-diketonates in 10 mL of methanol, while maintaining constant stirring. Add to the resulting mixture 10 g of sodium acetate in 30 mL of distilled water over a period of 20 minutes. Heat the reaction mixture with constant stirring for about 30 min on water. After completion of reaction was cooled to room temperature and the obtained precipitate was collected by filtration and cold distilled water and vacuum dry for 30 minutes before drying in an oven at 110^{0}C. Cu(II)-acetyl acetonate ($Cu(acac)_2$), Cu(II)-methylacetoacetate ($Cu(maa)_2$), Cu(II)-ethyl acetoacetate ($Cu(eaa)_2$), Cu(II)-ter-butyl-acetyl acetonate ($Cu(tbob)_2$), respectively. The formation of Cu(β-diketonates)$_2$ complexes were confirmed by powder XRD technique. The FTIR, ^{1}H- NMR and mass spectra of in house synthesized copper metal complexes are shown in ESI (Scheme 1, S1-S9†).

Synthesis of copper nanoparticles

Copper nanoparticles (CuNPs) were synthesized by reduction of four different Cu(β-diketonates)$_2$ complexes using glycine and potassium hydroxide as reducing agents. In a typical synthesis process, the mixture of $Cu(acac)_2$ (10 mmol) was dissolved in 15 ml of EG (Ethylene Glycol) and 15 mmol of glycine was added with constant stirring. Finally 15 mmol of KOH in 5 ml of EG was added when the solution completely turned blue, after 10 minutes of stirring. The resulting mixture was irradiated in a microwave for about 10 minute till a dark red colour appeared. The reaction mixture was cooled and centrifuged for about 10 min at 7000 rpm yield copper nanoparticle. The isolated product was then washed with absolute ethanol and dried under vacuum at 80 °C for 4 h to obtain powdered CuNPs. The Experiment was repeated with $Cu(maa)_2$, $Cu(eaa)_2$ and $Cu(tbob)_2$ respectively, and in every case the end product was CuNPs only.

Characterization of Copper nanoparticles

The crystallinity and phase composition of the copper nanoparticles were investigated using an X-Ray Diffraction (XRD) – analysis was done with Rigaku X-ray difractometer, FT-IR studies were carried out using a Thermofisher Scientific FTIR spectrophotometer (Nicolet 6700 FT-IR). Scanning electron Microscopy (SEM) and X-ray Energy dispersive Spectroscopy (EDS) analysis was done using ULTRA55 FESEM equipped with EDS.

Antimicrobial assay

The antibacterial activities of the synthesized silver nanoparticles were assessed against both gram positive (*S. aureus*) and gram negative pathogen (*P. aeruginosa*) through agar disk diffusion method.[17,18] The pure bacterial and fungal strains were maintained on nutrient agar and potato dextrose agar (PDA), respectively. The dried powder of CuNPs was taken at the concentration of 50 µg/ml for the antibacterial tests. The wells were made in agar plates and 50 µL of CuNPs were added into the wells and subsequently incubated at 37 °C for 24 h. Zone of inhibitions were determined by measuring the diameter of the bacterial growth inhibition around the wells. All assays were carried out in triplicates and results are presented as mean±standard deviation (SD).

RESULTS AND DISCUSSION

Synthesis and characterization

Metal-β-diketonate fragments have attracted widespread attention because of their potential applications as a high quality advanced materials for the synthesis of metal/metal oxide nano materials.[19] Generally, the β-diketone ligands are considered as potential ligands due to their enclosing ability in metal complexes synthesis. Recently, we have reported the synthesis of metal-β-diketonate fragments for the synthesis of different metal/metal oxide nanoparticles.[20,21] We have developed four copper metal-β-diketonate complexes (Scheme 1, ESI†) for the synthesis of copper nanomateraials by MW method. The main stretching modes in the infrared spectra of the complex resulting from β-diketones are υC=O, υM-O, υC-O (ESI, Figure S1†). The coupled vibrations of Cu-O stretching modes appeared below 700-742cm^{-1} in the complex and the 457-489 cm^{-1} band have been assigned as pure υ(Cu-O) vibrations.[22,23] In the H^1- NMR spectrum of Cu (β-ketonate)$_2$ shows, the peak at δ = 4.86-5.47 corresponds to the -CH- proton in between the two carbonyl groups in the acetyl acetone of Cu(β-ketonate) and peak at δ = 1.2-2.22 corresponds to the CH_3-C=O protons (ESI, Figure S2†). The mass spectra (ESI,

Figure S3†) and powder XRD data also (ESI, Figure S4†) supported the formation of Cu(β-diketonates)$_2$.

For the past few years, our research has been focused to develop novel synthetic protocols for the synthesis of metal/metal oxide nanopaerticles maintaining some of the sustainable principles. In this process, we attempted the reaction of Cu(β-diketonates)$_2$ for the synthesis copper nanoparticles by microwave-assisted method in EG. The obtained powder materials was confirmed by the powder XRD spectra (Figure 2).

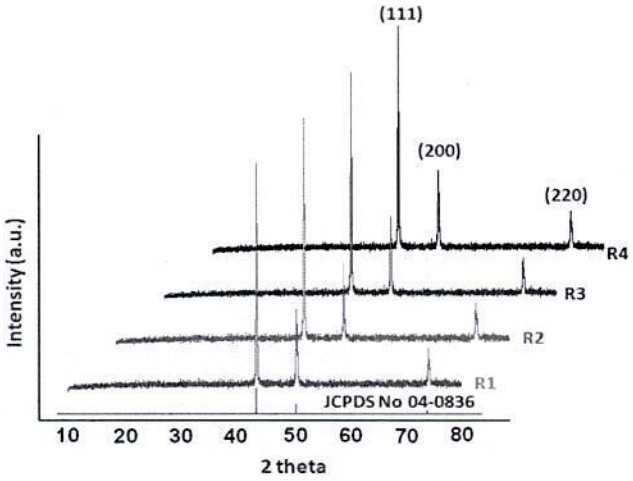

Figure 1: Powder XRD of CuNPs by microwave method.

The powder XRD confirms the formation of pure single crystalline CuNPs is shown in Figure 1. In Figure 1, the $2\theta = 43.4$, 50.5, and 74.0^0, attributed to the (111), (200), and (220) crystal planes, respectively, belonging to pure copper with face-centered cubic symmetry (FCC) [24,25] and corresponding to the diffraction pattern of metallic copper (JCPDS number 04-0836) [26], as shown at the bottom of this figure.

Microwave technology has been demonstrated to speed up reactions, often achieving good purity and product yield. We decided to investigate the selectivity of the reaction between Cu(acac)$_2$ and glycine and explore the effect of microwave irradiation for the formation of copper nanopartciles. The formation of copper nanopartciles by MW method was studied by powder XRD technique (Figure 1). The each sample was collected 2 min interval of the reaction and centrifuge the samples and characterized by XRD and it clearly shows that, the lower angle peaks (belongs to the organic moieties) was disappeserd with increasing the microwave irradiation time. The peak (111) was appeared at 3 min and peak (200), (220) were apeared at 12 min of microwave irradiation.The pure phase of copper nanoparticle was achieved at 18 min of microwave irradiation.

We have also discussed the effect of different reducing agents for the synthesis of copper naopartilces by microwave method (Table 1). Among the different reducing agents, glycine was produced copper nanoparticles quickly in 18 minutes in good yields compare others.

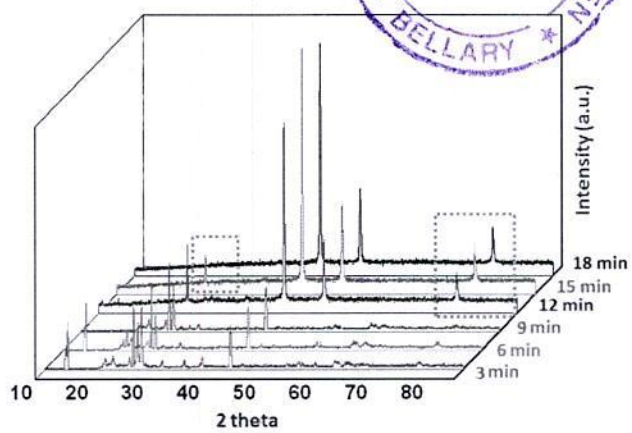

Figure 2: Powder XRD of the CuNPs by microwave method at different time intervals.

Table 1. Effect of reducing agents for the synthesis of CuNPs by MW method.

Complex	Reducing agent	Time (min)	Solvent
Cu(acac)$_2$	Glycine (15 mmol)	18	EG
Cu(acac)$_2$	Hydrazine Hydrate (15 mmol)	35	EG
Cu(acac)$_2$	CTAB (15 mmol)	45	EG
Cu(acac)$_2$	$NaBH_4$ (15 mmol)	45	EG

Table 2. Effect of solvents for the synthesis of CuNPs by MW method.

SOLVENT	TIME (MIN)	REDUCING AGENT
Ethanol	40	Glycine (15 mmol)
Propane 1,3 diol	30	Glycine (15 mmol)
Decanol	30	Glycine (15 mmol)
Ethylene Glycol	18	Glycine (15 mmol)

Microwave-assisted reactions is based on the efficiency of the interaction of molecules in a reaction mixture (substrates, catalyst and solvents) with electromagnetic waves generated by a "*microwave dielectric effect*". The reaction medium with a high value of (*tan δ*) at the standard operating frequency (2.45 GHz) of microwave system is required for the good absorption i.e. high heating rate. We different solvents for the synthesis of copper nanoparticles are high-lighted in Table 2.

The powder XRD of the copper nanoparticles in different solvents under microwave irradiation method was shown in Figure 2. The results indicates that, EG has been used because of high boiling point, high dielectric loss constant, because of chelating properties (auto surfactant). There is no extra satellite peaks were absorbed in EG solvent assisted synthesis of copper nanoparticles. The morphology of the copper nanopaticles synthesis form different solvents by microwave method is as shown in Fig 4.

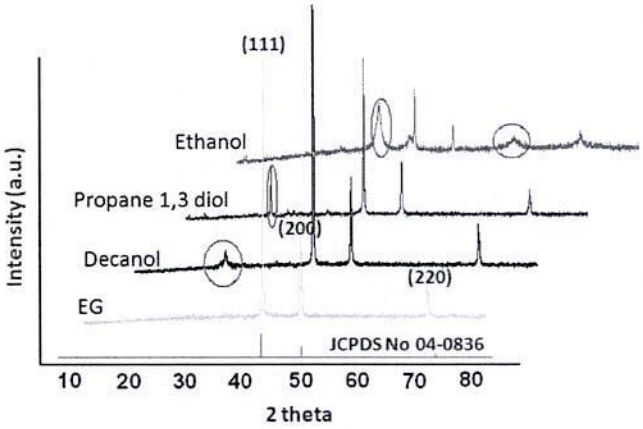

Figure 3: Powder XRD of the CuNPs synthesis by different solvent at microwave method.

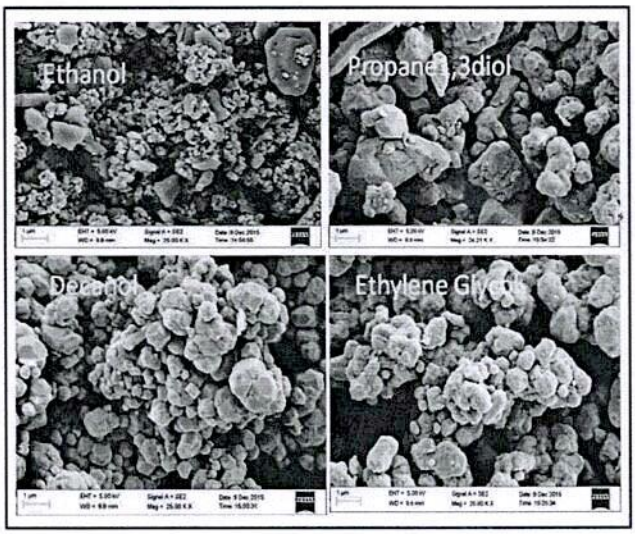

Figure 4: SEM images of the CuNPs synthesis by different solvent at microwave method.

The typical SEM (Figure 5) of CuNPs shows large number of single crystals were formed at 40 min of MW irradiation in EG solvent. Uniform and crystalline CuNPs was obtained because MW provided suitable condition for nucleation and crystal growth (Figure 5). The chemical purity and stoichiometry of the obtained CuNPs were obtained by EDX spectrum (Figure 6).

We studied the effect of different metal β-diketones complexes for the preparation of CuNPs, the presence of β-diketones during the microwave reaction affected the morphology and size of the nanoparticles. From the SEM images and Image J (ESI, Figure S8†) the CuNPs from $Cu(acac)_2$ had an average size of 79.5 nm, and the CuNPs were spherical and uniform as shown in Figure 5(a) (ESI S9†). On the other hand, the CuNPs from $Cu(maa)_2$ had an average size of 36.4 nm with uniform distribution of size and shape as shown in Figure 5(b). The Cu-NPs from $Cu(eaa)_2$ and $Cu(tbob)_2$ had an average size of 85.7 nm and 37.9 nm respectively Figure 5(c,d). The drastic change in the size and

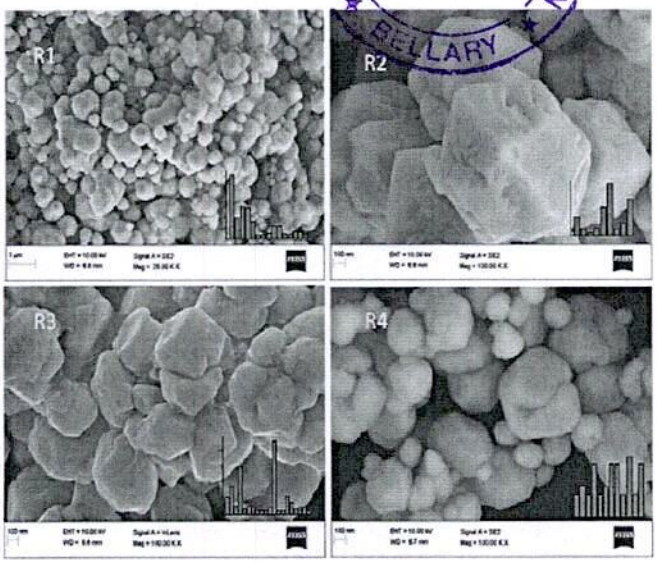

Figure 5. SEM image of single crystalline Cu-NPs: R1= $Cu(acac)_2$, R2= $Cu(maa)_2$, R3 = $Cu(eaa)_2$ and R4 = $Cu(tbob)_2$ respectively.

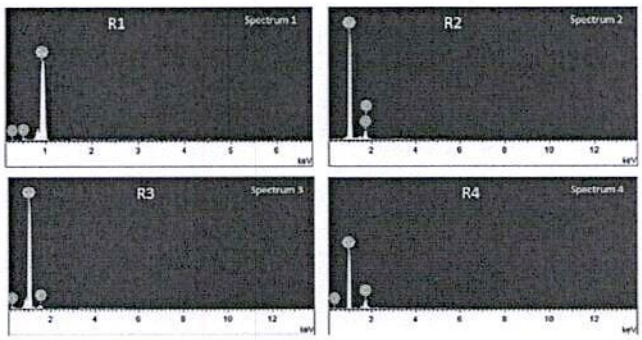

Figure 6. EDX spectrum of R1, R2, R3 and R4 CuNPs respectively.

morphology was thought to be because the presence of glycine enhances the growth of crystalline CuNPs as the temperature is increases. These results clearly showed that the CuNPs were produced from $Cu(maa)_2$, was more crystalline and uniform size distribution compare to other metal complexes.

The formation of copper nanoparticles was also confirmed by FTIR analysis.

X-ray photoelectron spectroscopy (XPS) was employed for copper nanoparticle (R2) resulted from $Cu(maa)_2$. Figure 7 shows the core shell XPS spectra of Cu 2p recorded from powder and supported copper nanostructures. The two strong peaks observed at 932.65 eV and 952.56 eV are in agreement with the binding energies of Cu 2p3/2 and Cu 2p1/2, respectively.[27,28] All the obtained nanoparticles will have different structural morphology with different sizes.

Nanoparticles applications in medicine depend on the size and the composition of the nanoparticles. The ability to target diverse bacterial structures was the important property of nanoparticles. Copper naoparticles have a great bactericidal effect and it possess

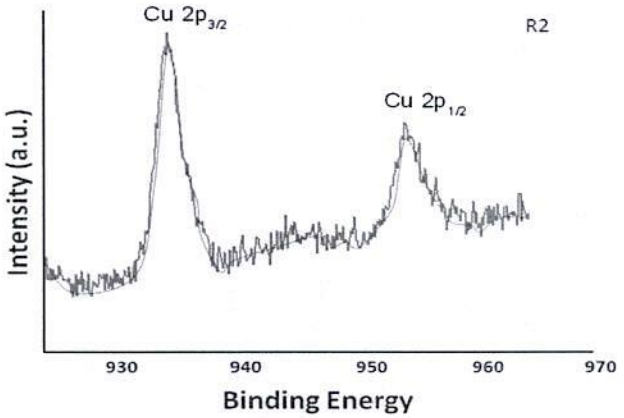

Figure 7. XPS spectra of R2 copper nanoparticles.

Impact of morphology on Antimicrobial activity

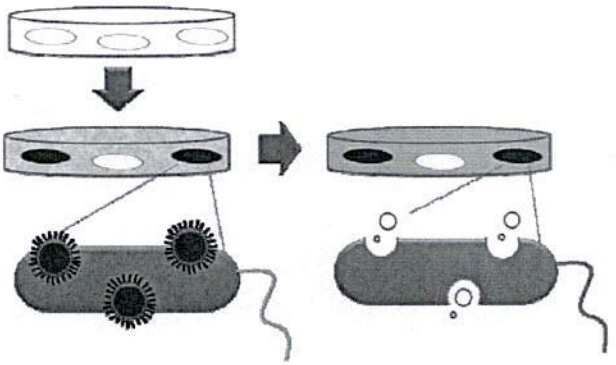

Figure 8 Pictorial demonstration showing the anti-bacterial action of CuNPs respectively.

well-developed surface chemistry, chemical stability and appropriate smaller size which make them easier to interact with the microorganisms. The mechanism of action is as shown in Figure 8. The antibacterial activity of copper naoparticles against gram positive (*S. aureus*) and gram negative pathogen (*P. aeruginosa*) is as shown in Figure 8. Figure 9 shows the enlarged microscopic images of antimicrobial activity. The growth inhibition zones obtained from the antibacterial study of the synthesized copper nanoparticles was shown in Figure 10. The results display that the copper nanoparticles, prepared from all the four copper metal complexes, showed a good antibacterial activity against gram-negative than gram-positive bacteria. The largest inhibition zone was obtained for the Gram-negative bacteria (*P. aeruginosa*) compare to *Staphylococcus aureus*.

The obtained results shows that, the antibacterial activity was dependent on the size of the nanoparticles–the highest activity was observed for CuNPs synthesized from the $Cu(acac)_2$ by microwave-assisted method. In our case, we believe that the CuNPs from microwave-assisted method had the crystalline, smaller size and the largest surface/volume ratio. Small CuNPs are able to be penetrated inside the bacteria and caused further damage, lose their activity and finally cell death. At last, the CuNPs release copper ions, which will have an additional contribution to the antibacterial activity of the CuNPs. This characteristic enhances biological and chemical activity of the nanoparticles with high antibacterial efficacy.

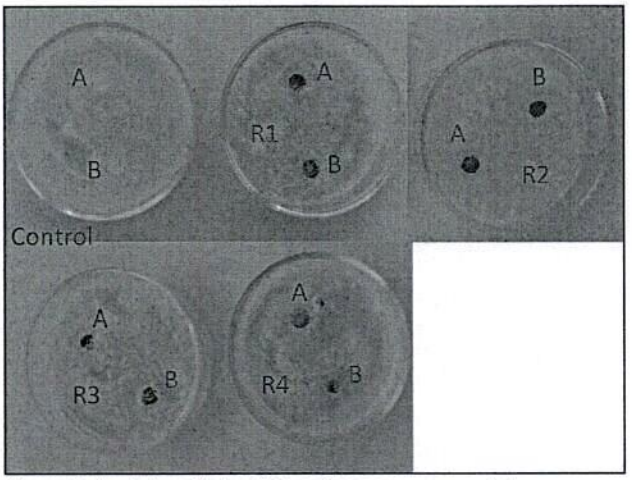

Figure 8. Antimicrobial activity of copper nanoparticles.

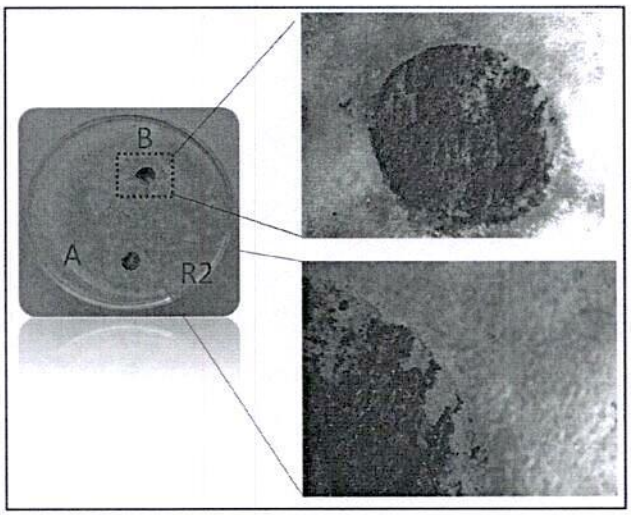

Figure 9. Microscopic images of the antimicrobial activity of copper nanoparticles.

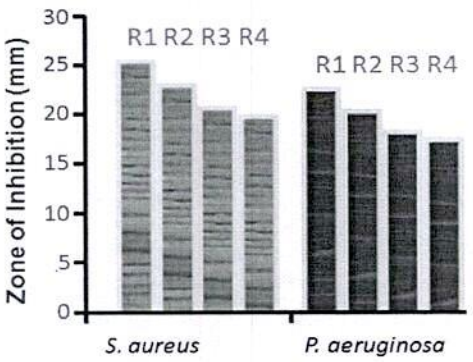

Figure 10. Zone of inhibition of antimicrobial activity CuNPs.

CONCLUSION

Copper nanoparticles were synthesized from different copper metal β-diketones by microwave-assisted method. The crystalline metallic copper nanoparticles were confirmed from XRD results. The morphology of these copper nanoparticles was found to be spherical through SEM micrographs. The SEM analyses revealed that the size of the CuNPs synthesized from different copper metal β-diketones by microwave-assisted method varied in the order: $Cu(acac)_2$<$Cu(eaa)_2$<$Cu(tbob)_2$<$Cu(maa)_2$. Antimicrobial study displayed that the CuNPs synthesized from the $Cu(maa)_2$ showed the highest activity, which can be attributed to the single crystalline and smallest size of the CuNPs. Results obtained from our present work would be helpful in the development of new morphology oriented copper nanoparticles and their potential applications in biological, pharmaceutical and physiological fields in future.

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Synthesis & Characterization of Cu & Co Doped Tio2 Nano Particles via Hydrothermal route	A M Kalamma	Physics	Journal of Interdisciplinary Cycle Research	2020	0022-1945	http://www.jicrjournal.com/gallery/55-jicr-june-2808-2.pdf	https://jicrjournal.com/?s=Synthesis+%26+Characterization+of+Cu+%26+Co+Doped+Tio2+Nano+Particles+	Yes

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Synthesis and Characterization of Cu And Co Doped Tio$_2$ Nanoparticles via Hydrothermal Route

A M Kalamma[1],T Subba Rao[1] ,ShirajAhammad Hungund[2], Ambreensaba Mulla[3] ,Mohammed Afzal[3*],

[1]*Department of Physics, Sri Krishnadevaraya University Ananthapuramu-515003 Andhra Pradesh (AP), India*
[2]*Department of Basic Science, SECAB Institution of Engineering & Technology, Vijayapur-586101 Karnataka, India*
[3]*Department of Physics, SECAB's A.R.S.I Degree College for Women, Vijayapur-586101 Karnataka, India*
[*]*Corresponding Author_ mdafzal12@gmail.com.*

ABSTRACT

In the present investigation copper and cobalt co-doped TiO_2 nanoparticles (NPs) have been synthesized via hydrothermal method. The structural, optical, morphological and compositional properties of all the prepared samples have been characterized by X-ray diffraction (XRD), energy dispersive X-ray spectroscopy (EDS), field emission scanning electron microscope (FESEM) and UV-Vis spectrophotometry.XRD analysis have revealed that all prepared nano powders were nanocrystalline and had TiO_2 rutile structure. The FESEM analysis shows the NPs were of spherical shape with an average size of 10 nm to 20 nm. EDS analysis confirms the chemical composition of the NPs having Ti and O elements. UV-Vis measurement shows variation in indirect band gap of 3.07eV, 2.84eV, 3.95eV and 4.01eV for TiO_2 NPs, Cu-TiO_2 NPs, Co-TiO_2 NPs and (Cu-Co)TiO_2 NPs respectively. Zeta potential measurements show a stable dispersion without particle settlement in DMSO solvent.

KEY WORDS

Hydrothermal, Tio2, Cu doped Tio2 NPs, Co doped Tio2 NPs, (Cu-Co) doped Tio2 NPs.

I.INTRODUCTION

Commercial production of titanium dioxide or titania (TiO_2) was started in 1923. It is derived from a variety of ores. The bulk material of TiO_2 mainly exists in three phases: Rutile, Anatase and Brookite. Most of the TiO_2 exists in rutile and anatase phases because both have tetragonal structures. As rutile is a high temperature stable phase and has an optical energy bandgap of 3.0 eV (451nm), whereas anatase is formed at a lower temperature with an optical energy bandgap of 3.2eV(380nm) and refractive index [1]. Among these polymorphs, rutile and anatase are studied widely, whereas brookite is studied rarely due to its complicated structure and difficulty in sample preparation [2]. These three phases can be represented as constituted by arrangements of the same building block Ti-O_6 octahedron in which Ti atom is surrounded by six oxygen atoms situated at the corners of distorted octahedron. Even though the similarities in building blocks of Ti-O_6 octahedral for these polymorphs, the electronic structure are significantly different[3]. Photocatalysis using TiO_2 as a catalyst has been widely reported as a most promising technology for the removal of various organic and inorganic pollutants from contaminated water and air because of its stability, low cost, and non-toxicity [4].

Nanosized transition metal oxides including doped and undoped TiO_2 are the areas of sustained scientific concern due to their potential applications in sensing, catalyses, opto-electronic devices, biomedical field, cosmetics and magnetism [5-7]. CuO has a narrow band gap (1.2eV) and is a p-type semiconductor with photochemical and photoconductive properties and has found applications in gas sensing [8,9], in catalysis [10-13], as antimicrobial agent[14-18], in batteries [19], magnetic devices [20-22], super capacitors [23] and field emission [24]. TiO_2 is an n-type semiconductor with wide band gap ranging from 3.2eV to 3.6eV. It has numerous applications such as medical devices coating, cosmetics and gas sensors [25-27]. The presence of cobalt ions in TiO_2 structure causes a significant absorption shift towards the visible region compared to the pure TiO_2 powder [28,29] A significant advantage of TiO_2 is the formation of a heterojunction on reaction with another material [30,31]. In these applications an important parameter is the specific surface area, which is strongly related to the morphology. The properties of nanoscale materials are significantly different from those of the bulk material of same chemical composition. The physical and chemical properties of doped and undoped TiO_2 depend on their microstructure such as morphology, the size and the orientation

of the constituent grains. To improve and extend the functions of these inorganic nano materials, one or more components are often combined to form nanocomposites for various applications in photocatalysis, electronics and gas sensors [32, 33].

The exclusive properties of composite nano materials originate from their ability to combine the most desirable physiochemical properties of their constituents. Synthesis of high quality nano crystals of desired size is essential for investigating and utilizing their size dependent properties. Several approaches such as chemical precipitation [15], sol-gel method [16, 34, 35], hydrothermal method [11,36], microwave assisted method [37], sonochemical synthesis [38], and solvothermal synthesis [39] have been reported for the synthesis of uniform sized metal oxide nanocomposites with varied morphologies.

Inspite of all the progress made, the synthesis of Cu doped TiO_2, Co doped TiO_2 and Cu-Co doped TiO_2 nanoparticles of controlled size and shape still a challenge. Size and shape needs to be tailored by an appropriate choice of the synthesis methods and conditions. Fine-tuning of the morphology is of key importance, since the electronic structure, the surface energy, bonding and the chemical reactivity of nanomaterials are all directly related to surface morphology [40]. The purity and stoichiometry depends on the synthesis route. In this paper we report on the synthesis ofTiO_2, Cu doped TiO_2, Co doped TiO_2, Cu-Co doped TiO_2 nanoparticles by hydrothermal process via a precursor solution of titanium(IV) n butoxide and copper nitrate hexahydrate, cobalt nitrate hexahydrate as dopants. The influence of amount of dopant on; crystal structure, composition, surface morphology and optical properties of Cu and Co co-doped TiO_2 nanoparticles were characterized by means of XRD,FESEM,EDS and UV-Vis spectrometer respectively.

II. MATERIALS AND METHOD

2.1 Chemicals: Titanium (IV) n butoxide (TNB) wt 99% liquid analytical grade, Copper nitrate hexahydrate [$Cu(NO_3)_2.6H_2O$], [$Co(NO_3)_2.6H_2O$] and EDTA (di-sodium salt dehydrate) were procured from Alfa Aesar Chemicals, India. De-ionized water (DW) was used in the preparation of all solutions.

2.2 Synthesis of Cu-TiO_2, Co-TiO2 and TiO_2 Nanoparticles

Copper doped Titanium dioxide Nano particles were synthesized via hydrothermal route.30ml of 0.1M E. D. T.A($C_{10}H_{14}N_2Na_2O_8.2H_2O$)was prepared by dispersing 0.56gm in 15ml of de-ionised water (DW) with continuous stirring with the aid of magnetic stirrer for 10 minutes by adding 15ml of DW. Then 5ml of 0 .1M Cu $(NO_3)_2.6H_2O$ and 1ml of Titanium(IV) n butoxide were added drop wise with continuous stirring for 30 minutes. The colloidal solution was then transferred to a 50ml Teflon-lined stainless steel auto clave, the autoclave was sealed and placed in an oven heated up to 180^0C for 3hours, then the autoclave was cooled down to room temperature. Under ambient conditions, the reactant mixture was centrifuged to collect the product; the product was washed continuously with DW several times to remove the organic molecules bonded to the surface of the product. The final product was dried in an oven at100^0C for one hour and the same procedure, as adopted in Cu-TiO_2 was used to synthesize Co-TiO_2, CuCo-TiO_2 and TiO_2.

2.3 Characterization techniques

2.3.1UV-vis spectroscopy: UV-Vis absorbance spectra in the wavelength range 200-800nm were measured using UV-Vis spectrophotometer (model: SPECORD 200+ Analytikjena) at SECAB college, Vijayapur.

2.3.2 XRD: The crystal structure of the powder sample at a scanning rate of 0.02^0 per second in the range of 20^0 to $80^0$with the use of Cu K_α radiation of wavelength 1.54060A^0 were analysed by XRD (model: Rigaku pro analytical) at MIT Manipal. Peak analysis was carried out using PCPDFWIN software.

2.3.3 FESEM: The surface morphology and nanonature of the samples at an operating voltage 5kV were examined using FESEM (model: xford -EDX system IE 250 X Max 80) At Mangalore university, Mangalore.

2.3.4 EDS: Elemental compositions were analysed using EDS (model: FEI Quanta 200 F) at Mangalore university, Mangalore.

2.3.5 Zeta potential: The zeta potential was based on the surface charge of the particles relative to the local environment of the prepared particle. This electrostatic potential of shear plane of the particle was carried out in ultrasonicated dispersion of 0.01 g/100 mL in DMSO in room temperature using the Horiba SZ-100 nanoparticles analyzer.

III. RESULTS AND DISCUSSIONS

3.1 Optical properties:

3.1.1 UV-Vis Spectroscopy;

UV-Vis Spectra were recorded for TiO_2 NPs, Cu-TiO_2NPs,Co-TiO_2NPs and (Cu-Co)TiO_2 NPs in an ethanol solvent at room temperature and are shown in Fig 1(a, b, c and d). From the Fig1(a) it is observed that the absorption maxima (λ_{max}) for TiO_2 NPs , Cu-TiO_2NPs ,Co-TiO_2 NPs and(Cu-Co)TiO_2NPs were found to be 341 nm ,250.23 nm,370.8nm and 259.37nm respectively which is a preliminary indication for the presence of TiO_2 material. The band gap of all the samples were estimated using the absorption data with the help of (K–M) transformation method [7].Band gap energy of the semiconductor was estimated using the optical absorption coefficient (α) and is expressed by equation (1)

$$\alpha = \frac{A(h\nu - E_g)^{1/n}}{h\nu} \quad \text{..... (1)}$$

Where,

hν is an energy of photon, E_g is the band gap energy, A is a constant depends on the transition probability and depends on the nature of the transition for allowed direct transition (n= ½), for allowed indirect transition (n=2).In our cases for an indirect gap, the value of n is 2 for TiO_2 NPs, Cu-TiO_2NPs,Co-TiO_2NPs and (Cu-Co)TiO_2 NPs. Using Tauc's plot the estimated E_g values were found to be 3.07eV, 2.84 eV ,3.95ev and 4.01eV respectively.

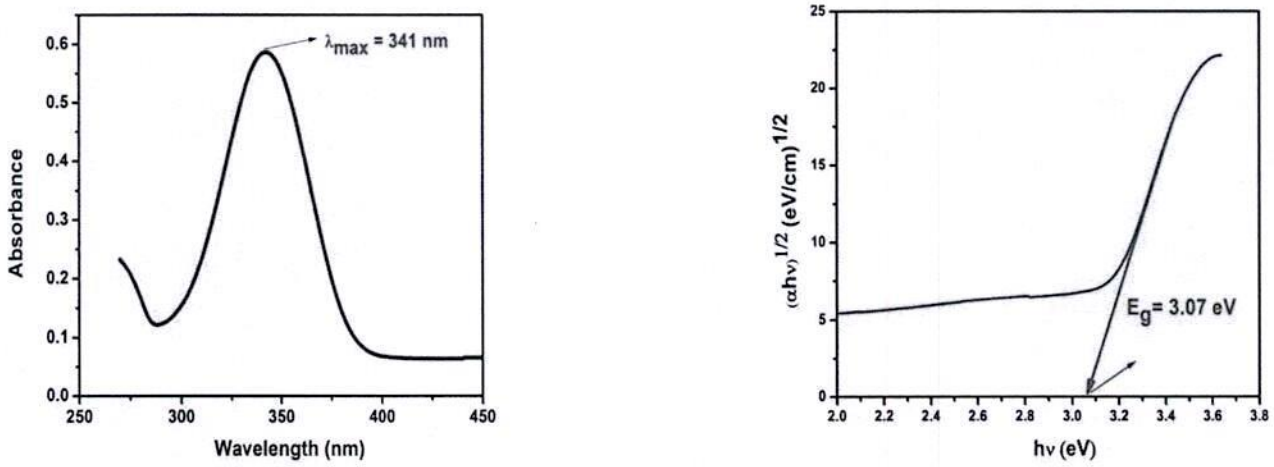


Fig 1 (a): UV and Tauc's plot TiO_2

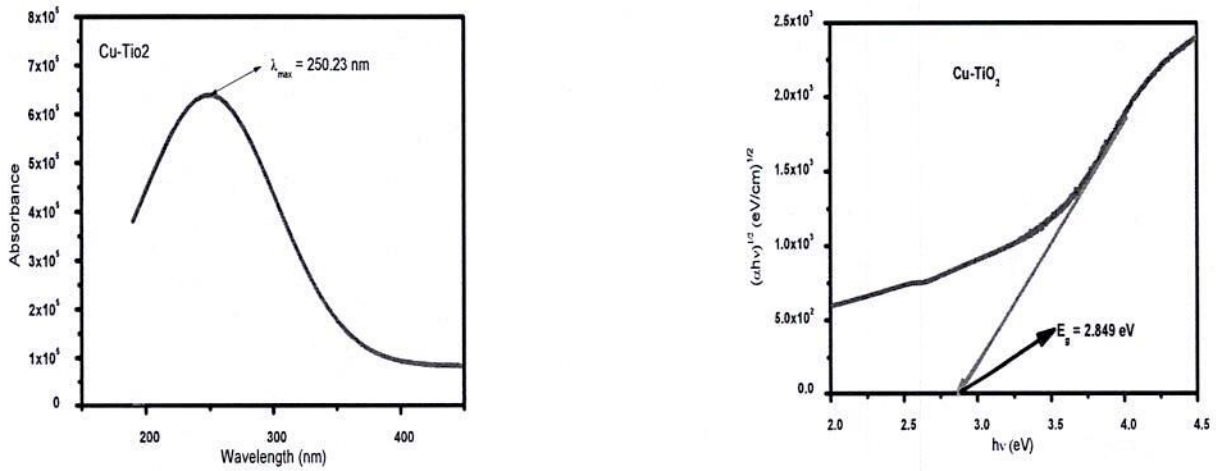
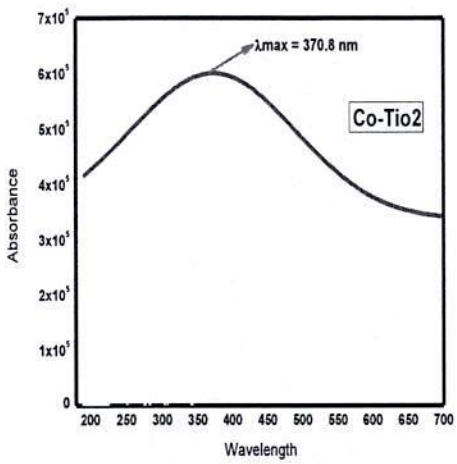


Fig 1(b): UV and Tauc's plot Cu-TiO_2



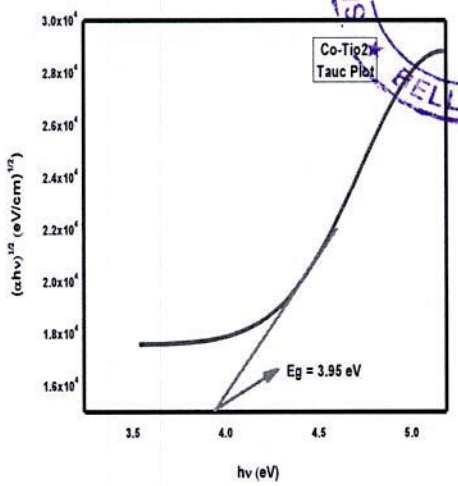
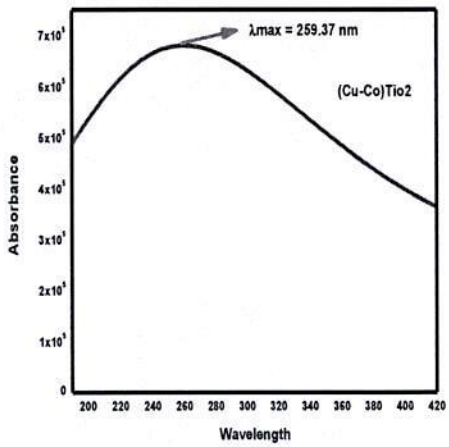


Fig 1(c): UV and Tauc's plot Co-TiO_2



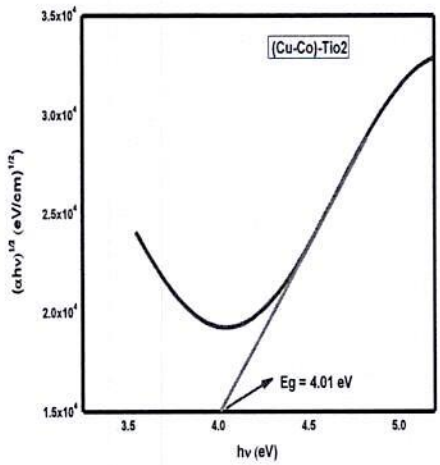


Fig 1(d): UV and Tauc's plot (Cu-Co)-TiO_2

3.2 Structural properties

XRD analysis was carried out to verify the presence of nano crystalline and phase formation. Fig 3 (a, b, c and d) shows XRD patterns for TiO_2, Cu-TiO_2,Co-TiO_2 and (Cu-Co)TiO_2 powders respectively. It is observed that, the presence of strong and sharp peaks may indicate the formation of the well crystallized samples. From the Fig 3 (a) it is observed that the Bragg's reflection at 2Θ=25.3429,37.8769,47.9727,54.0791,62.7467,75.1348 and 82.6813 can be indexed to (101),(004),(200),(211),(204),(215) and (224) crystal planes respectively. The comparison of 2Θvalues in observed Fig 3(a)XRD pattern with those from the standard Joint Committee on Powder Diffraction Standards(JCPDS) data no. 89.4921 confirms the formation of the TiO_2 having rutile phase and tetragonal crystal structure. Fig 3(b) shows the XRD patterns for Cu-TiO_2 powders, it is observed that the Bragg's reflection at 2Θ=25.3803, 37.8187,47.9622,54.1718,62.7795,68.9548,75.0959 and 82.8946can be indexed to (311),(422),(442),(444),(731),(822),(753) and (844) crystal planes respectively. The comparison of 2Θvalues in observed Fig 3(b)XRD pattern with those from the standard JCPDS data no. 81.1611 confirms the formation of the Cu-TiO_2 having Rutile phase and tetragonal crystal structure. Fig3(c) shows the XRD pattern of Co-TiO_2 powders, it is observed that, the Bragg's reflection at2Θ=25.3669,37.7705,48.0267,54.1788,62.749,75.1144 and 82.8806 can be indexed to (220),(311),(002),(060),(402),(650) and (660) crystal planes respectively. The comparison of 2Θ values in observed fig3(c) XRD pattern with those from the standard JCPDS data no. 35.0793 confirms the formation of theCo-TiO_2 having Rutile phase and orthorhombic crystal structure.Fig3(d) shows the XRD pattern of (Cu-Co)TiO_2 powders, it is observed that, the Bragg's

reflection at 2Θ=25.4254,37.8603,48.0919,54.1802,62.7517,68.6983,75.1736 and 82.8828 can be indexed to (006),(012),(009),(018),(113),(011),(024) and(119) crystal planes respectively. The comparison of 2Θ values in observed fig3(d) XRD pattern with those from the standard JCPDS data no. 41.0904 confirms the formation of theCo-TiO_2 having Rutile phase and rhombohedral crystal structure. The Scherer's equation [2] is used to estimate an average crystalline size by determining the full width at half maximum (FWHM) of the most intense reflection plane and this equation is given by

$$D \approx \frac{0.9\lambda}{\beta \cos \theta} \qquad (2)$$

Where D is an average crystalline size, λ is the wavelength of X-ray used (1.50406 x 10^{-10} m), Θ is the Bragg's angle in radian and β is the full width at half maximum of the most intense reflection in radian. In our case, the most intense peak forTiO_2, Cu-TiO_2,Co-TiO_2 and (Cu-Co)TiO_2were found to be (101) ,(311),(006) and (220) plane and the estimated average crystalline size is 7.07nm , 8.66nm,5.73nm and 5.78nm respectively.

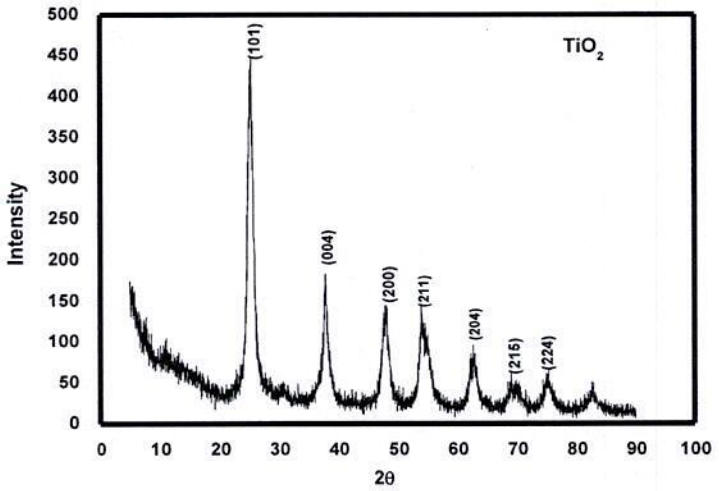


Fig.3(a)XRD pattern for TiO_2

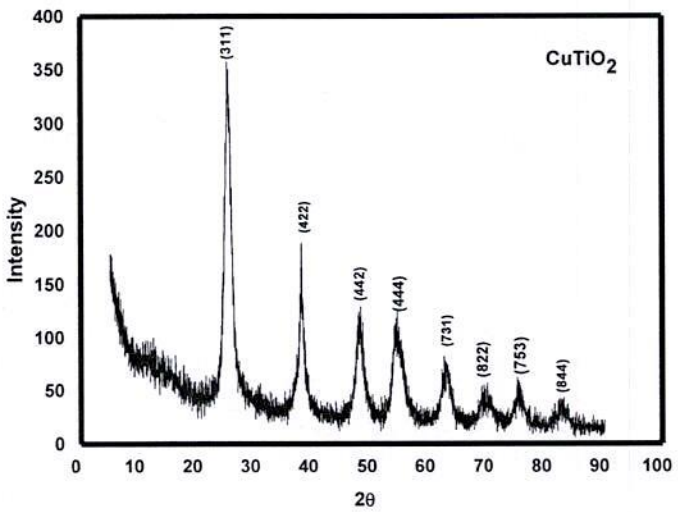


Fig.3(b) XRD pattern for CU-TiO_2

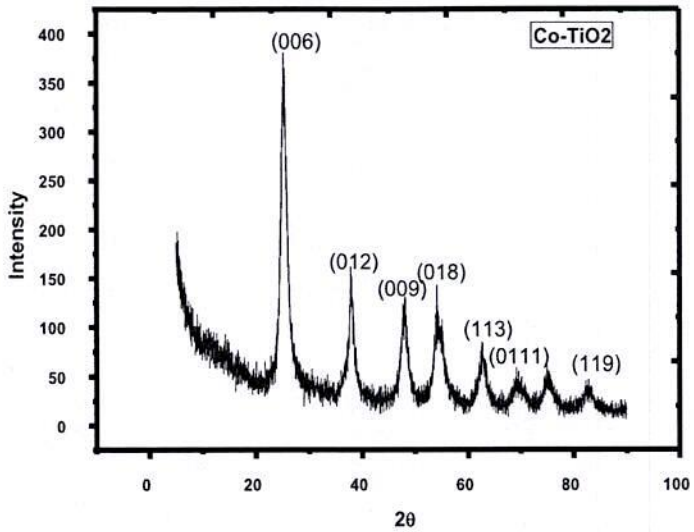


Fig 3 (c) XRD pattern for Co-TiO_2

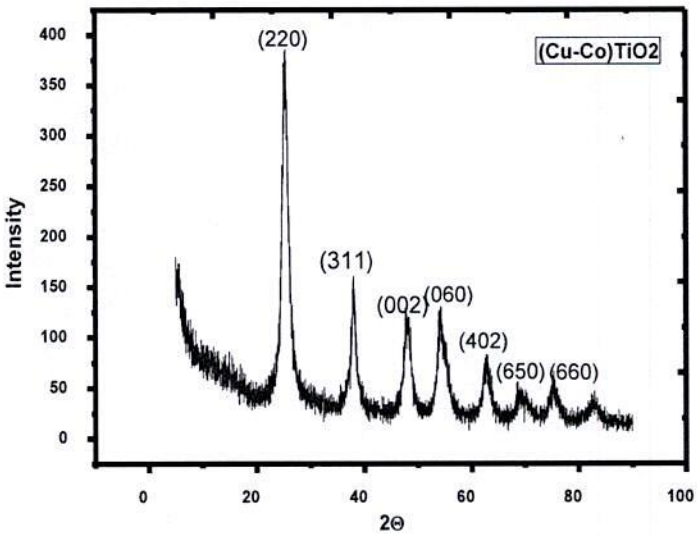


Fig.3 (d) XRD pattern for (Cu-Co)TiO_2

3.2 Morphology, Size Distribution and Elemental Analysis

FE-SEM analysis was used to examine the surface morphology and nano nature of the samples. Fig 4(a, b, c and d) shows the particles are having the spherical cluster with average size of about 10 nm to 20 nm. EDS was examined to investigate the chemical composition in copper and cobalt doped TiO_2 NPs. Fig 4(e, f, g and h) represents the EDS spectrum for TiO_2, Cu-TiO_2, Co-TiO_2 and (Cu-Co)TiO_2 NPs, hence EDS spectrum confirms the presence of elements i.e. Ti and O, in addition small quantities of element C was observed since it is residue of oil contaminants. The weight percentage (%) and atomic weight percentage (%) of NPs are shown inset of Fig 4 (e, f, g and h).

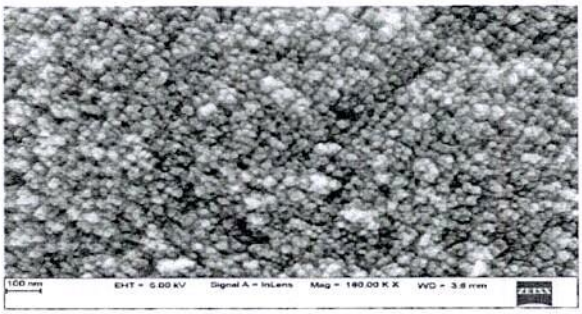


Fig 4(a) FE- SEM image of TiO_2

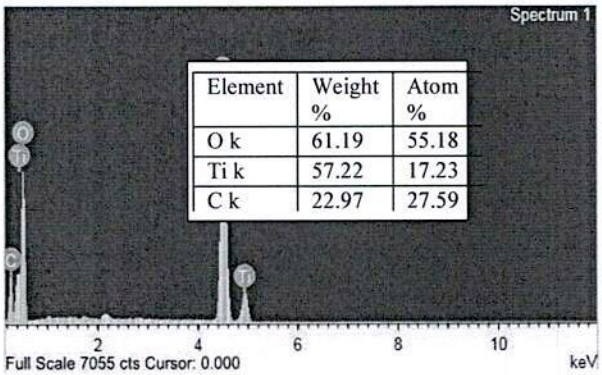


Fig 4(e) EDS spectrum of TiO_2 NPs inset corresponding weight % and atomic % of element

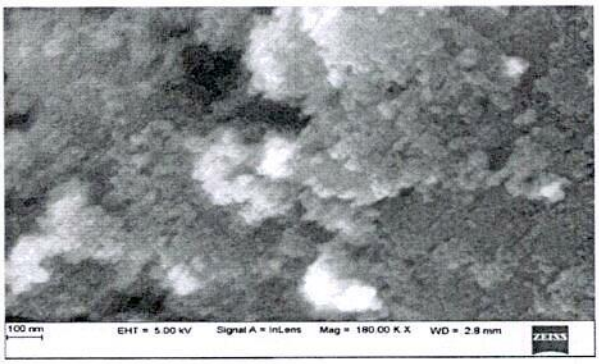


Fig 4(b) FE- SEM image of Cu-TiO_2

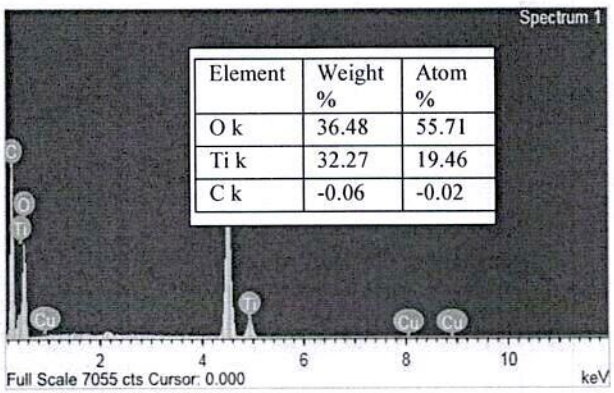


Fig 4(f) EDS spectrum of Cu-TiO_2 NPs inset corresponding weight % and atomic % of elements

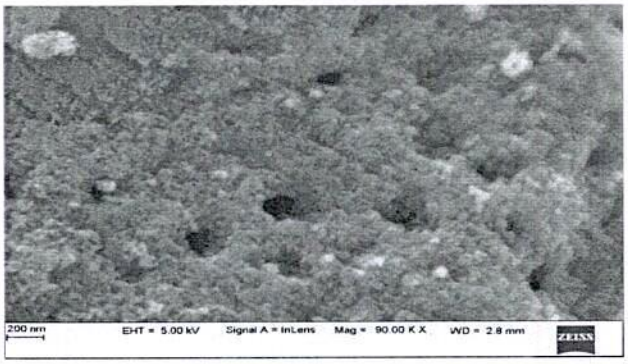


Fig 4(c) FE- SEM image of Co-TiO_2

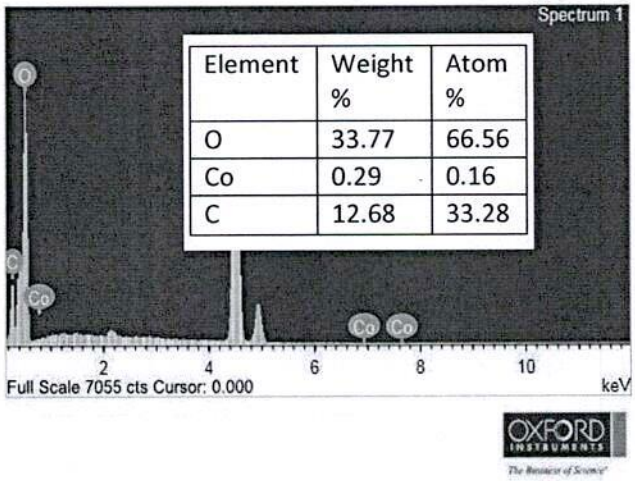


Fig 4(g) EDS spectrum of Co-TiO_2NPs inset corresponding weight % and atomic % of elements.

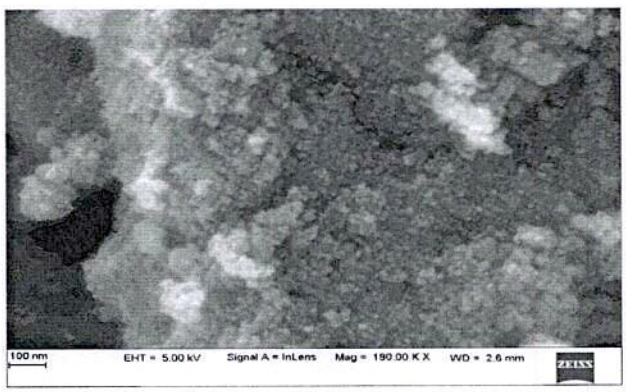
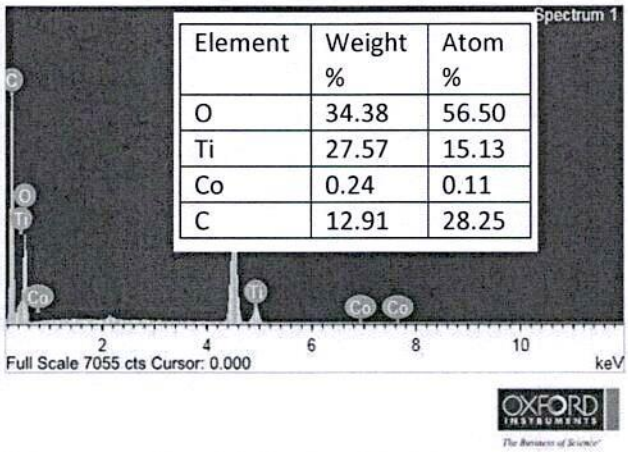


Fig 4(d) FE- SEM image of (Cu-Co)TiO_2



Element	Weight %	Atom %
O	34.38	56.50
Ti	27.57	15.13
Co	0.24	0.11
C	12.91	28.25

Fig 4(h) EDS spectrum of (Cu-Co) TiO_2 NPs inset corresponding weight % and atomic % of elements

Zeta Potential Study

Zeta potential and electrophoretic mobility of pure, copper and cobalt doped TiO_2suspension in DMSO are given in table (1).The studies reveals that, doping with copper gives positive value of zeta potential of 30.0mV and cobalt doping gives the positive value of zeta potential of 47.6mV, but doping with both copper and cobalt shows reduced values of zeta potential and electrophoretic mobility. The zeta potential graphs shown in the Fig.6 (a, b, c and d), which clearly indicates a stable dispersion without particle settlement. Furthermore, the study of prepared suspension corroborates with general criteria of zeta potential (ξ) value 30 mV with positive or negative sign for better stability.

Sample	Zeta potential	Electrophoretic mobility
TiO_2	27.2mV	0.000055 cm^2/Vs
Cu- TiO_2	30.0mV	0.000061 cm^2/Vs
Co-TiO_2,	47.6mV	0.000097 cm^2/Vs
Co-Cu TiO_2	22.9mV	0.000047 cm^2/Vs

Table.1 Zeta potential and electrophoretic mobility of pure, copper and cobalt doped TiO_2

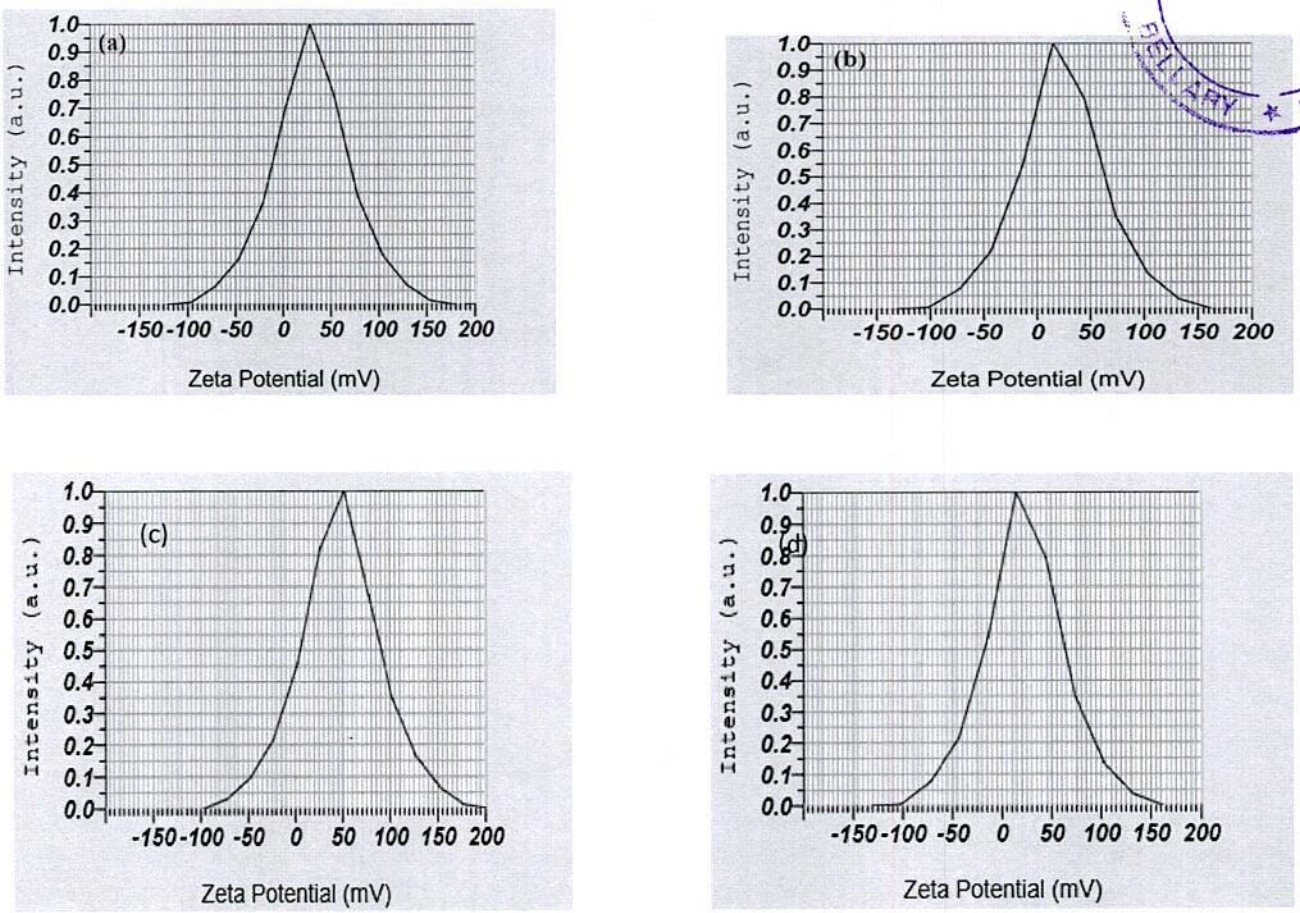


Fig. 6 : Zeta potential evaluation of (a) TiO_2 NPs and (b) Cu-TiO_2 NPs (c) Co –TiO_2 NPs and (d) (Cu-Co)TiO_2 NPs in DMSO solvent.

IV .CONCLUSION

In summary, we have synthesized copper and cobalt co-doped TiO_2 NPs via hydrothermal route. These NPS were characterized using XRD, EDS, FESEM and UV-Vis spectrophotometer. The XRD data obtained for all synthesized NPs holds in good agreement with the standard JCPDS data and they are having rutile phase with tetragonal structure for TiO_2NPs and Cu-TiO_2 NPs, orthorhombic for CO-TiO_2 NPs and rhombohedral structure for (Cu-Co) TiO_2NPs. EDS analysis confirms the presence of Ti and O compositions. FESEM images confirms the average particle size of about 10nm to20nm.UV-vis spectroscopy confirms the presence of TiO_2 material and from the Tauc's plot it is inferred that, the indirect band gap of TiO_2 NPs, Cu-TiO_2NPs,Co-TiO_2NPs and (Cu-Co)TiO_2 NPs were 3.07eV, 2.84 eV ,3.95eV and 4.01eV respectively, the results of Tauc's plot shows increase of band gap due to cobalt doping, Zeta potential measurements reveals that ,Cu-TiO_2 and Co-TiO_2 shows stable dispersion without particle settlement since zeta potential values are positive 30mV and 47.6mV respectively. Furthermore, we may be concluded that these synthesized TiO_2 NPs can be used for photocatalytic degradation of dyes.

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Limonia acidissima L. leaf mediated synthesis of silver and zinc oxide nanoparticles and their antibacterial activities

Bheemanagouda N. Patil, T.C. Taranath*

P. G. Department of Studies in Botany, Environmental Biology Laboratory, Karnatak University, Dharwad 580003, Karnataka, India

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ABSTRACT

Green chemistry is a novel method for the synthesis of silver and zinc oxide nanoparticles. The present investigation focused on synthesis of biogenic silver and zinc oxide nanoparticles. They were assayed for their antibacterial activities against test bacterial species. The results revealed that the silver nanoparticles showed the maximum zone of inhibition 15.16, 15.5 and 13.33 mm at 400 μg/mL to *S. aureus*, *S. typhi* and *P. aeruginosa* respectively, when compared to the *Erythromycin*. While zinc oxide nanoparticles showed less activity in comparison to silver nanoparticles owing to the agglomeration of nanoparticles. It is evident from our investigation that silver nanoparticles could be used as an antimicrobial due to their intrinsic properties in biomedical application and food packing industries.

1. Introduction

Nanotechnology is an emerging area of research for manipulation of dimension of materials less than 1 nm with varying sizes and shapes. Different methods are in vogue for synthesis of nanoparticles. Chemical and physical synthesis of nanoparticles involve hazardous chemicals and high energy consumption which affects the environmental quality [1,2]. Biological methods are nontoxic, environmental friendly and involve the use of micro-organisms [3], algae [4], plant extracts [5–7], agro-wastes [8–20], enzymes [21–26], arthropods [27] and pigments for the synthesis of nanoparticles [28–33]. Silver, zinc oxide, gold and copper nanoparticles were used for antimicrobial activity [3]. The antimicrobial activity of silver known since time immemorial [34,35]. Silver has been used as a disinfectant to prevent the human infection in the medical field because of its natural antimicrobial activity towards many pathogens such as bacteria, viruses and fungi [36]. It is notable that silver ions and silver based chemicals are profoundly lethal to microorganisms [14,32,37] and is not lethal to human beings [13]. Nanoparticles are used in industrial sectors viz., food safety, medicine and other fields.

Zinc oxide nanoparticles were used in the biological applications as biosensors in medical diagnostics [38] and to combat mycobaterial growth [6]. Nanoparticles enhance the immobilization and activity of catalysts in the pharmaceutical industry [39,40], gas sensors [41], antifungal activity [42,43] electronic nanodevices, and UV filters [44] due to the novel properties exhibited by the material. Biological method allows reduction, capping, and manipulation of size and shape. The biofabrication of zinc nanoparticles synthesized by *Justicia adhathoda* [45] and *Aloe barbadenis*, *Limonia acidissima* and *Cochlospermum religiosum* leaf extract were used to synthesize of zinc oxide nanoparticles [6,46,47]. The *Pongamia pinnata* coated zinc oxide nanoparticles are used for antimicrobial and anticancer activity [48]. Bacterial composite zinc oxide nanoparticles were used for the wound healing properties [49]. Zinc oxide is a non-toxic, inexpensive, and non-hygroscopic polar inorganic crystalline material. The emerging multidrug resistance gram negative bacteria of *P. aeruginosa* causing respiration tract and vaginal infection may be controlled by nanoparticles.

In India, rural folk used the decoction of *L. acidissima* leaves for the treatment of blocking, heaving, cardiotonic and diuretic [50]. The leaves are known to have hepatoprotective activity [51]. Leaves, bark and product of this plant have been utilized as a customary medication for their antimicrobial activity [52,53], astringent, mitigation [54] and insulin secretagogue exercises [55]. Essential oil extracted from the leaves has shown antimicrobial activity [56]. The present investigation was undertaken to assay the comparative antimicrobial activities of various concentrations of silver and zinc oxide nanoparticles.

2. Materials and method

2.1. AgNPs and ZnONPs

The silver and zinc oxide nanoparticles synthesized by leaf extract of *L. acidissima* showed a characteristic surface plasmon resonance (SPR) at 452 nm and 374 nm respectively. The biogenic silver and zinc oxide

* Corresponding author.
E-mail addresses: bnpatil089@kud.ac.in (B.N. Patil), tctaranath@kud.ac.in (T.C. Taranath).

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nanoparticles were spherical in shape with size ranging from 21 to 42 nm and 12–53 nm respectively [5,6]. The stock solution of AgNPs and ZnONPs was prepared by dispersing 1 mg of silver and zinc oxide nanopowder in 1 mL 2% DMSO (Dimethyl sulphoxide) respectively. The resulting suspension was sonicated (Ultrasonic bath Fisherbrand unheated, 230 V, 50 Hz) for 30 min, followed by 10 min vertex. Stock solutions were kept at 4 °C in the dark to prevent the photo oxidation. The various exposure concentrations were prepared from this stock solution.

2.2. Antibacterial activity

The antibacterial activity of biosynthesized silver and zinc oxide nanoparticles was tested against Gram positive (*Staphylococcus aureus* MTCC 3160, *Bacillus cereus* MTCC 8733, *Enterococcus faecalis* ATCC 35550), Gram negative (*Escherichia coli* MTCC 433, *Salmonella typhi* MTCC 3216 and *Pseudomonas aeruginosa* ATCC 25619) bacteria were procured from the Council of Scientific and Industrial Research-Institute of Microbial Technology (CSIR-IMTECH), Chandigarh, India. About 100 µL of test bacteria (inoculums obtained as 18-h culture, i.e. 10^6 CFU/mL growth in Mueller-Hinton broth) were used to seed uniformly onto the surface of the freshly prepared plates of Mueller–Hinton Agar (Hi-media Mumbai) using a sterile glass spreader. The Hi-media sterile disc 6 mm diameter was impregnated with silver and zinc oxide nanoparticles in different concentrations (100, 200 and 400 µg/mL). Antibiotic *Erythromycin* (15mcg/disc) for bacteria was used as a standard control (empty sterile disc), 1 mM $AgNO_3$, $ZnNO_3$ and 2% DMSO were used as control. These discs were gently pressed in Muller Hinton agar plates and were inverted and incubated for 24 h, for measurement of zones of inhibition (in millimeters including disc) using the Hi-media antimicrobial zone scale. Each screening, treatment was conducted in triplicates and mean and standard errors were calculated using IBM SPSS Statistics 20 software. The Tukey's post hock test was used to assess the statistical significance (P value ≤ .05).

3. Results and discussion

The silver nanoparticles exhibited effective zone of inhibition against *B. cereus* (16.10 ± 0.20) followed by *S. typhi* (15.50 ± 0.28), *S. aureus* (15.16 ± 1.66), *P. aeruginosa* (13.33 ± 1.66), *E. coli* (9.83 ± 0.16) and *E. faecalis* (9.33 ± 0.33) at 400 µg/mL (Fig. 2, Table 1). In silver nanoparticles the F value 3259.984, 5.33, 13.625 of *B. cereus*, *S. aureus* and *P. aeruginosa* respectively, with (2, 6) degree of freedom shows a significant P value which show factors level means are statistically significant. Where as in case of *E. faecalis*, *E.coli* and *S. typhi* F value is 0.583, 2.400 and 4.876 respectively with (2, 6) degree of freedom shows the P value is greater than the critical value which reveals the factors level means are statistically insignificant (Table 1).

The *B. cereus* (13.50 ± 0.28) showed the highest zone of inhibition when treated with the zinc oxide nanoparticles followed by *S. typhi* (8.33 ± 0.28), *E. faecalis* (7.66 ± 1.66), *P. aeruginosa* (7.50 ± 0.50), *S. aureus* (7.33 ± 0.57) and *E.coli* (7.00 ± 0.00) at 400 µg/mL (Fig. 2, Table 2). In zinc oxide nanoparticles, the F value of *B. cereus*, *S. aureus*, *E.coli*, *S. typhi* and *P. aeruginosa* is 178.00, 248.714, 31.00, 86.00 and 354.00 respectively, with (2, 6) degree of freedom shows a significant P value which shows factors level means are statistically significant. Further, in case of *E. faecalis* of 4.750 with (2, 6) degree of freedom; here P value is greater than the critical value which reveals that the factor level means are statistically insignificant. The silver nanoparticles show the greater zone of inhibition in *S. aureus*, *S. typhi* and *P. aeruginosa* when to compared to the standard *Erythromycin* (Figs. 1 and 2; Tables 1 and 3).

The synthesis of silver and zinc oxide nanoparticles by addition of a leaf extract to silver nitrate and zinc nitrate solution indicated by a change in color of the reaction mixture to deep brown color. Zinc oxide nanoparticles show the yellowish color due to the surface plasmon resonance The same results have been reported by several investigators [13,14,57]. Formation of nanoparticles further confirmed by their characteristic absorption spectra of silver and zinc oxide nanoparticles at 452 and 374 nm. The observed maximum absorbance peak fall within the range previously reported [58,59]. The microscopic analysis using HR-TEM results showed that the silver and zinc oxide nanoparticles were spherical in shape with size ranging from 21 to 42 nm and 12–53 nm respectively.

The leaf mediated synthesis of silver nanoparticles shows prominent absorption peaks at 1612 cm^{-1} attributed to stretch mode of the amide linkage [14]. The intense peak at 1268 cm^{-1} indicates stretching vibration of C-O group [60]. The absorption spectrum at 2849 and 2918 cm^{-1} were corresponding to antisymmetric and symmetric vibrations of hydrocarbons [5]. The zinc oxide nanoparticles show intense absorption band at 3412 cm^{-1} indicates due to the presence of the phenol molecules, and the spectra 1610 cm^{-1} show carboxylic group. The spectrum at 1056 cm^{-1} was attributed to the Si–O–Si proteins. The presence of alcohol, phenol, carboxylic acids and alkaloids are responsible for reducing and reduction, capping and stabilization of silver and zinc oxide nanoparticles [6,61,62].

Silver and zinc oxide nanoparticles exhibit inhibitory activity against test species of bacteria. The current study reveals for the first time the comparative assay of antimicrobial activity of bioinspired silver and zinc oxide nanoparticles synthesized by *L. acidissima* leaf extract. The biogenic silver and zinc oxide nanoparticles exhibited effective antibacterial activity against human pathogens. The different concentration of silver nanoparticles 100–400 µg/mL effectively inhibited the growth of species viz., *S. aureus*, *E. faecalis*, *E. coli*, *S. typhi P. aeruginosa*. Several other investigations reported the similar antimicrobial activities of biogenic silver nanoparticles [7,13,14,22,23,43,63–66]. The size and concentration of nanoparticles are two important factors which combat the growth of microbes. The concentration of nanoparticles was restricted at 400 µg/mL, otherwise the higher doses might be harmful to the host of pathogens [67]. Similar results were observed in the synthesis of nanoparticles by *Theobroma cacao* mediated synthesis of silver nanoparticles [13,14]. The

Table 1
Antimicrobial activity of silver nanoparticles by *L. acidissima* leaf extract.

Strains	Concentrations (µg/mL)			F and P^* values
	100 µg/mL	200 µg/mL	400 µg/mL	
B. cereus	–	14.16 ± 0.16	16.10 ± 0.20	$F_{2,6} = 3259.984$ $P = .000$
S. aureus	15.83 ± 1.66	15.16 ± 1.66	15.16 ± 1.66	$F_{2,6} = 5.33$ $P = .047$
E. faecalis	08.83 ± 0.16	9.166 ± 0.76	09.33 ± 0.33	$F_{2,6} = 0.583$ $P = .587$
E. coli	10.16 ± 1.66	10.50 ± 0.28	09.83 ± 0.16	$F_{2,6} = 2.400$ $P = .710$
S. typhi	15.16 ± 1.66	14.33 ± 0.33	15.50 ± 0.28	$F_{2,6} = 4.876$ $P = .055$
P. aeruginosa	11.33 ± 0.33	12.50 ± 0.28	13.33 ± 1.66	$F_{2,6} = 13.625$ $P = .006$

*The mean difference is significant at p < .05 level.

Table 2
Antimicrobial activity of zinc oxide nanoparticles by *L. acidissima* leaf extract.

Strains	Concentrations (μg/mL)			F and P values
	100 μg/mL	200 μg/mL	400 μg/mL	
B. cereus	7.83 ± 0.16	9.83 ± 0.16	13.50 ± 0.28	$F_{2,6} = 178.00$ $P = .000$
S. aureus	–	6.50 ± 0.50	7.33 ± 0.57	$F_{2,6} = 248.714$ $P = .000$
E. faecalis	6.50 ± 0.28	7.00 ± 0.00	7.33 ± 0.28	$F_{2,6} = 4.750$ $P = .58$
E. coli	6.00 ± 0.00	6.16 ± 0.28	7.00 ± 0.00	$F_{2,6} = 31.000$ $P = .001$
S. typhi	6.00 ± 0.00	6.33 ± 0.28	8.33 ± 0.28	$F_{2,6} = 86.000$ $P = .000$
P. aeruginosa	–	6.23 ± 0.14	7.33 ± 0.57	$F_{2,6} = 354.00$ $P = .000$

*The mean difference is significant at $p < .05$ level.

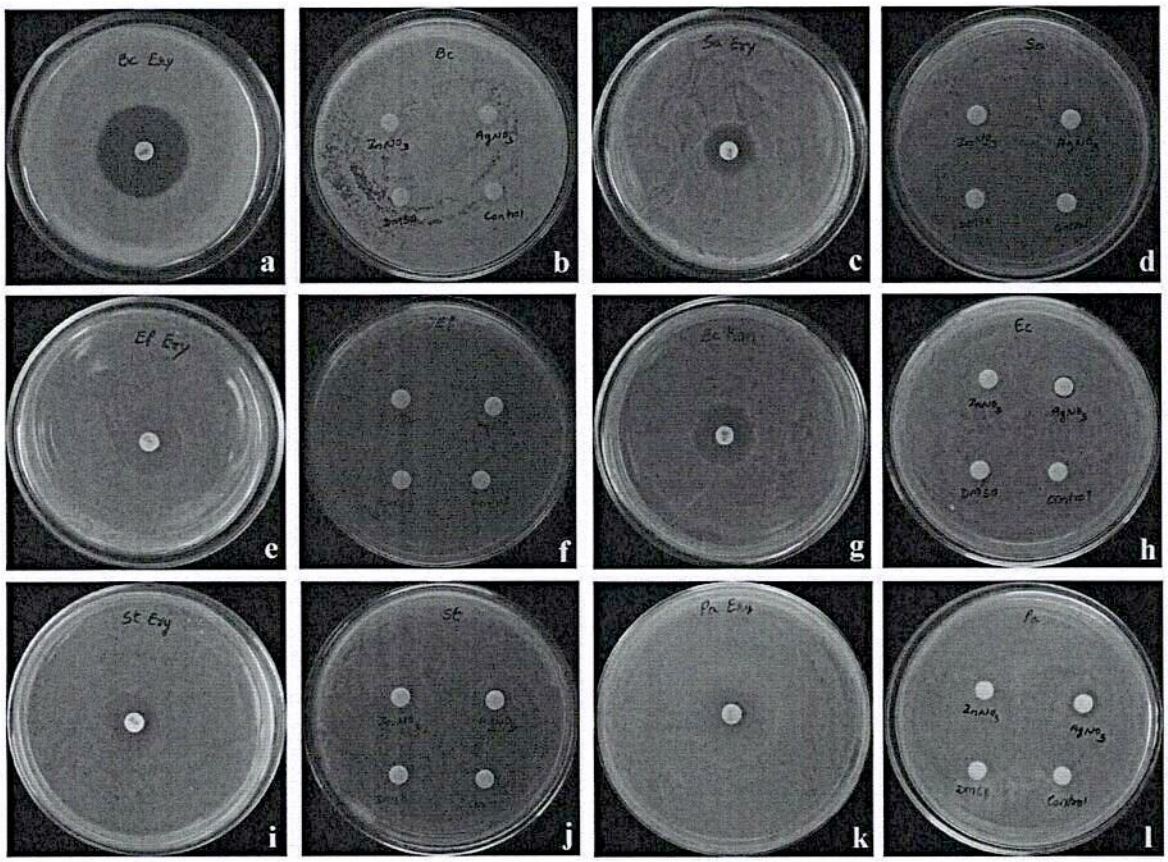

Fig. 1. Antimicrobial activity of *Erythromycin* (a, c, e, g, i, k) and Control, $AgNO_3$, $ZnNO_3$, 2% DMSO (b, d, f, h, j, l) *B. cereus* (a, b), *S. aureus* (c, d), *E. faecalis* (e, f), *E. coli* (g, h), *S. typhi* (i, j) and *P. aeruginosa* (k, l).

silver and zinc oxide nanoparticles were tested for their activity against different microbes, silver nanoparticles showed remarkable zone of inhibition against *B. cereus*, but in case of *S. aureus* 200 and 400 μg/mL of concentration showed the same zone of inhibition and found to be dose response relationship is not significant. Similar result was observed with the silver nanoparticles synthesized by *Cola nitida* pod extract; they found that in *P. aeruginosa* 150 μg/mL shows the less zone of inhibition when compared to the 120 μg/mL [13].

The nanoparticles attach to the surface [68,69] and damages the structure of the cell membrane and reduce the activity of some membranous enzymes [70,71]. The physical vandalism such as disruption of phospholipid bilayer and protein on cell membrane by silver and zinc oxide nanoparticles causing a leakage of intracellular content of cell membrane to kill bacteria by pricking into the bacterial cell membrane. The nanoparticles induce an increase in permeability of bacterial cell membrane by antimicrobial peptides, which facilitate the better penetration of nanoparticles. The probable toxicity mechanism of silver and zinc oxide nanoparticles against the bacteria is shown in Fig. 3. Moreover, nanoparticles are also known to induce oxidative stress in bacteria. These properties will eventually lead to the killing of bacteria [38–40]. The entry of silver and zinc oxide nanoparticles into the bacteria seemed to utilize multiple pathways including clathrin intervened endocytosis [41], caveolae meditated endocytosis and to a lesser degree macropinocytosis [42], also play a vital role for internalization of the resulting receptor ligand complexes leading to receptor mediated endocytosis [44].

Alternatively, nanoparticles may interact with the membrane via hydrophobic and electrostatic interaction and taken into the cell through pinocytosis. The small sized nanoparticles (silver nanoparticles 21–42 nm and zinc oxide nanoparticles 12–53 nm) induce more cell

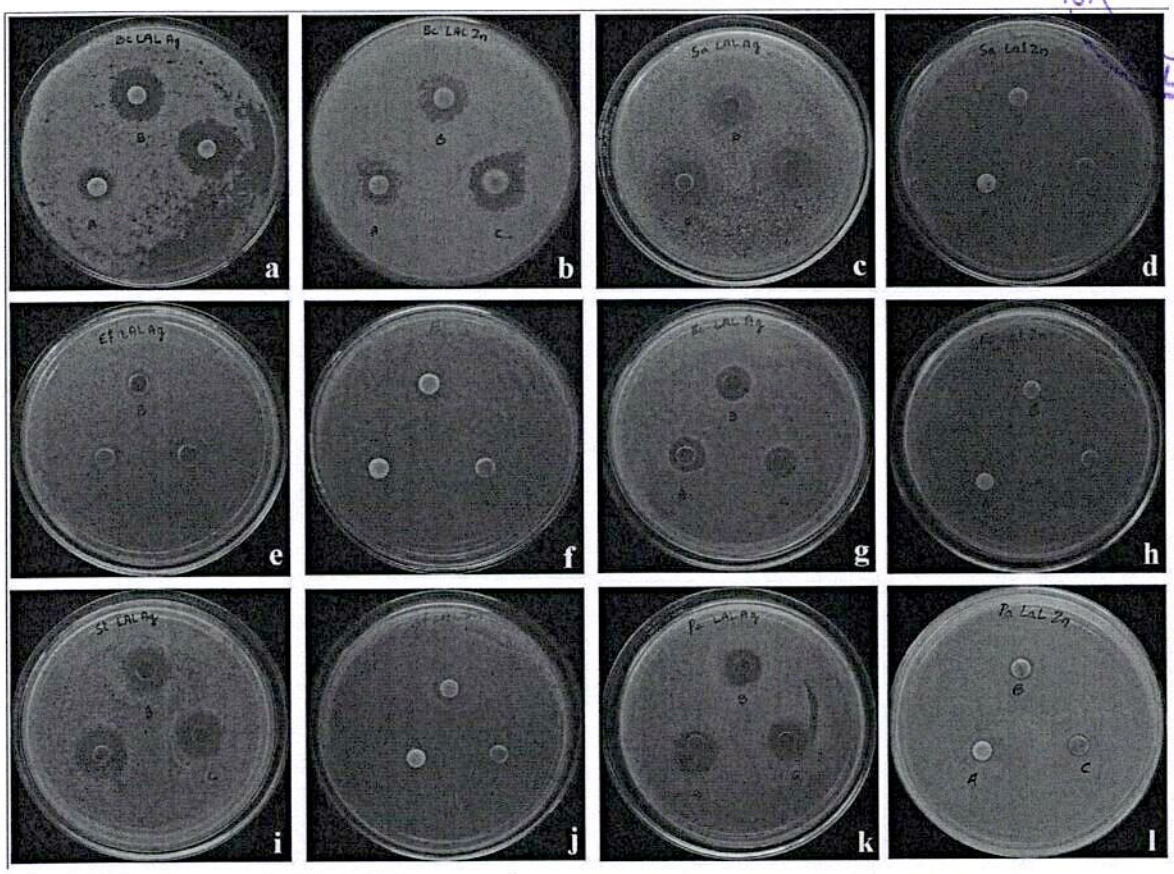

Fig. 2. Antimicrobial activity of silver nanoparticles (a, c, e, g, i, k) and zinc oxide nanoparticles (b, d, f, h, j, l) *B. cereus* (a, b), *S. aureus* (c, d), *E. faecalis* (e, f) *E. coli* (g, h), *S. typhi* (i, j) and *P. aeruginosa* (k, l).

Table 3
Antimicrobial activity of *Erythromycin*.

Strains	*Erythromycin* (Mean ± SE)
B. cereus	27.50 ± 0.28
S. aureus	14.83 ± 0.16
E. faecalis	19.66 ± 0.16
E. coli	16.50 ± 0.00
S. typhi	14.83 ± 0.16
P. aeruginosa	09.50 ± 0.28
F and *P** values	$F_{5,12}$ = 879.044 *P* = .000

*The mean difference is significant at p < .05 level.

permeability by creating intracellular loss and thereby leading to cell death [2]. In this study, the size of zinc oxide nanoparticles is lesser than silver nanoparticles but antibacterial activity shows the less effectuality when compared to the silver nanoparticles owing to agglomeration which shows the lesser zone of inhibition which confirms the findings of shekar and others [45].

The nanoparticles bind to DNA or with bacterial ribosome and affect polypeptide synthesis leading to inhibition of bacterial growth. Further nanoparticles initiate lipid peroxidation reaction, subsequently causing DNA damage, glutathione depletion, disruption of membrane morphology and electron transport chain, leading to cell death [46]. The DNA strand breaks induced by silver and zinc oxide nanoparticles. They may respond with sulfur or phosphorus containing delicate bases [4], for example R–S–R, PR_3 and R–SH RS– and it advances the loss of capacity of DNA replication [72] and finally to combat the bacterial development.

4. Conclusion

The present investigation focuses on synthesis of silver and zinc oxide nanoparticles through simple biological method using *L. acidissima* leaf extract which provided reducing and stabilizing agents for the biosynthesis of nanoparticles. The comparative assay of different concentrations of silver and zinc oxide nanoparticles on antibacterial activity silver revealed that the silver nanoparticles showed more effective zone of inhibition when compared to the zinc oxide nanoparticles, due to their ability of penetration into the cell leading to death of bacterium.

Conflicts of interest

The authors have no conflicts of interest.

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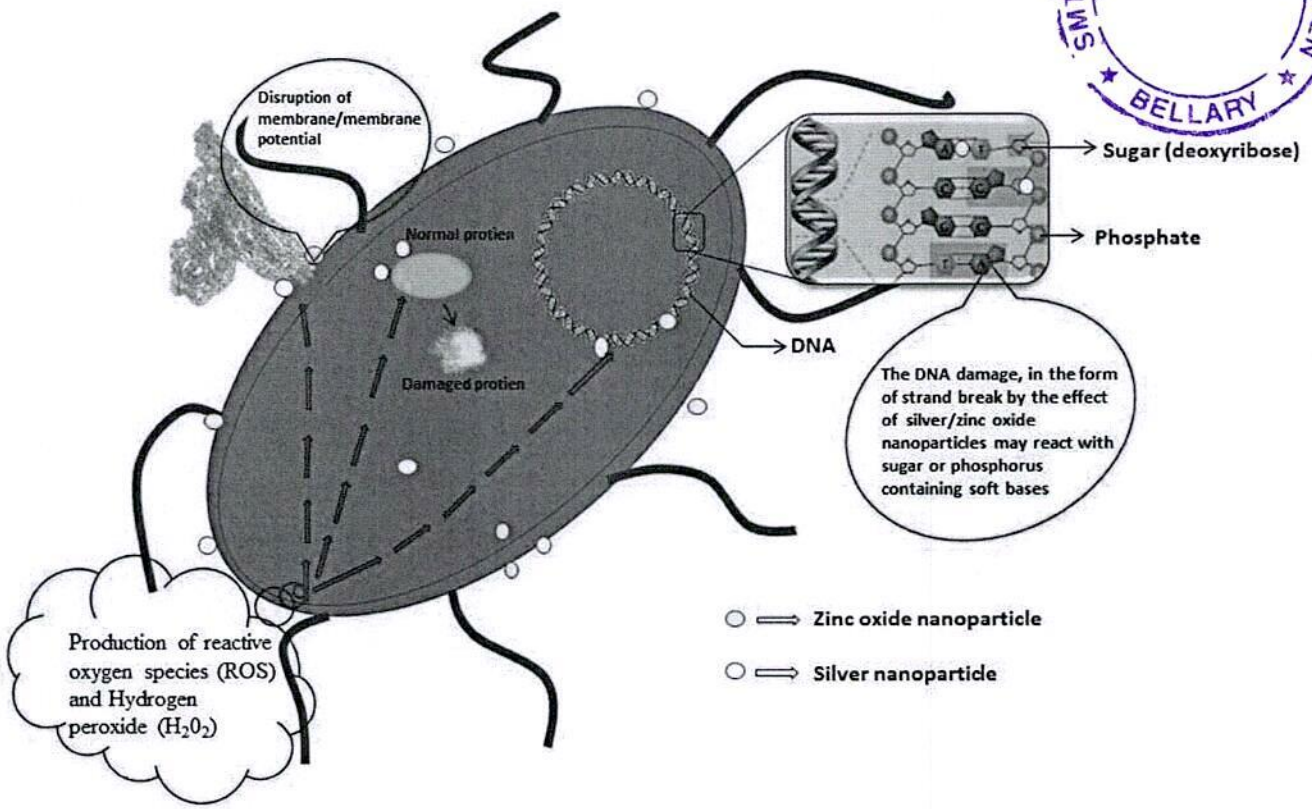

Fig. 3. Schematic diagram showing the possible toxicity mechanism of silver and zinc oxide nanoparticles against the bacteria.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.micpath.2017.12.035.

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