



## A REVIEW: GREEN SYNTHESIS OF THERAPEUTIC AGENTS USING ULTRASONICATION

DAYALI A. PAGARE <sup>1\*</sup> | DR. N.V. SHINDE <sup>2</sup> | PRIYANKA MAPARI <sup>3</sup>

<sup>1</sup> STUDENT, PHARMACEUTICAL CHEMISTRY, NASHIK, INDIA- 422010.

<sup>2</sup> PROFESSOR, PHARMACEUTICAL CHEMISTRY, NASHIK, INDIA- 422010.

<sup>3</sup> STUDENT, PHARMACEUTICAL CHEMISTRY, NASHIK, INDIA- 422010.

### ABSTRACT:

Ultrasound is one of the emerging technology which provides the higher yield, maximize quality, short reaction time, milder condition, ensure safety of products, and without generating pollution, it is safer to analyst. Ultrasonication is the fast, ecofriendly, more convenient greener technology. It is advantageous over the conventional method due to rapid and cleaner reaction, easy to work up, avoiding use of harmful solvents, reliable and economical approach for synthesizing therapeutic agents. Use of such techniques in the synthesis of various organic intermediates or medicinal compounds is of great interest to the chemist working in this field. This review focusses on use of ultrasonication in the synthesis of various silver, gold, zinc oxide, silicon, palladium nanoparticles and various organic intermediates. It also highlights the importance of this techniques in terms of percentage yield, safety and efficacy proving it to be an effective green method.

### KEYWORDS:

ULTRASOUND, GREEN SYNTHESIS, ECOFRIENDLY, NANOPARTICLES SHORT REACTION TIME, HIGHER YIELD.

### Introduction

#### 1. Green chemistry:

The green Chemistry was designed in 1991 for elimination or reduction in hazardous substances, trying to reduce the exposure of human and environment to chemical[1][2].

The term "green chemistry" refers to a resource-efficient, ecofriendly technology that uses resources in a way that minimizes or even completely eliminates the formation of undesirable by products during the product's development and manufacture[3].

Green chemistry efficiently uses raw materials (ideally renewable sources), reduces waste, and omits the use of hazardous and/or toxic reagents and solvents in the production and use of chemical products[4].

Paul Anastas and John C. Warner introduce the twelve principles for "green chemistry." The fundamental ideas of green chemistry serve as its basis and aid in accomplishing the following requirements:

#### 1.2 Concept of Green Chemistry

Green chemistry is a term that encompasses a new approach towards the synthesis, processing and application of chemical substances in such a manner which reduce threats for environment and health. This new approach is also called as clean chemistry or environmentally benign chemistry.

Green Chemistry is the designing of chemical products and processes that reduce or eliminate the use and generation of hazardous substances. For fact, in green chemistry, we can utilise water in the laboratory to conduct chemical reactions, preventing pollution and the potentially

dangerous effects of volatile solvents.

Green chemistry applies combined approaches of physical chemistry, organic chemistry, inorganic chemistry, biochemistry, & analytical chemistry to minimize waste and utilize renewable resources. It has been considered as an important area of scientific research and The Nobel Prize Committee recognized the importance of green chemistry in 2005 by awarding Yves Chauvin, and Richard R. Schrock, Robert H. Grubbs the Nobel Prize for Chemistry for "The development of the metathesis method in organic synthesis"[5][6].

#### Advantages:

- 1) Green synthesis is used to minimize effects of toxic chemicals
- 2) Prevention of unnecessary waste , avoiding the unwanted waste in organic reaction/synthesis
- 3) By using Green Chemistry, contamination prevention via permanent analysis of reaction intermediates
- 4) Green synthesis gives the degradable reaction products, non persisting in the environment
- 5) Green process are cheaper and cost effective, frequently resulting in products with the better quality
- 6) Use of most selective catalyst, resulting higher yield of reaction products and better quality and required less energy as compared to conventional

methods

- 7) Green reaction allows avoiding problem with many environmental law and regulations
- 8) Reduction of precursor and intermediate chemical losses during the synthesis of the final materials
- 9) Low toxic and safe separation agents and solvent (water, organic compounds for example, extracts)[1].

The following are some impressive advantages of ultrasonication as a green synthetic technique: (1) responses were conducted at room temperature; (2) the reaction took substantially less time to complete as hence, the ultrasonic process uses less time and energy than conventional refluxing; (3) A significantly increased reaction rate; (4) A relatively smaller amount of DMF was used; (5) A quicker and cleaner work-up process; (6) the reactions are done in an environmentally sustainable manner an enclosed acoustic space[7].

#### Disadvantages:

1. Green process and technology required the effort to improve energy efficiency or to reduce the pollution.
2. The largest drawback of the green Chemistry is that it often requires a large initial cost.
3. Inadequate saving [8].

#### Principle:

- a. To design and development of such process which maximizes the conversion of raw material to products so that maximum yield of product is obtained.
- b. To implement the usage of such substances which are environmentally friendly or substances which are derived from environment including solvent, whenever possible
- c. Designing of energy efficient process
- d. Disposal of waste material so avoided that it should not produce in the reaction or if not possible should be treated in such a way that it should not harm the environment [3].

#### Based on these twelve principles, green chemistry includes:

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to Human health and the environment.
4. Chemical products should be designed to preserve efficacy of function while reducing

toxicity.

5. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary whenever possible and, Innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic Methods should be conducted at ambient temperature and pressure.
7. When technically and economically feasible, a raw material feedstock should be renewable rather than diminishing.
8. Unnecessary derivatization (blocking group, protection/ deprotection, temporary modification of physical/ chemical processes) should be avoided whenever possible.
9. Stoichiometric reagents are inferior to catalytic reagents, which should be as selective as feasible.
10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
11. It is necessary to improve analytical approaches further to enable real-time in-process monitoring and control before the formation of hazardous compounds.
12. Substances and the form of a substance used in a chemical process should chosen so as to minimize the potential for chemical Accidents, including releases, explosions, and fires [9][10].

### 1.3 Ultrasonication

In 1944, the first patent was granted in Switzerland for using Ultrasonication.

Ultrasonication is the science of sound waves above the audible range of human beings. Frequency of the sound determines its tone and pitch. While high frequency sound waves produce treble tones, low frequency sound waves produce bass tones. Typically, frequencies above 18 kHz are regarded as ultrasonic and are inaudible to the human ear.

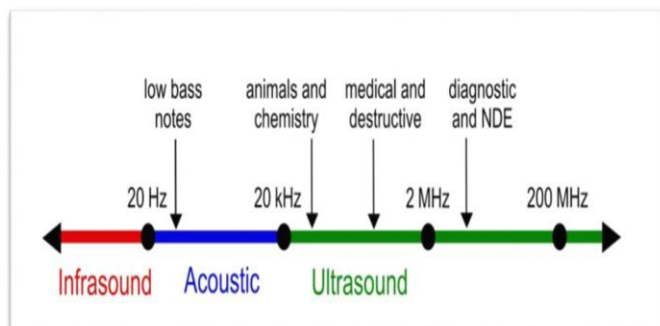
Ultrasonication treatment has been in the range of 10 to 1000 W/cm<sup>2</sup> and frequencies of 20 to 100 kHz. It has a pronounced effect on physical and chemical properties of liquids.

A sound wave known as an ultrasound is an acoustic wave that travels at a frequency greater than 20 kHz, exceeding the range of human hearing[11]. Acoustics is the study of sound of all mechanical waves in solids, gases, and liquids, Including sound, ultrasonic, infrasound, and vibration[12].

#### Principle:

Ultrasonic is a type of mechanical energy created when electrical energy is applied to a transducer, which is a piezoelectric material. The transducer then converts the

electrical energy into mechanical vibrations that travel through the fluid at a specific frequency. Sound energy is the term used to describe mechanical vibration at higher frequencies [13][53]. The standard human hearing range is between 16 and 20,000 Hz. The mechanical vibration is known as ultrasonic above this point. Beyond this point, the mechanical vibration is known as ultrasonic vibration [14][12]. As displayed in Figure (1):

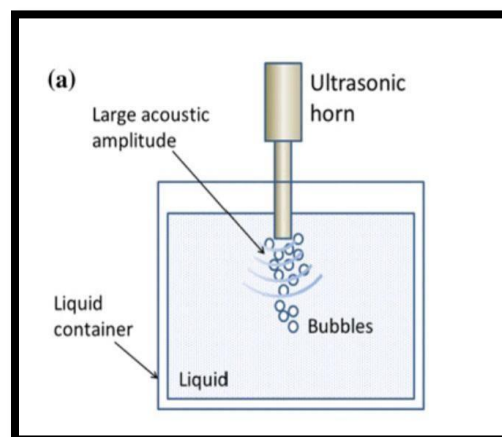


**Figure (1): Illustration of Ultrasound Frequencies**

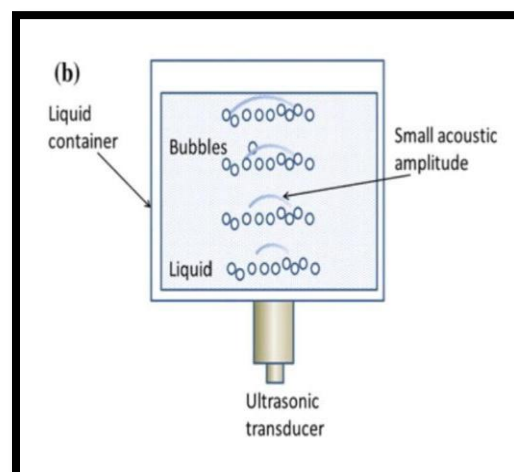
Ultrasonic waves hit the surface of material and generate a force, when the force is perpendicular to the surface. It results in a compression wave that moves through the molecule or field; also if the force is parallel to the surface it produces a shear wave. However, the waves become attenuated as they move through the molecules or compound. Ultrasonication produces a very rapid localized change in pressure and temperature, which causes shear disruption, cavitation, thinning of cell membranes, localized heating and free radical production with a lethal effect on microorganisms and reducing the size of fat globules. The medium responds to the diffusion of ultrasonic waves and sustains them by vibrating elastically[12].

McClements and Muthukumar suggested that depending on wave time, distance, Frequency, and maximum pressure amplitude, the acoustic pressure follows a sinusoidal wave[12].

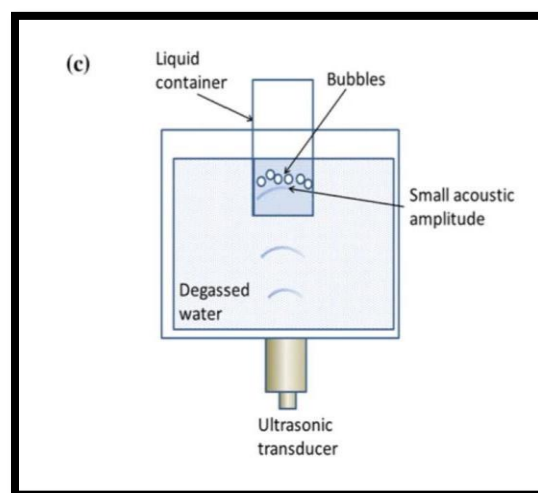
Suslick discovered that heat, pressure, and turbulence (which is utilized to increase up the mass transfer in chemical reactions) develop new reaction pathways in chemical reactions & dislodge the particle, or even produce different products than those attained under ordinary circumstances[15]. For the creation of acoustic cavitation, there are mainly two kinds of experimental setups. One method is to utilize an ultrasonic horn submerged in liquid. The tip of a horn emits an acoustic wave that is much shorter than the wavelength of sound. The other option is to utilize an ultrasonic bath, which is commonly used in ultrasonic cleaning. One or more ultrasonic transducers are mounted to the outside of a liquid container or the inside of a tiny closed box immersed in the liquid. In the case of an ultrasonic bath, indirect ultrasound irradiation is also available[11].



**Figure 2: Horn Type**



**Figure 3: Bath Type**



**Figure 4: Indirect Irradiation Type**

Three experimental techniques for producing acoustic cavitation. (A)Horn Type, (b)bath type, and (c) indirect irradiation in bath Type[16].

## Synthesis of medicinal compound and organic intermediate

### 2.1. Synthesis of silver nanoparticles

1. Vladimir Popov, Ivaylo Hinkov performed the

green synthesis of silver nanoparticles Ultrasound method. Silver nanoparticles were incorporated in cellulose using US bath and shown to have a strong antimicrobial activity against *Escherichia coli* bacteria. The most important aspect of cellulose containing silver nanoparticles prepared by this method is its high antimicrobial efficiency. In this work they concluded that this method doesn't require seed to integrate the Ag nanoparticles thus is a convenient and fast pathway for low cost production of cellulose based bacteria nanoparticle[17]

2. Sonication assisted green synthesis of silver nanoparticles using *Piper retrofractum* fruit extract and their antimicrobial assay was performed by Akhmad Sabarudin and Sutiman B.Sumitro.

They discovered that Ag nanoparticles were produced from an *Piper retrofractum* fruit extract, in liquid form using a sonication-assisted, environmentally friendly Method. In the synthesis of AgNPs the chemical from *Piper retrofractum* extract can serve as capping and reducing agent. The starting component was silver nitrate.

Silver nanoparticles that environmental exhibited antimicrobial activity against *S. aureus* and *E. coli*. The silver nanoparticles' morphology was spherical and high levels of silver were detected in the EDS spectra. In the green synthesis of AgNPs, this work demonstrated the benefit of plant extract. [18].

3. Noble metal nanoparticles their unique characteristics, which could be utilized in cosmetic products, synthetic fibres, antimicrobial applications, and biosensor materials Electrical components and tubing materials make them a very important topic to address. The unique characteristics of the AgNPs depend on their size and form. For the synthesis of the AgNPs, published preparation methods exist, for example, chemical reduction, biological synthetic drug, and thermal decomposition, microwave processing, photochemical methods, and technologies.

Remziye Guzel and Gulbahar Erdal concluded that AgNPs are accessible by biological, physical, and chemical process[19].

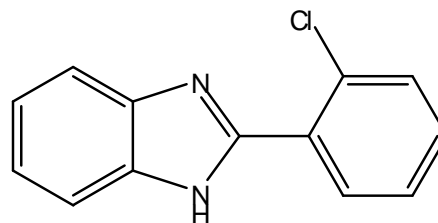
4. Ultrasonic-assisted green synthesis of silver nanoparticles using *Mentha aquatica* leaf extract for enhanced antibacterial properties and catalytic activity by Afsaneh Nouria, Mohammad Tavakkoli Yarak, Aseman Lajevardid, Zahra Rezaei, Mohammad Ghorbanpour, MarjanTanzifi

*Mentha aquatica* leaf (MAL) extract was used as a capping and reducing agents during biogenic techniques. used to create ultra-small Ag nanoparticles (AgNPs). The Ag<sup>+</sup> ions in the extract could be converted to Ag<sup>0</sup> by the phytochemicals

present, forming nanoparticles. The characterization of biosynthesized AgNPs was carried out using a variety of analytical techniques, including UV-VIS spectroscopy, X-ray diffraction (XRD), Transmission microscopy (TEM) coupled to energy-dispersive X-ray spectroscopy (EDX), and Fourier transforms infrared spectroscopy (FTIR).

When compared to AgNPs made by the hydrothermal approach, the sonochemically produced smaller AgNPs had stronger antibacterial activity. As an added bonus, the produced AgNPs with ultrasonic assistance had a lot of catalyst function in chemical reduction of many dyes of various kinds[20].

5. Sonochemical Synthesis of Silver Nanoparticles Using Starch: A Comparison performed by Brajesh Kumar, Kumari Smita, Luis Cumbal, Alexis Debut, and Ravinandan Nath Pathak Utilizing starch with sonication, an unique method was used to create silver nanoparticles. With an increase in starch concentration, colloidal silver nanoparticle solution absorbance improved from 420 to 440 nm. The ideal reaction conditions include sonication for 20 minutes at room temperature, 25 mg starch, 10 ml of 1M AgNO<sub>3</sub>, a pH range of 11. The sonochemical reduction method exhibits a great potential for producing colloidal silver nanoparticles of the desired particle size. Sonication is a safer and more environmentally friendly method of creating AgNPs than other synthetic techniques. For the synthesis of aryl benzimidazole, starched AgNPs demonstrated effective catalytic activity[21].



2-(2-chlorophenyl)-1H-benzimidazole [1]

6. Green sonochemical synthesis of silver nanoparticles at varying concentrations of kappa carrageenan Performed by Nor Azowa Ibrahim, Randa Fawzi Elsupikhe, Mansor B Ahmad, Norhazlin Zainudin & Kamyar Shameli.

In various concentrations of kappa carrageenan for the synthesis of AgNPs, a green sonochemical approach was created. Ultrasonic irradiation served as a green reducing agent, while kappa-carrageenan served as a natural, eco-friendly stabilizer. The quantity of AgNPs grew along with increasing the levels of carrageenan. In various concentrations of kappa-carrageenan, they noted the successful use of ultrasonic irradiation as a green and physical reducing approach for the synthesis

of AgNPs. The largest surface plasmon resonance peak at 402 to 420 nm for each sample, as shown by UV-visible spectroscopy, is evidence that the AgNPs were successfully produced. All of the samples' fcc crystal structures for AgNPs were visible in the XRD pattern without any impurities. The interactions between -carrageenan and AgNPs were shown by FTIR. The particle size distributions and TEM pictures showed that as the carrageenan concentrations increased, so did the quantity of AgNPs. According to SEM data, the surface of Ag/Ag-carrageenan changed as -carrageenan concentration increased, resulting during the generation of tiny, spherical AgNPs[22].

7. Ultra-sonication-enhanced green synthesis of silver nanoparticles using *Barleria buxifolia* leaf extract and their possible application Performed by Vanaraj Sekar Cindhu Balakrishnan , Preethi Kathirvel, Sathiskumar Swamiappan , Mohammed Ali Alshehri, Samy Sayedand Chellasamy Panneerselvam

The study's objective was to establish a quick and environmentally friendly method for synthesizing AgNP utilizing *Barleria buxifolia* leaf extract.

The AgNPs have been precisely characterised by UV, XRD, SEM, TEM, DLS, and FTIR investigation. Strong antioxidant qualities, improved antibacterial, anti-biofilm, and EPS inhibitory action against MDR strains are all displayed by the green synthetic AgNPs. Additionally, MCF-7, HeLa, and HepG2 breast cancer cell lines showed good anticancer activity. They described some interesting aspects of the eco-friendly, ultrasonic-assisted green process, including its simplicity, lack of hazards, cost-effectiveness, and ability to produce nanocrystals quickly and without agglomeration[23].

8. Green Synthesis of Silver Nanoparticles by Sonicated Method using Pulicha indeca Stem Extract: Characterization Antibacterial and Anticancer Activity and Cell Viability tested by Gugulothu Yaku ,Venkateswerlu and TVD Prasad Rao

Pulicha indeca extract was used to sonochemically produce green silver nanoparticles that can serve as both a stabilizing and reducing agent. At 440 nm, the UV-Vis SPR peak was seen, which corresponds to the typical plasmon resonance of nanostructures. An efficient and environmentally friendly "green" method has been developed for the green synthesis of AgNPs. They discovered that Ag nanoparticles were produced from an aqueous extract of *Piper retrofractum* fruit using a sonication-assisted, environmentally friendly method. According to observations on the antibacterial activity of AgNPs, the produced AgNPs exhibit positive antibacterial activity

against Gram-negative *Staphylococcus aureus*, Grampositive *Bacillus subtilis*, and Gram-negative *Klebsiella pneumoniae* bacteria. The silver nanoparticles exhibit positive anticancer activity against Hela cancer cells. Synthesized AgNPs exhibit negative antibacterial activity against dangerous mirabilis (Gram-negative) bacteria (49.34). With such a cheap supply of material, stable AgNPs may be produced in an economical and environmentally sustainable manner with a kind of possible uses[24].

9. AartiR.Deshmukh, Beomsoo Kim Arvind Gupta worked On Ultrasound Assisted Green

Synthesis of Silver and Iron Oxide Nanoparticles Using Fenugreek Seed Extract and Their

Enhanced Antibacterial and Antioxidant Activities

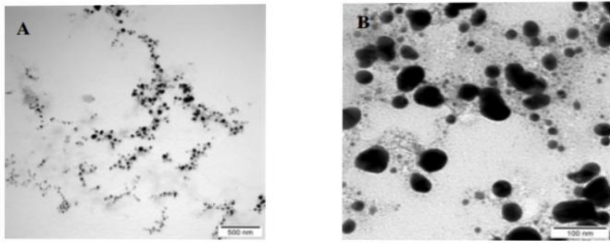
An easy and environmentally friendly method for the ultrasound-assisted production of silver and iron oxide NPs, as well as their improved antioxidant and antibacterial properties. In the fabrication of nanoparticles, to reduce, cap, and stabilize the sample, fenugreek seed extract was used.

Aqueous extract of fenugreek seed was used in the successful synthesis of the silver and iron oxide nanoparticles utilizing a simple, environmentally safe method. To understand the stability and usefulness of the nanoparticle, multiple methodologies were used to characterize all nanoparticles. Due to the combined actions of ultrasound and proteins bound to the surface of the nanoparticles, the nanoparticles synthesized with the aid of ultrasound showed increased stability and antibacterial and antioxidant activities. FTIR spectra confirmed the effectiveness of fenugreek seed extract as a capping and reducing agent. It was confirmed by EDX elemental analysis that ultrasound improved process yield. Using TEM analysis to examine the characteristics of the generated nanoparticles, it was reported that the ultrasonication-assisted approach preserved almost homogenous and relatively small particle sizes[25].

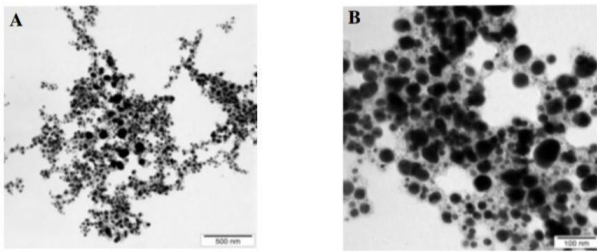
10. Obtaining Silver nanoparticles by sonochemical method performed by Vasile-SorinMĂNOIU , Angel ALOMAN

This study provides info on the sonochemical approach of producing silver nanoparticles. With this technique, a silver nitrate solution, AgNO<sub>3</sub>, is exposed to extremely vigorous ultrasonic flow, which causes minute bubbles (cavities) to develop. According to the analysis of TEM microscopy data, there are no significant changes between the shapes of the structures made by ultra sonicating liquids containing various concentrations of silver nitrate. A spheroidal shape and a nonuniform dimensional distribution

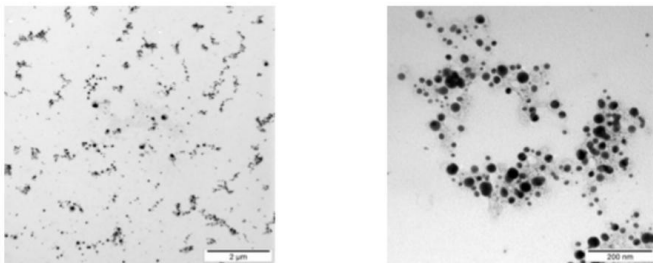
of nanoparticles with the sonochemical approach for silver nitrate may be formed[26].



**Figure 5: Particles Obtained By Ultrasonication of AgNO<sub>3</sub>**



**Figure 6: Particles Obtained By Ultrasonication of AgNO<sub>3</sub> (0.01M)**



**Figure 7: Particles Obtained By Ultrasonication of AgNO<sub>3</sub> (0.001M)**

11. Ultrasonic synthesis of nanochitosan and its size effects on turbidity removal and dealkalization in wastewater treatment performed by mita nurhayati , firdha zahra, muhamad nasir, yustika desti yolanda, pakorn opaprakasit , eng-poh ng and min-yeo choo

A distinct Study on the synthesis of chitosan nanoparticles below ultrasonication is studied in this paper. By using this easy technique, chitosan molecule in nanometer variety may be easily prepared without the use of any hazardous and costly chemicals. Chitosan nanoparticles have been successfully created using ultrasonication. The result report that increasing ultrasonic amplitude and exposure\slime, where both parameters are important in the breakdown of chemical bonds and micro aggregates, gives rise to the formation of discrete and small crystallites. The NCS7 (120 min ultrasonic treatment, 70% amplitude) demonstrates the smallest crystallite size with a narrow particle size distribution (77.47-28.81) out of the seven produced samples.

Additionally, the NCS-7 sample achieved extremely high turbidity removal efficiency (75.5%) and demineralization (58.3%), demonstrating the excellent biocoagulant / biofloculant and dealkalization properties of the chitosan nanoparticles, providing a green alternative to the current water treatment system [27].

## 2.2 Synthesis Of Gold Nanoparticles

1. Ji-Hwan Lee , Stephen U S Choi , Seok Pil Jang and Seoung Youn Lee synthesized aqueous, spherical gold nanoparticles (GNPs) under air conditions was investigated using a conventional ultrasonic bath. Ultrasonic energy's affects on the growth and shape of GNPs were also studied . Successful production of highly monodispersed circular GNPs using sodium citrate reduction was observed in a conventional ultrasonic bath without the use of a heater or magnetic stirrer as evidenced by TEM and ultraviolet-visible spectra. They discovered that the sonication energy significantly influences the particle shape and size of GNP sand occurrence. This research demonstrates the significance of the creation of ultrasonic waves uses ultrasonic energy of configurable, water-soluble GNPs of diameters (20–50 nm)lowering of citrate. This study provides novel ways to make spherical monodisperse GNPs in aqueous solutions without using a magnetic stirrer[28].
2. Synthesis of multiple shapes of gold nanoparticles with Controlled sizes in aqueous solution using ultrasound

The generation of gold nanoparticles (AuNPs) was studied by Jong-Eun Park, Mahito Atobe , Toshio Fuchigami in relation to the concentration of the stabilizer (sodium dodecylsulfate: SDS) and the strength of the ultrasonic irradiation. By changing the concentration, Au-NPs of various sizes and forms were synthesized.TEM and UV-vis spectroscopy were used to evaluate the sonochemically created AuNPs[29].

3. Synthesis of gold nanoparticles: a new approach in using a Nanoporous membrane in conjunction with ultrasonication Carried out by G.R. Kiani<sup>1</sup>, L. Saghatforoush , G.R. Mahdavinia , K. E. Geckeler.

HAuCl<sub>4</sub> was chemically reduced to form gold nanoparticles inside the pores of a polycarbonate-based membrane, which was then dissolved in dichloromethane and subjected to additional sonication. Investigations were done on the sonication time as the primary factor impacting nanoparticle size. This research concentrated on creating gold nanoparticles using a polycarbonate membrane as a template. Using TEM , the morphology of the gold nanoparticles was examined, and the creation of gold

nanoparticles was unequivocally established. Additionally, it was discovered that the length of the sonication process had a significant impact on the nanoparticles' average size and size distribution. The practical preparation of GNPs using this technique may present dependable potential[30].

4. Rapid sonochemically-assisted synthesis of highly stable gold nanoparticles as computed tomography contrast agents conducted by mohammed ali dheyab, azlan abdul aziz, mahmood s. jameel, pegah moradi khaniabadi and ammar a. oglat.

Good X-ray attenuation, flexibility in size and form, tailorable surface chemistry, excellent biocompatibility, and high amounts of contrast-generating material are just a few of the advantages AuNPs provide for this application. A sonochemical technique was used to create AuNPs that were around the size 18.5 nm and semi-spherical in form. The production of very stable AuNPs in various media after a five-minute ultrasound treatment has been demonstrated (AuNPs were 42.1 mV and 39.5 mV, respectively, in water and phosphatebuffered saline (PBS). The AuNPs CT value (HU = 395) increased linearly as AuNP dosage was raised. The results support the use of ultrasound Treatment for metal nanostructure synthesis, especially for very stable non-toxic AuNPs, Using a simple and quick approach, synthesized with excellent shape and crystal structure [31].

5. Sonochemical preparation of gold nanoparticles for sensitive colorimetric performed by determination of nereistoxin insecticides in environmental samples Fumiki Takahashi , Naoto Yamamoto , Miyuki Todoriki, Jiyejin

An effective approach for the precise and using gold nanoparticles, a sensitive detection method for insecticides that are analog of nereistoxin was developed. A sonochemical process without surfactants was used to create the AuNPs, and the ultrasonic frequency used was 430 kHz. If the AuNPs were covered with a tiny quantity of thioctic acid, they aggregated and this caused a colour change in the presence of NRT (TA). At the TA adsorbed on the AuNPs was deprotonated, whereas NRT was protonated (NRT-H<sup>+</sup>), at a pH of about 5.

This study used sonochemically produced, surfactant-free AuNPs to design a quick and effective post-modification method to change the surface charge of AuNPs[32].

6. Sonochemical synthesis of gold nanoparticles: effects of ultrasound frequency carried out by kenji okitsu, muthupandian ashokkumar, and franz grieser

In the aqueous solutions containing 1-propanol, it has been discovered that the frequency of sonochemical reduction of Au(III) to form Au nanoparticles is substantially dependent on the ultrasonic frequency. The sonochemical reduction of Au(III) ions has been studied extensively by several groups. 2,10-12 As has been mentioned in the article, the color of the Au(III) solution changed from a initial pale yellow to reddish purple with increasing time of ultrasonic irradiation[33].

7. H.M. Elmehdi J.H. Pagea , M.G. Scanlon performed "Using ultrasound to investigate the cellular structure of bread crumb"

In order to better understand how altering the concentration, size, and form of the crumb cells affects the mechanical characteristics of breadcrumbs, ultrasonic methods were applied. These effects, which can serve as the foundation for methods for evaluating loaf quality afterward the gas cells control structural integrity of the bread crumb, are therefore extremely important to the study of food and cereals. Samples of breadcrumbs that were freeze-dried were made with red spring wheat flour. By proving the dough for varying amounts of time, the crumb's density was adjusted from 100 to 300 kg/m<sup>3</sup>. The 54 kHz longitudinal waves amplitude and ultrasonic velocity both increased with  $\rho$ , with the latter fluctuating about as  $\rho^{0.5}$ .

These results showed that the compressed and uncompressed samples have various mechanical characteristics. The ability to use ultrasound as a tool for defining the mechanical and structural characteristics of bread crumb and, consequently, for measuring some of the defining characteristics of bread quality, is seen by how ultrasonic waves respond to changes in the size and shape of crumb cells [14].

8. Green synthesis of gold nanoparticles using Citrus maxima peel extract and their catalytic/antibacterial activities performed by Chun-Gang Yuan , Can Huo , Bing Gui , WeiPing Cao

In the food industry, the peel of Citrus maxima (C. maxima) is the main byproduct of the preparation of fruit or the juice and it has long been assumed as biomass waste that needs additional processing. Using C. maxima peel extract used as the capping and reducing agents, the authors reported that a clear and simple and ecologically friendly method to create gold nanoparticles . The C. maxima peel extract was used to create AuNPs. The synthesis method shown to be easy, affordable, and environmentally benign. By using TEM, EDS, XRD, and FTIR to characterize the morphologies of the AuNPs, it was established that the NPs were mostly

subspheroidal and differed in size from 8 to 25 nm. Both *S. aureus* (a gram positive) and *E. coli* (a bacilli bacteria) were resistant to the as-obtained AuNPs antibacterial effects and strong catalytic role in degradation of 4-NP[34].

9. Canxia Kan , Weiping Cai, Cuncheng Li, Lide Zhang and Hofmeister studied the

“Ultrasonic synthesis and optical Properties of Au/Pd bimetallic Nanoparticles in ethylene glycol”

By sequential and simultaneous sonochemical irradiation of their metal precursors in ethylene glycol, respectively, Au/Pd bimetallic nanoparticles, even with core-shell structure, were created. By first reducing Pd(NO<sub>3</sub>)<sub>2</sub>, then adding HAuCl<sub>4</sub> solution, Pd clusters or NPs are produced using the multistep process. Due to the priority of Au<sup>3+</sup> ion reduction to Pd<sup>2+</sup> ions in the successive approach, pre-reduced Pd will be converted back into Pd<sup>2+</sup> ions after the addition of Au<sup>3+</sup> ions and subsequent ultrasonic irradiation. Thus, Au nanoparticles are created. Further radiation causes the Pd<sup>2+</sup> ions to be reduced and Pd-shells to form on the Au particles, which in turn causes the Au SPR to drop and shift to the blue while increasing background absorption. The Mie-like model for core-shell structured bimetallic nanoparticles may accurately represent the evolution of optical absorption spectra with radiation. Thus, they may regulate the optical characteristics by varying the Pd-shell thickness. The results also show that the sequential strategy produces the core-shell structure more successfully than the simultaneous one[35].

### 2.3 Synthesis of Zinc Oxide Nanoparticles

1. Synthesis of ZnO-ag with clove oil using ultrasonication method and its antibiofilm activity against *k. pneumoniae* presented by y a prasetya , a hisbiyah1, k nisyak, e d iftitah and a srihardyastutie

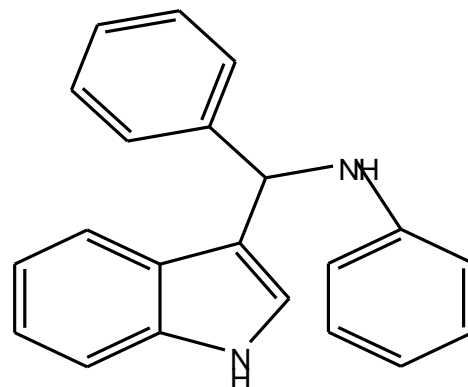
Clove oil was used as a reducing agent during the ultrasonication process that produced the ZnO-Ag nanocomposite. Time variations of 30, 60, 90, 120, 240, and 300 minutes were used for the execution of the synthesis processes. X-Ray Diffractometer was used to evaluate ZnO-Ag crystallinity.(XRD), and the Scherrer equation was employed to establish the average particle size. Using clove essential oil and the ultrasonication process, ZnO-Ag has been created in an easy, environmentally friendly way. Clove oil's primary ingredient may function of reducing agent in the production of ZnO-Ag. 90 minutes is the optimum amount of time for the ultrasonication technique to synthesize ZnO-Ag using clove oil. The final particle size is 21.46 nm, and its constituents are as follows: Ag (51.4%) (cubic), wulfingite (20%), Zn(OH)<sub>2</sub> (22.9%), and ZnO (5.7%) (cubic). Strong

antibacterial activity of ZnO-Ag against *K. pneumoniae* can stop the development of *K. pneumoniae* biofilms. They were advised to carry out calcination methods to create ZnO so that the crystallinity is good for future investigation[36].

2. Ultrasonication-Assisted Synthesis of 3-Substituted Indoles in Water Using Polymer Grafted ZnO Nanoparticles as Eco-Friendly Catalyst studied by Tauhid Shaikh, Anuj , and Harjinder Kaur

In this article, zinc oxide nanoparticles were investigated as a catalyst for the synthesis of 3-substituted indoles in water using ultrasound. The stability and dispersion of ZnO nanoparticles in water were improved by grafting them to a biodegradable polymer (poly lactic acid). The suggested technology is capable of producing required compounds with high yield (83-97%), and 25 indole derivatives were synthesized.

By grafting ZnO nanoparticles with polylactic acid, they created an affordable, biodegradable hybrid material that proved to be an excellent catalyst for the generation of 3-substituted indoles. The current catalyst system is promising since it produces a high yield of the desired product in a short reaction time and utilises water as a harmless solvent. Green chemistry measures calculated indicate a low E-factor and a higher atom economy[37].



N-[(3H-indol-3-yl)(phenyl)methyl]aniline [3]

3. Green synthesis of zinc oxide nanoparticles using Peganumharmala Seed extract, and loaded on Peganumharmala seed powdered Activated carbon as new adsorbent for removal of Cr(VI) from aqueous Solution presented by Mehdi Fazlzadeh, Rasoul Khosravi, Ahmad Zarei

In the proposed investigation, powdered activated carbon (PPAC) was made from Peganumharmala seed, coated with green ZnO nanoparticles, and then used to remove Cr(VI). A novel physicochemical technique was used to activate PPAC when UV waves were present. Ultrasonic waves used as the activator agent to create a novel kind of powdered activated carbon. The

synthesized activated carbon exhibits a large surface area and porosity, according to BET and FESEM tests. In the current study, zinc oxide nanoparticles were created using a brand-new, environmentally friendly process called green synthesis. For the synthesis of NPs, extract from *Peganum harmala* seed was employed as a stabilizing and coating agent.

The polyphenolic chemicals and proteins necessary for the formation of NPs were validated by the FTIR spectra. Furthermore, the NPs' size was shown on TEM pictures to be 40 nm. The investigation showed that the NPs had a coating of capping components made of plant extract. The potential of removing Cr(VI) from aqueous solution using activated carbon and green zinc oxide nanoparticles (GZnO) was investigated[38]

## 2.4 Synthesis of Silicon Nanoparticles

1. P G Kale , Mihir Kumar Sahoo , Nishit Kumar Sadual And S K Behera presents "Synthesis of Graphene-wrapped Silicon Nanoparticles by Ultra-sonication"

Anodes for Li-ion batteries can be constructed using composite electrodes that combine silicon nanoparticles (SiNPs) and graphene oxide (GO), which are both made using the ultrasonication technique.

The PS, fabricated by electrochemical anodization, was coated with GO. The sample was examined using HRTEM and FESEM techniques to identify it. Graphene and graphene composite SiNPs are confirmed by the characterization approach. The inter-atomic distance and crystal orientation of Si is 0.31 nm, Structure, respectively. The graphene-wrapped SiNPs can be used as anode in LIB to overcome the Lithiation problem[39].

2. Blue luminescent silicon nanoparticles synthesized from free-standing porous silicon layer by ultrasonic treatment performed by V.S. Vendamani, A.P. Pathak , S.V.S. Nageswara Rao It was possible to create blue luminous colloidal SiNPs by starting with nanostructured porous silicon. SiNPs with an average size of 1 to 5 nm have been prepared. They are crystalline and spherical. The fine dispersion of SiNPs in the solution is indicated by the absorption spectrum. The asymmetry and shift in the Raman peak relative to the substrate silicon peak provide additional evidence that SiNPs were successfully generated. The crystalline lattice fringes in the HRTEM picture of a single isolated SiNP have a lattice spacing of 0.32 nm, which corresponds to the inter-planar spacing of the Si [111] planes in the Si lattice. Colloidal Si NPs have an optical absorption edge of approximately - 2.85 eV. It clearly denotes the particle size distribution in the solution and is compatible with the size

distribution established using other analytical techniques. The observed emission peak and chromaticity diagram demonstrate the successful synthesis of strong blue luminescent Si NPs for micro and nanoscale applications Uses for opto-electronics[40].

## 2.5 Synthesis of Tin Nanoparticle

1. Synthesis of SnO<sub>2</sub> Nanoparticles Using Ultrasonication performed by Samhita Majumdar, P. Sujatha Devi

Utilizing ultrasonic energy for chemical synthesis has recently become a significant and expanding subject of study. They were used this source of energy to create SnO<sub>2</sub> nanoparticles (8–30 nm) at room temperature using a sonication-assisted precipitation method. The precipitation time was modified during preparation to better understand how ultrasonic energy affected particle size and distribution. Sonication assisted precipitation with NH<sub>4</sub>OH as the precipitating agent was used to create SnO<sub>2</sub> nanoparticles. On the phase development of SnO<sub>2</sub>, the impact of sonication time has been observed. Longer sonication times resulted in powders with better qualities, such as a high affinity for detecting butane and a quick recovery time[41].

2. Biosynthesis of tin oxide (SnO<sub>2</sub>) nanoparticles using jujube fruit For photocatalytic degradation of organic dyes performed by Moones Honarman, Morteza Golmohammadi, Atena Naeimi

In this study, jujube fruit was used as a non-toxic, renewable reducing agent and good stabiliser to create tin oxide (SnO<sub>2</sub>) NPs in a green manner. By using XRD, FT-IR, SEM, and EDX analysis, the structure, size, and morphology of the biosynthesized SnO<sub>2</sub> nanoparticles were studied. The tetragonal rutile structure of SnO<sub>2</sub> NPs was identified using an XRD pattern, with the average crystallite size being roughly 18 nm. The effective synthesis of SnO<sub>2</sub> in the presence of the extract was validated by the FT-IR analysis of biosynthesized SnO<sub>2</sub> nanoparticles. The SEM scan showed that all SnO<sub>2</sub> Nps have a spherical shape. EDX used to evaluate the amount of tin (Sn) and oxygen (O) elements in the structure of the biosynthesized NPs. Then, under direct sunlight, two dangerous organic dyes, namely MB and EBT, were degraded using the biosynthesized SnO<sub>2</sub> NPs as an effective photo catalyst. The results Indicated that synthetic nanoparticles can remove MB and EBT with remarkable efficiency of up to 90% and 83%, respectively. Together, the quick adsorption, good dye degradation, and simple and environmentally friendly synthetic procedure make the biosynthesized SnO<sub>2</sub> nanoparticles ideal for the effective remediation of environmental contaminants[42].

- F.F. Xia, C. Liu, F. Wang, M.H. Wu, J.D. Wang, H.L. Fu, J.X. Wang performed "Preparation and characterization of Nano Ni-TiN coatings deposited by ultrasonic electrodeposition"

By using ultrasonic electrodeposition on the surface of mild steel, nano Ni-TiN coatings were successfully created. X-ray diffraction, high-resolution transmission electron microscopy (HRTEM), atomic force microscopy (AFM), and scanning electron microscopy were used to analyze the coating microstructure (XRD). The AFM results demonstrate that uniform dispersion of TiNPs in the coatings was achieved with mild ultrasonication. The average diameter of Ni grains and TiNPs, according to TEM and XRD data, was about 60 nm and 40 nm, respectively. Ni-TiN nanocoatings increased the substrate's microhardness more than Ni coatings did because TiN particles had a higher microhardness. Because TiN particles reduced interspaces and increased coating density, Ni-TiN Nano coatings demonstrated greater corrosion resistance in tests than Ni coatings[43].

## 2.6 Synthesis of Palladium Nanoparticles

- Ultrasound assisted green synthesis of Urchin like palladium oxide nanoparticles using alginate and its photocatalytic application by Brajesh Kumar, Kumari Smita, Alexis Debut and Luis Cumbal

They produced a quick, effective, high yield, and greener method to create AA-stabilized urchin-shaped PdO-NPs in this work. UV-vis, DLS, TEM, XRD, and FTIR characterization methods were employed to investigate the spectroscopic and microscopic characteristics of produced nanoparticles. While FTIR examination showed the existence of an AA layer around the PdO-NPs, XRD confirmed the FCC structure of the PdO-NPs.

The majority of the PdO-NPs' spherical, urchin-like shape was visible in TEM images, and the particles' sizes ranged from 60 to 70 nm. Under 420 minutes of direct sunshine, PdONPs photo catalytic behavior in the degradation of MB (10 mg/L,  $k_4 = 2.082 \times 10^3 \text{ min}^{-1}$ ) was examined. The photo catalytic performance of PdO-NPs might be further expanded to include the degradation of pharmaceutical waste and pesticides, etc [44].

- Sonochemical in situ immobilization of Pd nanoparticles on green tea extract Coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles: An efficient and magnetically recyclable Nano catalyst for synthesis of biphenyl compounds under ultrasound Irradiations performed by Hojat Veisi, Miladv Ghorbani, Saba Hemmati

In this work, an environmentally acceptable

method for immobilizing Pd nanoparticles on surfaces is described. Fe<sub>3</sub>O<sub>4</sub> nanoparticles were created utilizing ultrasonic irradiation, green tea extract, and no harmful reduction agents. Agents and (ii) the creation of an easy-to-follow process assisted by ultrasound for the synthesis of biphenyl compounds. The developed approach depends on Fe<sub>3</sub>O<sub>4</sub> magnetic NPs coated with a coating of green tea extract for the stability and immobilization of Pd nano-particles (NPs) with the aid of ultrasound. Different analytical methods were used to characterize the produced Pd/Fe<sub>3</sub>O<sub>4</sub> NPs, confirming their effective synthesis. The produced nanocatalyst proved to be efficient in converting aryl halides into the required biphenyl compounds with discernible yields and in a short amount of time when used in a series of ultrasound-assisted Suzuki-Miyaura coupling reactions. The results of this study show that ultrasonication of the reaction mixture can significantly speed up the Suzuki-Miyaura coupling process when magnetic nanoparticles made of Pd/Fe<sub>3</sub>O<sub>4</sub> are present. As a result, the created ultrasound-assisted synthesis technique and the designed catalyst both offered certain benefits, including high efficiency, viability, simplicity, quick reaction times, and a green approach for Using ultrasonic irradiation and Suzuki-Miyaura coupling reactions as Powerful and useful technology[45].

- Controllable synthesis of palladium nanoparticles via a Simple son electrochemical method performed by Xiao-Feng Qiu and Jin-Zhong Xu

In the presence of cetyltrimethylammonium bromide (CTAB) at ambient temperature, extensively distributed spherical palladium particles and a dendritic Pd superstructure were produced using a straightforward pulse son electrochemical method. The results showed that a straightforward son electrochemical approach could successfully alter the form and size of Pd nanoparticles. The effects of various reaction conditions on the size and morphology of Pd nanoparticles were investigated. This technique offers a simple way to create highly distributed and irregularly shaped palladium nanoparticles and superstructures, which makes it rather appealing. The produced Pd nanoparticles could be used in a wide range of processes, particularly catalysis. Other metals and compounds can also be included in the method's application[46].

- Ultrasound-assisted green synthesis of palladium nanoparticles and their nanocatalytic application in multicomponent reaction conducted by Kanchan Mishra, Nagaraj Basavegowda, and Yong Rok Lee

This study describes a novel, environmentally friendly one-pot process for producing palladium

nanoparticles (PdNPs). Without the need of additional surfactants or capping agents, Pd<sup>2+</sup> ions were reduced to Pd<sup>0</sup> using an aqueous extract of *Perillafrutescens* leaves. It is considered that polyphenols and flavonoids actively contribute to the depletion process. The synthetic approach overcome the drawbacks of temperature and pressure conditions and produced highly crystalline materials without the use of any precarious reducing or capping chemicals. UV The bioactive compounds found in the leaf extract are crucial in the reduction of the palladium chloride solution to stabilized palladium nanoparticles, according to visible spectroscopy. The palladium nanoparticles were spherical, measuring 10–17 nm in size with a mean diameter of 13 nm, according to transmission electron microscopy. According to Xray diffraction, the produced palladium nanoparticles were crystalline. The pyrazolyl phosphonate derivatives can potentially be produced using the y generated nanoparticles as catalysts[47].

## 2.7 Synthesis of Organic Intermediate

1. Copper perchlorate hexahydrate was used as an efficient catalyst in the four-component condensation reaction of aldehyde, ethyl acetoacetate, dimedone, and ammonium acetate at room temperature with excellent output and rapid response times when exposed to ultrasound.. This modern synthetic technique is particularly popular because it provides collaboration between copper perchlorate hexahydrate and ultrasound irradiation that provides high yields and quick results.

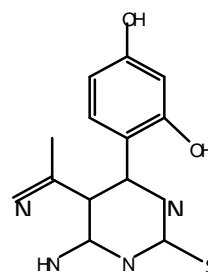
In comparison to the conventional methods Saurabh Puri, Balbir Kaur, Anupama Parmar, and Harish Kumar reported that , the reaction times, simplicity, and ease of workup were improved[48][64].

2. Ganesh N Yallapa, Nagaraja D Chandrashekar U were studied the Green synthesis of pyrazolo[3,4]-pyrimidine -thione using ionic liquids 2-methyl imidazolium oxalate as potent Ehrlich Ascites Carcinoma receptor antagonist.

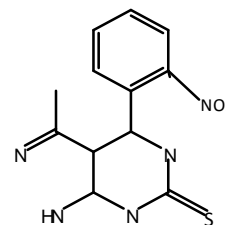
The objective of this study is to synthesis several pyrazole-pyrimidine class derivatives using straightforward procedure and environmentally friendly chemistry. The goal of creating these molecules is to investigate their antitumor activity against the Ehrlich ascites carcinoma (EAC) cell line.

The ultrasonication method completed all reactions in a shorter time (7 minutes). Among the 8 molecules, 8a and 8d finished the reactions the fastest. They reported IC<sub>50</sub> values for all molecules, and 8e and 8g demonstrated excellent strength against EAC cell lines at variety of

concentrations. An ionic liquid, 2-methyl-imidazolium-oxalate, was discovered to be a good catalyst for organic synthesis. Pyrazolopyrimidines have shown to be effective cancer treatment molecules[49].



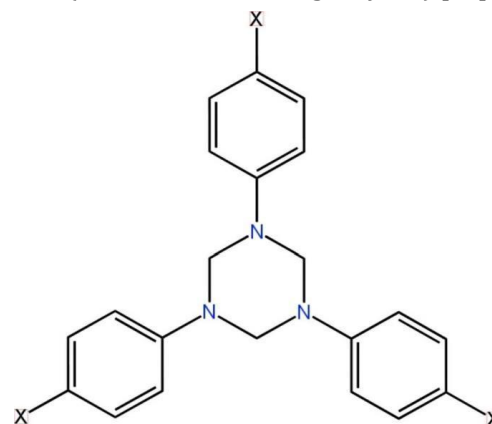
8g [4]



8e [5]

3. Antitumor, antimicrobial, and anti-cancer properties of symmetrizes have been documented by the Ashish K Singh, Sudhish K Shukla ,Mumtaz A Quraishi in the “Ultrasound mediated green synthesis of hexa-hydro triazines”.

They constructed 1,3,5-triaryl-1,3,5-hexahydrotri-azine via ultrasound-assisted reactions of aryl amines with aqueous formaldehyde. They also have come to the conclusion that synthesizing several 1,3,5-Hexahydrotriazine derivatives using ultrasound is an effective, clean, and rapid Process. (Derivatives with a higher yield) [50].



2 a-f [6]

4. Ultrasound Assisted Synthesis of 5-7 Membered Heterocyclic Rings in Organic molecules by the Ghulam Shabir , Imran Shafique, Aamer Saeed

In this article , ultrasound-supported examples. Synthetic procedures using many components in a single pot, as well as flow synthesis in different step ultrasound assisted synthesis has been proved to be an ecofriendly friendly and safe method of synthesis. The synthesis of 5-7 membered heterocyclic rings containing one to three heteroatoms. Moreover Under mild conditions, ultrasound synthesis has provided excellent yield in the major majority of reactions without requiring complicated purification

procedures

The successful one-pot synthesis of multicomponent reactions using ultrasound radiations was accomplished without the separation of intermediates. Most ultrasonication reactions are environmentally friendly and produce high yields in a short period of time. High stereoselectivity and isomeric purity were obtained without using complicated chromatographic separations. However, there is still a lot of work to do in terms of identifying and developing novel pharmacologically active compounds, broadening the scope of ultrasonication approaches, overcoming the challenges of assembling huge rings, and generating new heterocycles[51].

5. Avoiding the use of potentially harmful chemicals and solvents, the reaction of 3-acetylcoumarins with substituted aromatic aldehyde in the presence of potassium Hydroxide and dual frequency ultrasonic irradiation has been developed to produce Highly effective and environmentally friendly 3-acetylcoumarin chalcones. The synthesized compound characterized by Melting points, FTIR, and <sup>1</sup>H NMR spectra were used to recognize the compounds.

S.P. Sharma, Neeraj Vashisht, Surender Kumar and Kritika were independently conducted reactions using an ultrasonic bath and probe as well, but the results in terms of reaction time and yield were not encouraging. Compared to current methods, the sonochemical approach has a number of benefits, including higher yield, clean reaction, and convenience. It effective and environmental friendly process for obtaining coumarinyl chalcones[52].

6. Ultrasonic Irradiation: Synthesis, Characterization, and Preliminary Antimicrobial Activity of novel series of 4,6-Disubstituted-1,3,5-triazine Containing Hydrazone Derivatives

Hessa H. Al-Rasheed, Monirah Al Alshaikh, Jamal M. Khaled, Naiyf S. Alharbi, and Ayman Eel-Faham synthesized a unique series of 4,6-disubstituted-1,3,5-triazines, including hydrazone derivatives, using standard heating technique and ultrasonic irradiation. Ultrasonication produced the desired products more quickly and with increased output and purity .Only two compounds, 7i (pyridine derivative) and 7k (4-chlorobenzaldehyde Derivative), had biological activities against some Gram-positive and Gram-Negative bacteria, according to the biological activity for the produced compounds, Whereas none of the tested compounds showed any antifungal activity. It is obvious that altering either the benzylidene

moiety or the s-triazine ring substituent could have an impact on the antibacterial activity[53].

7. An Ultrasound Mediated Green Synthesis of Benzimidazolyl thiounsaturatednitriles Using Water as A Green Solvent Performed by Chittireddy Venkata Ramana Reddy, and Pramod Kumar Dubey , Sadhu Srinivas Rao.

It is an effective and straightforward process that is environmentally sustainable to react 2cyanothiomethylbenzimidazole 1, an aromatic aldehyde, and 10–13 minutes of ultrasonic irradiation on water to produce the corresponding unsaturated nitriles 2a–h. Without any laborious workup methods, the unsaturated nitrile compounds produced at a yield of 86–98% in a short reaction time[54].

8. Green Chemistry Approach for Synthesis of 2,3-diphenyl quinoxaline carried out by Pranita Mahadik,Devaanshi Jagwani And Rupen Joshi

The goal of this study is to present a green method of 2,3-diphenyl quinoxaline synthesis. For the synthesis of 2,3-diphenyl quinoxaline, ultrasonicwave technique is preferable to conventional methods due to faster reaction durations(8min to 20min), refraining from using organic solvents, cleaner reactions, ease of work up, and minimizing of waste products., and reactions may be performed with a better yield(94 – 97%), and milder circumstances, without creating any pollution, and they are also safer for the analyst .

They also noted that synthesizing a greater number of organic heterocyclic compounds using ultrasonication is a green chemistry perspective. As a outcome , it is an effective and practical approach for producing drugs, intermediates, and compounds[55].

9. Ultrasound Promoted Synthesis Of Indole appended Heterocycles Performed by Anna Pratima G. Nikalje, Sameer I. Shaikh .

By using ultrasonic irradiation, indole linked heterocycles with a variety of pharmacological properties can be synthesized. By using novel methods from the field of green chemistry, reactions of indole-appended heterocycles can be changed. When compared to traditional methods, the key benefits of using ultrasound in the formation of different indole derivatives are transparent: shorter reaction times and higher yields. [56].

10. Ultrasonication-Induced Synthesis and Antimicrobial Evaluation of Some multifluorinated pyrazolone derivatives by Shashikant Kuchekar, Anil Gadhave, and Bhausahab Karale. Both traditional heating methods and the ultrasonic irradiation approach were used to synthesizing

each chemical. It was explored that the ultrasonication technique was more effective than traditional heating techniques. IR was used to characterise each molecule that was produced mass, elemental, and H-NMR analyses. Short reaction times, excellent yields, and a clean reaction process made the ultrasonication approach more effective. Antimicrobial activity data indicates that some Promising action was shown by some of the synthesized substances against the tested fungi and bacterial strains[57].

11. Synthesis Of Benzothiazole derivatives using ultrasonicprobe irradiation an effective and environmentally friendly technique for producing benzothiazole derivatives using ultrasonic probe irradiation is described by Su-Yin Kan , Wei SernYiong , Fu Siong Julius Yong , Poh Wai. Chia.They demonstrated a straightforward and effective procedure for synthesizing benzothiazole derivatives while being introduced to ultrasonic probe radiation. The main benefits of this method include quick reaction times, catalyst- and solvent-free conditions, and the moderate to good output (65-83%) for the finished products. Compounds (4a-4i) were synthesized in 20 minutes at room temperature[58].

12. Ultrasound Assisted Synthesis of4-(Benzyloxy)-N-(3-chloro-2-(substitutedphenyl)-4oxoazetid-1-yl) Benzamide as Challenging Anti-Tubercular Scaffold performed by Urja D. Nimbalkar, Rachna Borkute, Anna Pratima G. Nikalje, Manoj G. Damale, Jaiprakash N. Sangshetti, Dhiman Sarkar and Julio A. Seijas.

Ten novel derivatives in a series of 4-(benzyloxy)-N-(3-chloro-2-(substitutedphenyl)-4oxoazetid-1-yl) benzamide 6a-j have been synthesized in precise yield from the important thing compound4-(benzyloxy)-N-(substitutedbenzylidene) benzo hydrazide, known as Schiff's bases 5a-j, through Staudinger reaction [(2 + 2) ketene-imine cycloaddition reaction) with chloro acetyl chloride in the existence of catalyst triethylamine and solvent dimethyl formamide (DMF), via way of means of the usage of ultra-sonication as one of the green chemistry tools. The conclusion of the laboratory tests for anti-tubercular activity were reinforced by the computational molecular docking analysis, which showed that the synthesized derivatives 6a, 6e, and 6g are the most active and have the ability to be anti-mycobacterial. With an IC50 of 0.652 g/mL against *Mycobacterium tuberculosis* H37Ra (ATCC 25177) strains, compound 6a was shown in-vitro anti tubular activity improving rapidly. This was further demonstrated by the docking score of 8.647, which indicates that it inhibits the enzyme InhA (Fabi/ENR). With an IC50 of 0.654 g/mL and a docking score of 8.6156, compound 6e inhibits

the enzyme InhA (Fabi/ENR), which has shown to have significant in vitro anti-tubercular action. With an IC50 of 0.718 g/mL and a docking score of 8.476 for the enzyme InhA (Fabi/ENR), compound 6g also demonstrated substantial in vitro anti-tubercular activity.

In the inference, compounds 6a, 6e, and 6g have anti-tubercular action at 50% inhibitory concentration (IC50) in addition to having good docking scores. When compared to the standard drug Rifampicin, these compounds were found to be the active moiety with powerful antitubercular effect. The drug's pharmacokinetics and a possible pharmacophore for future drug development is provided by the features of the synthesized derivative process[7].

13. Ultrasound-assisted green synthesis of five-membered O- and S-heterocycles performed by Navjeet Kaur

This review provides the use of ultrasound in synthesizing several heterocyclic compounds. Many organic syntheses have been thought to be effective when using ultrasonic irradiation as a technique.

A practical and effective catalyst-free course for the formation of five-membered O- and S-heterocycles under ultrasonic irradiation was reported in the article. Most of the treatments covered in this review use basic ultrasonic cleaning baths as their energy source. These low power ultrasonic radiation sources usually require longer reaction times and are less effective than immersion sonication probes. However, these cleaning treatments are reasonably priced and easily accessible in chemistry labs[59].

14. Green synthesis of 3-(1-naphthyl), 4-methyl-3-(1-naphthyl) coumarins and 3phenylcoumarins using dual-frequency ultrasonication conducted by Neeraj Vashisth , Satya Parkash Sharma, Surender Kumar, and Aruna Yadav . A one-step green synthesis of 3-(1naphthyl), 4-methyl-3-(1-naphthyl), and 3-phenylcoumarins was obtained by reacting 2hydroxybenzaldehyde with2-hydroxyacetophenones and hydres with 1-naphthylacetic Phenyl acetic anhydride and anhydride, respectively, Dual-frequency ultrasound, often known as an ultrasonic bath of 20 kHz and a 40 kHz probe.

Only One purification was achieved as a outcome of the combined use of a 20 kHz probe and a 40 kHz ultrasonic bath due to their synergistic effects. Step, speeded up the reaction process, and improved yields. It is Clearly proven that quick coumarin synthesis Is one of the potential uses for this technique[60].

15. Ultrasound Mediated Green Synthesis of

Rhodanine Derivatives: Synthesis, Chemical Behavior and Antibacterial Activity by the Wael A. A. Arafa, Mervat F. Fareed, Saleh A. Rabeh & Raafat M. Shaker

A three-component synthesis involving carbon disulfide, amines, and dialkylacetylene dicarboxylate in polyethylene glycol with standard stirring and ultrasound irradiation was used to create a range of rhodanine derivatives.

The environmentally friendly, ultrasound-assisted reactions used to create a variety of functionalized rhodanine compounds have many benefits, including rapid reaction times, operational simplicity, non-toxicity, simple experimental set-up, and great yields. In vitro bactericidal action of produced compounds against the tested species showed promise. The conclusion that the hybrid compounds with hydroxyl groups or halo atoms play a significant role and may be advantageous to boost the effectiveness against both Gram-positive strain and Gram-negative [61].

16. Ultrasound promoted synthesis of N-(substituted phenyl)-2-(7-hydroxy-4-methyl-2H-chromen-2-ylidene)hydrazine-1-carboxamides as cytotoxic and antioxidant agents performed by Amena Ali, Abuzer Ali, Mohammed Afroz Bakht, Mohamed Jawed Ahsand

In two phases, new N-(substituted phenyl)-2-(7-hydroxy-4-methyl-2H-chromen-2-ylidene)hydrazine-1-carboxamides (5a-l) were created using ecologically friendly ultrasonic irradiation. For the synthesis of coumarin-based hydrazine carboxamides, an ultrasound-promoted synthetic approach with high conversion and rapid response is used (5a-l). The cytotoxic activity of the prepared molecules was assessed using nine distinct panels of a total of 60 NCI cancer cell lines. The compounds 5b and 5d demonstrated equal cytotoxicity and comparable interactions with the active site of FGFR4, suggesting a potential mechanism of cytotoxicity. The compound 5b showed the highest sensitivity against CCRFCM (leukemia).

Additionally, both compounds (5b and 5d) showed potential antioxidant activity [62].

17. Ultrasound Assisted Preparation, Characterization and Adsorption Study of Ternary Chitosan/ZnO-TiO<sub>2</sub> Nanocomposite: Advantage over conventional Method conducted by S.H. Sonawane, B.A. Bhanvase, A. Veer, S.R. Shirsath

The mechanical stirring (traditional) and ultrasonic assisted technique tools were employed to create the ternary chitosan/zinc oxide/titanium dioxide (CTS-ZnO-TiO<sub>2</sub>) nanocomposite. XRD, TEM, and FTIR were applied to demonstrate the CTS-ZnO-TiO<sub>2</sub> adsorbent that had been synthesized, and the results of these analyses

demonstrated that the ternary nanocomposite had been successfully prepared. When testing the created nanocomposite's ability to absorb crystal violet (CV) dye as a pollutant, it was established that the nanocomposite made with ultrasonic assistance was more effective. For the CTS-ZnO-TiO<sub>2</sub> nanocomposite made using ultrasound-assisted synthesis, the CV dye adsorption was considerable. An increase in temperature led to an increase in adsorption capacity. Around 80% removal of crystal violet was seen at 25°C for an initial CV concentration of 50 mg/L using a 1 g/L nanocomposite made using an ultrasonic technique [63].

18. Green synthesis of biocompatible chitosan-graphene oxide hybrid nanosheet by ultrasonication method performed by Yanzhe Gai, Wucong Wang, Jingfu Jia, Yaping Zhao

The chitosan modified graphene oxidation (CS-NGO) hybrid nanosheet has been made initially without a catalyst employing ultrasonication in SCCO<sub>2</sub>. By using FTIR, SEM, TEM, XPS, and TGA to analyze the characteristics and structure of the CS-NGO, it was compared to the CSNGO produced in water with a catalyst. It was determined that the NGO and chitosan had established an amide bond. When the ratio of chitosan to NGO in the raw materials was 2:1 and the ultrasonication period was 6 hours, the highest conversion rate was attained. However, there is still room to improve conversion rate. For the amidation reaction to be induced, more than 360 W was required. In comparison, the CSNGO demonstrated greater stability in physiological and acidic aqueous solutions [64].

19. Ultrasound promoted efficient and green synthesis of  $\beta$ -amino carbonyl compounds in aqueous hydrotropic medium conducted by Santosh Kamble, Arjun Kumbhar, Gajanan Rashinkar, Madhuri Barge, Rajashri Salunkhe

The synthetic intermediates known as  $\beta$ -amino carbonyl compounds are useful for both pharmaceutical and natural product production. A number of techniques have been described by Gajanan Rashinkar, Santosh Kamble, Rajashri Salunkhe, Arjun Kumbhar, Madhuri Barge, the literature for the synthesis of  $\beta$ -amino carbonyl compounds due to their significance as essential building blocks for the preparation of 1,3-amino alcohols,  $\beta$ -amino acids, as well as for the synthesis of various bioactive molecules, including the antibiotic nikkomycins and neopolyoxines

The synthesis of  $\beta$ -amino carbonyl compounds in aqueous hydrotropic solution under ultrasonic irradiation is described using a basic, effective, and environmentally friendly technique. Efficiency, high yield, rapid reaction times,

generality, minimal costs, environmentally friendly reaction profiles, simplicity of product segregation, and the utilization of alternative energy sources are major characteristics of technique[65].

20. Synthesis of Pyrazole Compounds by Using Sonication Method performed by Prashant

Ganpatrao KUMDALE and Nana Vikram Shitole Sonication is a simple procedure for cyclizing cyanide with hydrazine hydrate to produce pyrazoles derivatives.  $^1\text{H}$ ,  $^{13}\text{C}$  NMR, as well as IR Spectroscopy were used to characterize all the produced compounds. An effective technique, such as a quick, easy, and practical synthesis of pyrazole compounds employing the sonication method. The method is advantageous for the synthesis of pyrazole derivatives because it has various benefits, including an increase in product yield, the use of a cheap starting material, and a simple experimental workup methodology[66].

21. Some Applications of Ultrasound Irradiation in Organic Synthesis presented by Ji-Tai Li, ShuXiang Wang, Guo-Feng Chen and Tong-Shuang Li

Ultrasound has a wide range of chemical effects, including significant enhancements in both stoichiometric and catalytic chemical procedure. Ultrasonic irradiation can boost reactivities by over a million fold in some circumstances. The chemical effects of ultrasound are categorized into homogeneous liquid sonochemistry and heterogeneous liquid-liquid or liquid-solid systems.

In this paper reviewed some recent applications of ultrasound in organic synthesis, including the Knoevenagel condensation, Biginelli reaction, Michael addition, Pinacol coupling reaction, Claisen-Schmidt condensation, Bucherer-Bergs reaction.

Employing ultrasound in organic syntheses, which can increase yield, change harsh reaction conditions to milder ones, improve selectivity, and most of all it can make the reactions that do not proceed under normal conditions occur smoothly[67].

22. Ultrasonic Studies of  $\text{Nd}^{3+}$ : L-Tryptophan Amino Acid Complexes performed by M. Kiran Kumar, P. Sreeram Naik, Y.N.Ch Ravi Babu and A. Suresh Kumar

They were investigate the ultrasonic characteristics of L-tryptophan amino acid complexes doped in aqueous solutions with various concentrations of  $\text{Nd}^{3+}$  (0.1, 0.25, 0.5, 1.0, and 2.0 mol%). All of the complexes under examination had their density and ultrasonic velocities measured experimentally. The resulting data was utilized to derive ultrasonic

characteristic factors such as velocity ( $u$ ), isothermal compressibility ( $T$ ), free length ( $L_f$ ), isentropic compressibility ( $K_S$ ), thermal expansion coefficient ( $\alpha$ ) and others. All of these complexes have the same acoustic impedance ( $Z$ ). The ultrasonic velocity measuring technique appears to serve an important and simple role in illuminating specific physical and chemical features of various solution media[68].

23. A green one-pot three-component synthesis of tetrahydrobenzo [b]pyran and 3,4-dihydropyrano[c]chromene derivatives using  $\text{Fe}_3\text{O}_4/\text{SiO}_2$ -imid-PMAN Magnetic nanocatalyst under ultrasonic Irradiation or reflux conditions presented by

Mohsen Esmaeil pour, Jaber Javidi, Farzaneh Dehghania and Fatemeh Nowroozi Dodeji A one-pot, three-component synthesis involving a range of aldehydes, malononitrile, and dimedone or hydroxycoumarin can now be used to effectively and environmentally friendly produce tetrahydrobenzo[b]pyran and 3,4-dihydropyrano[c]chromene derivatives. Nanoparticles function as magnetic catalysts when exposed to ultrasonic radiation or water reflux.

This method offers significant benefits including simple and direct preparation, heterogeneous nature, thermal consistency and ease of isolation of the catalyst, clean and simple technique, good yields, quick reaction time, ease of product separation and purification, lower catalyst loading compared to different techniques, and dening of the use of potentially harmful organic solvents, which makes this method a valuable substitute to the prior methodologies for the scaling up of these one. Additionally, the catalyst can be extracted magnetically, which eliminates the need for catalyst filtration after the reaction is complete. From an economic and environmental standpoint, this is a significant advantage for reactions. The catalyst can also be accessed easily and reused after being used at least eight times with the help of a permanent magnet [69].

24. Green synthesis of metals and their oxides nanoparticles is a highly attractive research area. Here The Jagpreet Singh Tanushree Datta, explored the fundamental process and mechanisms of green synthesis approaches for metal and metal oxides nanoparticles using natural extract. They covered application of such synthesized products to environmental remediation in terms of antimicrobial, catalytic activity, removal of pollutants dyes and heavy metal ion sensing[70].
25. Ultrasound-assisted green synthesis of nanocrystalline ZnO in the ionic liquid [hmim][NTf2] conducted by Elaheh K. Goharshadi,

Yulong Ding, Majid Namayandeh Jorabchi, Paul Nancarrow

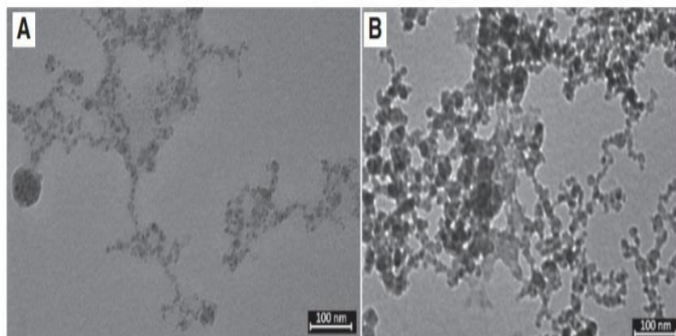
The synthesis of ZnO NPs employing the sonochemical approach in an anionic liquid, 1-hexyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide, as a solvent, has been simplified and made more widely applicable. By using XRD, SEM, and TEM, the structure and morphology of the produced ZnO nanoparticles have been identified. A potential process has been given up to demonstrate how ZnO nanostructures develop. Our technique combines the benefits of RTIL with ultrasonic technology. It might be a universal strategy for producing high yields of ZnO nanoparticles. More significantly, our approach is highly efficient for producing nanoparticles in a green media[71].

## 2.8 Synthesis of Copper Nanoparticles

1. Green synthesis of copper nanoparticles with ultrasound assistance performed by

Pietro Giovanni Cerchier, Manuele Dabalà and Katya Brunelli

An analysis into the use of green reagents and ultrasound to create metallic copper (Cu) nanoparticles is described. This study's raw material, copper, was recovered from the pretreatment of electronic circuit boards. L-ascorbic acid and sodium borohydride were act as reducing agents, and various process factors, including the impact of ultrasound, reducing agents, and capping agents analyzed. In order to increase the synthesis of the nanoparticles, ultrasonic technology proved to be essential. Particularly, ultrasound allowed the production of nanoparticles with a mean size of about 5 nm, whereas without it the procedure would have taken several hours and the final powder obtained would have had a mean size of 1 m.



**Figure 8: Tem Bright Field Images of the Powder Obtained (A) With Ultrasound (B) Without Ultrasound Using A L-Ascorbic Acid As A Reducing Agent**

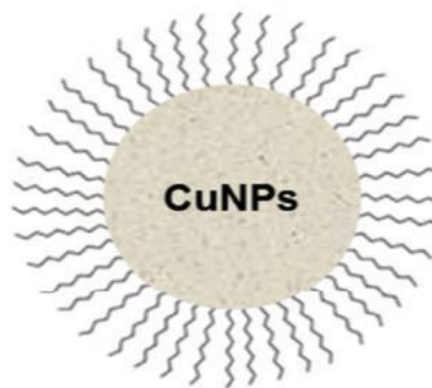
The use of ultrasound showed out to be essential for boosting nanoparticle production. The reaction

took many hours and the final powder formed had a mean size of 1 mm without ultrasound, however with ultrasound, nanoparticles with a mean size of roughly 5 nm were produced. Additionally, the production of copper nanoparticles with a size comparable to those made using sodium borohydride was made possible by using the L-ascorbic acid as a reducing agent and ultrasound[72].

2. Green synthesis and characterization of copper nanoparticles using *Piper retrofractum Vahl* extract as bioreductor and capping agent presented by Akhmad Sabarudin, Dwika Putri Pangesti, Masruri Masruri, Suci Amaliyah, Sutiman Bambang Sumitro

Copper nanoparticles (CuNPs) have received a lot of focus due to their variety of applications. CuNPs uses are determined by their physicochemical characteristics. This is the first report on the use of *Piper retrofractum Vahl* medicinal fruit extract as an environmental reagent in the production of CuNPs utilizing copper sulphate as a precursor. *Piper retrofractum Vahl* extract was utilised in the synthesis of copper oxide nanoparticles as a bioreductor and a capping agent. sonication and agitation aided the reaction process.

Copper nanoparticles (CuNPs) were effectively manufactured utilizing *Piper retrofractum* extract using a green production process. The stirring approach yields more uniformly sized CuNPs than the sonication procedure. Under optimal conditions, the produced CuNPs are spherical with particle size about 2 to 10 nm, stable in particular solvents, and exhibit antibacterial activity[73].



**Figure 9: Capped Cunps**

1. Synthesis of chitosan capped copper oxide Nano leaves using high Intensity (30 kHz) ultrasound sonication and their application in Antifouling coatings proposed that Tamilselvan Abiraman , Ethirajan Ramanathan , Ganapathy Kavitha, Ramasamy Rengasamy, Sengottuvelan Balasubramanian

In order to create chitosan-capped copper oxide

nanoleaves (CCCO NLs), three distinct reaction conditions were examined, including room temperature, 70 C, and high intensity ultrasound (30 kHz) sonication. It was discovered that the high intensity ultrasound (30 kHz) sonication method performed the best among the three. The current synthetic approach has the following benefits:

- a) a straightforward one-step process; b) a shorter reaction time; c) a good yield; d) reproducibility; and e) the absence of calcination. The product produced at 70 degrees Celsius displays the formation of larger micro-sized particles, which is recognized by XRD, FESEM, and HRTEM analysis. The product produced at room temperature did not demonstrate the formation of copper oxide nanoparticles. Only 30 kHz high intensity ultrasonography was used to acquire the CCCO NLs, and calcination was not performed. In order to coat the surfaces of three distinct panels, the CCCO NLs were combined with commercial paints (Poly urethane clear, Poly urethane white, and Acrylic emulsion) (wood, mild steel and cement slab). The generated CCCO nanopaint coatings have a strong antifouling impact (78-92%) against the adherence of microalgae in freshwater (*Arthrospira* and *Chlorella*) and marine environments (*Amphora*) without being leached out[18].
2. Biosynthesis of copper oxide nanoparticles using biomass, peel, and extract Polysaccharides of *Solanum tuberosum* for ultrasound-assisted adsorption of Azo direct red 80 contaminants performed by Zahra Hamami, Vahid Javanbakht. Recent scientific research has focused heavily on the bio-fabrication of nanomaterials utilizing plant polysaccharides due to its low cost and straightforward process.

Adsorption and ultrasonic-assisted adsorption processes are used to remove azo direct red 80 contaminants from aqueous solution. This is done by greenly synthesizing copper oxide nanoparticles. As environmentally acceptable stabilizing agents, *Solanum tuberosum*'s biomass, peel, and extract were used to create nanoparticles. using copper Oxide nanoparticles are biofabricated as adsorbents to remove azo remove aqueous solution's red 80 impurities by adsorption and methods for adsorption with ultrasonic aid. FESEM, XRD, and BET analyses were applying to characterize the copper nanoparticles, and the disc diffraction method was used to determine the produced CuO nanoparticles antibacterial properties using gram-negative bacteria. *Pseudomonas* and gram-positive syringe *Staphylococcus aureus*, the findings indicated. Highly effective against germs. In comparison to nanoparticles made from

*Solanum tuberosum* biomass and extract, CuO nanoparticles biosynthesized from peel extract show better structural characteristics. The Dye has adsorption capabilities of 13.09 and 14.07 mg/g. Adsorption and ultrasonic-assisted adsorption are two methods for elimination. Adsorption proceeded in a pseudo-second-order kinetic approach. Additionally recognized were the model and intraparticle diffusion's contribution. The nanoparticles' capacity for adsorption in adsorption and For binary dye, ultrasonic- assisted adsorption techniques were evaluated. Even after a fourth successive cycle of regeneration and reuse, the CuO nanoparticle has demonstrated its strong regeneration capabilities. The results shown here are encouraging for the actual application of environmental dye solutions on a big scale. In the result, the removal of dyes by the environmentally friendly CuO nanoparticles offers an alternative to better wastewater treatment, being profitable and working with the environment[74].

### Results:

Ultrasonication is a science of sound waves above the audible range of human beings (20100kHz). Beyond this range the mechanical vibration are observed, called ultrasonic. An acoustic wave with a frequency greater than 10 kHz is referred to as an ultrasound for convenience. Ultrasonication is the technique of breaking particles through cavitation by applying high frequency sound energy. Numerous small gas bubbles develop when a liquid, (such as water), is subjected to strong ultrasound radiation. Instantaneous local pressure in the liquid turns negative during the rarefaction phase of the ultrasonic wave. Only liquids or solids and impossible gases are capable of creating negative pressure. This force causes a liquid (or solid) element to expand. Gases can no longer be dissolved in liquid at the negative pressure; as a result, gases dissolved in liquid appear as gas bubbles.

In the food industry, ultrasound has a wide range of uses, including processing, extraction, emulsification, preservation, homogenization, etc. Green and pharmaceutical chemistry are very interested in the use of ultrasonic waves as an alternative energy source.

In terms of time, pressure, and energy per molecule, ultrasound irradiation is different from conventional energy sources (such as heat, light, or ionizing radiation). The interaction of matter and energy can be studied using ultrasound, which is a special technology. Through the formation and subsequent dissolution of cavitations bubbles, ultrasound accelerates chemical and physical processes in a liquid medium.

The different nanoparticles and organic intermediates synthesized by Ultrasonication. The activity of the above mentioned medicinal compounds are reviewed.

### Acknowledgment:

The authors thanks for their help in reviewing this manuscript.

## REFERENCES

1. O. V. Kharissova, B. I. Kharisov, C. M. O. González, Y. P. Méndez, and I. López, Greener synthesis of chemical compounds and materials, vol. 6, no. 11. 2019. doi: 10.1098/rsos.191378.

2. M. Draye, G. Chatel, and R. Duwald, "Ultrasound for drug synthesis: A green approach," Pharmaceuticals, vol. 13, no. 2, 2020, doi: 10.3390/ph13020023.

3. S. S. Gujral, M. A. Sheela, S. Khatri, and R. K Singla, "A Focus & Review on the Advancement of Green Chemistry," Indo Glob. J. Pharm. Sci., vol. 02, no. 04, pp. 397–408, 2012, doi: 10.35652/igjps.2012.46.

4. P. J. Dunn, A. S. Wells, and M. T. Williams, Asymmetric Catalysis on Industrial Scale Green Chemistry and Catalysis Handbook of Green Chemistry – Green Catalysis Microwaves in Organic Synthesis Handbook of Green Chemistry – Green Solvents Supercritical Carbon Dioxide Solvent-free Organic Synthesis. 2010.

5. P. Kumar Assistant Professor, S. Sharma Associate Professor, C. Pradeep Kumar

Assistant Professor, P. Kumar, and S. Sharma, "Enzymes in green chemistry: The need for environment and sustainability," vol. 2, no. 6, pp. 337–341, 2016, [Online]. Available: [www.allresearchjournal.com](http://www.allresearchjournal.com)

6. H. Duan, D. Wang, and Y. Li, "Green chemistry for nanoparticle synthesis," Chem. Soc. Rev., vol. 44, no. 16, pp. 5778–5792, 2015, doi: 10.1039/c4cs00363b.

7. U. D. Nimbalkar et al., "Ultrasound assisted synthesis of 4-(Benzyloxy)-N-(3-chloro-2(substitutedphenyl)-4-oxoazetid-1-yl) benzamide as challenging anti-tubercular scaffold," Molecules, vol. 23, no. 8, pp. 1–19, 2018, doi: 10.3390/molecules23081945.

8. A. Irvani, M. H. akbari, and M. Zohoori, "Advantages and Disadvantages of Green Technology; Goals, Challenges and Strengths," Int. J. Sci. Eng. Appl., vol. 6, no. 9, pp. 272–284, 2017, doi: 10.7753/ijsea0609.1005.

9. Robert Thornton morrison, Organic Chemistry, 7th ed. Pearson.

10. David j c constable, Green Chemistry and engineering. A John wiley, 2011.

11. A. A. Atchley and L. A. Crum, Acoustic cavitation and bubble dynamics. 1985.

12. A. R. S. Al-hilphy, D. K. Verma, and A. K. Niamah, "Technology for Treatment," no. March, 2016.

13. L. T. G, "The Acoustic Bubble," 1994.

14. H. M. Elmehdi, J. H. Page, and M. G. Scanlon, "Using ultrasound to investigate the cellular structure of bread crumb," J. Cereal Sci., vol. 38, no. 1, pp. 33–42, 2003, doi: 10.1016/S0733-5210(03)00002-X.

15. K. S. Suslick, S. J. Doktycz, and E. B. Flint, "On the origin of sonoluminescence and sonochemistry," Ultrasonics, vol. 28, no. 5, pp. 280–290, 1990, doi: 10.1016/0041624X(90)90033-K.

16. S. H. Cho, J. Y. Kim, J. H. Chun, and J. D. Kim, "Ultrasonic formation of nanobubbles and their zeta-potentials in aqueous electrolyte and surfactant solutions," Colloids Surfaces A Physicochem. Eng. Asp., vol. 269, no. 1–3, pp. 28–34, 2005, doi: 10.1016/j.colsurfa.2005.06.063.

17. V. Popov, I. Hinkov, S. Diankov, M. Karsheva, and Y. Handzhiyski, "Ultrasoundassisted green synthesis of silver nanoparticles and their incorporation in antibacterial cellulose packaging," Green Process. Synth., vol. 4, no. 2, pp. 125–131, 2015, doi: 10.1515/gps-2014-0085.

18. S. Amaliyah, M. Masruri, A. Sabarudin, and S. B. Sumitro, "Sonication-assisted green synthesis of silver nanoparticles using Piper retrofractum fruit extract and their antimicrobial assay," AIP Conf. Proc., vol. 2349, no. June, 2021, doi: 10.1063/5.0051539.

19. T. Mokhena, M. Mochane, M. Tshwafo, L. Liganiso, O. Thekiso, and S. Songca, "We are IntechOpen , the world ' s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %," Intech, pp. 225–240, 2016, [Online]. Available: <https://www.intechopen.com/books/advanced-biometric-technologies/livenessdetection-in-biometrics>

20. A. Nouri, M. Tavakkoli Yaraki, A. Lajevardi, Z. Rezaei, M. Ghorbanpour, and M. Tanzifi, "Ultrasonic-assisted green synthesis of silver nanoparticles using *Mentha aquatica* leaf extract for enhanced antibacterial properties and catalytic activity," *Colloids Interface Sci. Commun.*, vol. 35, no. February, p. 100252, 2020, doi: 10.1016/j.colcom.2020.100252.

21. B. Kumar, K. Smita, L. Cumbal, A. Debut, and R. N. Pathak, "Sonochemical synthesis of silver nanoparticles using starch: A comparison," *Bioinorg. Chem. Appl.*, vol. 2014, 2014, doi: 10.1155/2014/784268.

22. R. F. Elsupikhe, K. Shameli, M. B. Ahmad, N. A. Ibrahim, and N. Zainudin, "Green sonochemical synthesis of silver nanoparticles at varying concentrations of  $\kappa$ carrageenan," *Nanoscale Res. Lett.*, vol. 10, no. 1, pp. 1–8, 2015, doi: 10.1186/s11671015-0916-1.

23. V. Sekar et al., "Ultra-sonication-enhanced green synthesis of silver nanoparticles using *Barleria buxifolia* leaf extract and their possible application," *Artif. Cells, Nanomedicine Biotechnol.*, vol. 50, no. 1, pp. 177–187, 2022, doi: 10.1080/21691401.2022.2084100.

24. G. Yaku, V. Venkateswerlu, and T. P. Rao, "Green Synthesis of Silver Nanoparticles by Sonicated Method Using *Pulicha Indeca* Stem Extract: Characterization and Study of Antibacterial Activity, Anticancer Activity and Cell Viability Test," *Orient. J. Chem.*, vol. 35, no. 6, pp. 1767–1773, 2019, doi: 10.13005/ojc/350620.

25. A. R. Deshmukh, A. Gupta, and B. S. Kim, "Ultrasound Assisted Green Synthesis of Silver and Iron Oxide Nanoparticles Using Fenugreek Seed Extract and Their Enhanced Antibacterial and Antioxidant Activities," *Biomed Res. Int.*, vol. 2019, no. April, 2019, doi: 10.1155/2019/1714358.

26. V. S. Mănoiu and A. Aloman, "Obtaining silver nanoparticles by sonochemical methods," *UPB Sci. Bull. Ser. B Chem. Mater. Sci.*, vol. 72, no. 2, pp. 179–186, 2010.

27. E.-P. N. and M.-Y. C. Fitri Khoerunnisa, Mita Nurhayati, Firdha Zahra, Muhamad Nasir, Yustika Desti Yolanda, Pakorn Opaprakasit, "11. Ultrasonic Synthesis of Nanochitosan and Its Size Effects on Turbidity Removal and Dealkalization in Wastewater Treatment".

28. J. H. Lee, S. U. S. Choi, S. P. Jang, and S. Y. Lee, "Production of aqueous spherical gold nanoparticles using conventional ultrasonic bath," *Nanoscale Res. Lett.*, vol. 7, pp. 1–7, 2012, doi: 10.1186/1556-276X-7-420.

29. J. E. Park, M. Atobe, and T. Fuchigami, "Synthesis of multiple shapes of gold nanoparticles with controlled sizes in aqueous solution using ultrasound," *Ultrason. Sonochem.*, vol. 13, no. 3, pp. 237–241, 2006, doi: 10.1016/j.ultsonch.2005.04.003.

30. G. R. Kiani, "International Journal of Nano Dimension Synthesis of gold nanoparticles: a new approach in using a nanoporous membrane in conjunction with ultrasonication," vol. 1, no. 4, pp. 275–278, 2011.

31. M. A. Dheyab, A. A. Aziz, M. S. Jameel, P. M. Khaniabadi, and A. A. Oglat, "Rapid sonochemically-assisted synthesis of highly stable gold nanoparticles as computed tomography contrast agents," *Appl. Sci.*, vol. 10, no. 20, pp. 1–14, 2020, doi: 10.3390/app10207020.

32. F. Takahashi, N. Yamamoto, M. Todoriki, and J. Jin, "Sonochemical preparation of gold nanoparticles for sensitive colorimetric determination of nereistoxin insecticides in environmental samples," *Talanta*, vol. 188, no. April, pp. 651–657, 2018, doi: 10.1016/j.talanta.2018.06.042.

33. K. Okitsu, M. Ashokkumar, and F. Grieser, "Sonochemical synthesis of gold nanoparticles: Effects of ultrasound frequency," *J. Phys. Chem. B*, vol. 109, no. 44, pp. 20673–20675, 2005, doi: 10.1021/jp0549374.

34. C. G. Yuan, C. Huo, B. Gui, and W. P. Cao, "Green synthesis of gold nanoparticles using *Citrus maxima* peel extract and their catalytic/antibacterial activities," *IET Nanobiotechnology*, vol. 11, no. 5, pp. 523–530, 2017, doi: 10.1049/iet-nbt.2016.0183.

35. C. Kan, W. Cai, C. Li, L. Zhang, and H. Hofmeister, "Ultrasonic synthesis and optical properties of Au/Pd bimetallic nanoparticles in ethylene glycol," *J. Phys. D. Appl. Phys.*, vol. 36, no. 13, pp. 1609–1614, 2003, doi: 10.1088/0022-3727/36/13/328.

36. K. Nisyak, Y. A. Prasetya, A. Hisbiyah, E. D. Iftitah, and A. Srihardyastutie, "Synthesis of ZnO-Ag with Clove Oil Using Ultrasonication Method and Its Antibiofilm Activity Against *Klebsiella pneumoniae*," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 833, no. 1, 2020, doi: 10.1088/1757-899X/833/1/012081.

37. T. Shaikh, A. Sharma, and H. Kaur, "Ultrasonication-Assisted Synthesis of 3-Substituted Indoles in Water Using Polymer Grafted ZnO Nanoparticles as Eco-Friendly Catalyst," *ChemistrySelect*, vol. 4, no. 1, pp. 245–249, 2019, doi: 10.1002/slct.201802702.

38. T. Thunugunta, A. C. Reddy, and D. C. Lakshmana Reddy, "Green synthesis of nanoparticles: Current prospectus," *Nanotechnol. Rev.*, vol. 4, no. 4, pp. 303–323, 2015, doi: 10.1515/ntrev-2015-0023.

39. P. G. Kale, M. K. Sahoo, N. K. Sadual, and S. K. Behera, "Synthesis of Graphenewrapped Silicon Nanoparticles by Ultra-sonication," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 338, no. 1, 2018, doi: 10.1088/1757-899X/338/1/012034.

40. V. S. Vendamani, A. P. Pathak, and S. V. S. Nageswara Rao, "Blue luminescent silicon nanoparticles synthesized from free-standing porous silicon layer by ultrasonic treatment," *Opt. Mater. (Amst.)*, vol. 48, pp. 66–70, 2015, doi: 10.1016/j.optmat.2015.07.012.

41. S. Majumdar and P. Sujatha Devi, "Synthesis of SnO<sub>2</sub> nanoparticles using ultrasonication," *AIP Conf. Proc.*, vol. 1276, no. October 2010, pp. 1–7, 2010, doi: 10.1063/1.3504298.

42. M. Honarmand, M. Golmohammadi, and A. Naeimi, "Biosynthesis of tin oxide (SnO<sub>2</sub>) nanoparticles using jujube fruit for photocatalytic degradation of organic dyes," *Adv. Powder Technol.*, vol. 30, no. 8, pp. 1551–1557, 2019, doi: 10.1016/j.apt.2019.04.033.

43. F. F. Xia et al., "Preparation and characterization of Nano Ni-TiN coatings deposited by ultrasonic electrodeposition," *J. Alloys Compd.*, vol. 490, no. 1–2, pp. 431–435, 2010, doi: 10.1016/j.jallcom.2009.10.026.

44. K. Evans and M. D. Russell, "Short Communication," *Nematologica*, vol. 39, no. 1–4, pp. 411–414, 1993, doi: 10.1163/187529293X00358.

45. H. Veisi, M. Ghorbani, and S. Hemmati, "Sonochemical in situ immobilization of Pd nanoparticles on green tea extract coated Fe<sub>3</sub>O<sub>4</sub> nanoparticles: An efficient and magnetically recyclable nanocatalyst for synthesis of biphenyl compounds under ultrasound irradiations," *Mater. Sci. Eng. C*, vol. 98, no. December 2018, pp. 584–593, 2019, doi: 10.1016/j.msec.2019.01.009.

46. X. F. Qiu, J. Z. Xu, J. M. Zhu, J. J. Zhu, S. Xu, and H. Y. Chen, "Controllable synthesis of palladium nanoparticles via a simple sonoelectrochemical method," *J. Mater. Res.*, vol. 18, no. 6, pp. 1399–1404, 2003, doi: 10.1557/JMR.2003.0192.

47. N. Basavegowda, K. Mishra, and Y. R. Lee, "Ultrasonic-assisted green synthesis of palladium nanoparticles and their nanocatalytic application in multicomponent reaction," *New J. Chem.*, vol. 39, no. 2, pp. 972–977, 2015, doi: 10.1039/c4nj01543f.

48. S. Puri, B. Kaur, A. Parmar, and H. Kumar, "Copper Perchlorate Hexahydrate: An Efficient Catalyst for the Green Synthesis of Polyhydroquinolines under Ultrasonication," *ISRN Org. Chem.*, vol. 2011, pp. 1–4, 2011, doi: 10.5402/2011/948685.

49. D. N. Dasappa, G. N. Yallappa, and D. U. Chandrashekhar, "Green Synthesis of Pyrazolo [3,4]-Pyrimidine-thiones by using Ionic liquid 2-methyl-Imidazolium-Oxalate as Potent EAC receptor antagonists," *Turkish J. Pharm. Sci.*, vol. 12, no. 9, pp. 5–9, 2018, doi: 10.4274/tjps.14238.

50. A. K. Singh K., S. K. Shukla K., and M. A. Quraishi, "Ultrasound mediated Green synthesis of Hexa-hydro Triazines," *J. Mater. Environ. Sci.*, vol. 2, no. 4, pp. 403–406, 2011.

51. G. Shabir, I. Shafique, and A. Saeed, "Ultrasound assisted synthesis of 5–7 membered heterocyclic rings in organic molecules," *J. Heterocycl. Chem.*, pp. 0–2, 2022, doi: 10.1002/jhet.4527.

52. S. P. Sharma, N. Vashisht, and S. Kumar, "Ultrasound Promoted Green Synthesis of Chalcones of 3-Acetylcoumarin," *Chem. Sci. Trans.*, vol. 7, no. 3, pp. 396–401, 2018, doi: 10.7598/cst2018.1502.

53. H. H. Al-Rasheed, M. Al Alshaikh, J. M. Khaled, N. S. Alharbi, and A. El-Faham, "Ultrasonic Irradiation: Synthesis, Characterization, and Preliminary Antimicrobial Activity of Novel Series of 4,6-Disubstituted-1,3,5-triazine Containing Hydrazone Derivatives," *J. Chem.*, vol. 2016, 2016, doi: 10.1155/2016/3464758.

54. S. S. Rao, C. V. R. Reddy, and P. K. Dubey, "An Ultrasound Mediated Green Synthesis of Benzimidazolylthioureasaturated nitriles Using Water as a Green Solvent," *Org. Chem. Int.*, vol. 2014, pp. 1–5, 2014, doi: 10.1155/2014/403803.

55. P. Mahadik, D. Jagwani, and R. Joshi, "A Greener Chemistry Approach for Synthesis of 2,3-diphenyl quinoxaline," *IJISSET -International J. Innov. Sci. Eng. Technol.*, vol. 1, no. 6, pp. 482–490, 2014, [Online]. Available: [www.ijiset.com](http://www.ijiset.com)

56. A. P. G. Nikalje, S. I. Shaikh, and A. Pratima, "Ultrasound-Promoted Synthesis of Indole Appended Heterocycles," vol. 3, no. 4, pp. 1282–1302, 2014.

57. A. Gadhave, S. Kuchekar, and B. Karale, "Ultrasonication-Induced Synthesis and Antimicrobial Evaluation of Some Ultrasonicated Derivatives," vol. 2013, 2013.

58. S. Terbitan et al., "Malaysian Journal of Analytical Sciences Synthesis of Benzothiazole Derivatives Using Ultrasonic Probe Irradiation," *Malaysian J. Anal. Sci.*, vol. 21, no. 6, pp. 1219–1225, 2017.

59. N. Kaur, "Ultrasound-assisted green synthesis of five-membered O- and S-heterocycles," *Synth. Commun.*, vol. 48, no. 14, pp. 1715–1738, 2018, doi: 10.1080/00397911.2018.1460671.

60. N. Vashisht, S. P. Sharma, S. Kumar, and A. Yadav, "using dual - frequency ultrasonication," pp. 399–404, 2020.

61. W. A. A. Arafa, M. F. Fareed, S. A. Rabeh, and R. M. Shaker, "Ultrasound mediated green synthesis of rhodanine derivatives: Synthesis, chemical behavior, and antibacterial activity," *Phosphorus, Sulfur Silicon Relat. Elem.*, vol. 191, no. 8, pp. 1129–1136, 2016, doi: 10.1080/10426507.2016.1146276.

62. A. Ali, A. Ali, M. A. Bakht, and M. J. Ahsan, "Ultrasound promoted synthesis of N(substituted phenyl)-2-(7-hydroxy-4-methyl-2H-chromen-2-ylidene)hydrazine-1carboxamides as cytotoxic and antioxidant agents," *J. Mol. Struct.*, vol. 1238, p. 130452, 2021, doi: 10.1016/j.molstruc.2021.130452.

63. B. A. Bhanvase, A. Veer, S. R. Shirsath, and S. H. Sonawane, "Ultrasound assisted preparation, characterization and adsorption study of ternary chitosan-ZnO-TiO<sub>2</sub> nanocomposite: Advantage over conventional method," *Ultrason. Sonochem.*, vol. 52, pp. 120–130, 2019, doi: 10.1016/j.ultsonch.2018.11.003.

64. J. Jia, Y. Gai, W. Wang, and Y. Zhao, "Green synthesis of biocompatible chitosan-graphene oxide hybrid nanosheet by ultrasonication method," *Ultrason. Sonochem.*, vol. 32, pp. 300–306, 2016, doi: 10.1016/j.ultsonch.2016.03.027.

65. S. Kamble, A. Kumbhar, G. Rashinkar, M. Barge, and R. Salunkhe, "Ultrasound promoted efficient and green synthesis of  $\beta$ -amino carbonyl compounds in aqueous hydrotropic medium," *Ultrason. Sonochem.*, vol. 19, no. 4, pp. 812–815, 2012, doi: 10.1016/j.ultsonch.2011.12.001.

66. P. G. Kumdale and N. V. Shitole, "Synthesis of Pyrazole Compounds by Using Sonication Method," *Orient. J. Chem.*, vol. 38, no. 1, pp. 198–203, 2022, doi: 10.13005/ojc/380125.

67. J.-T. Li, S.-X. Wang, G.-F. Chen, and T.-S. Li, "Some Applications of Ultrasound Irradiation in Organic Synthesis," *Curr. Org. Synth.*, vol. 2, no. 3, pp. 415–436, 2005, doi: 10.2174/1570179054368509.

68. M. K. Kumar, P. S. Naik, Y. N. C. R. Babu, and A. S. Kumar, "Ultrasonic Studies of Nd<sup>3+</sup> : L-Tryptophan Amino Acid Complexes," vol. 7, no. February, pp. 159–162, 2014.

69. M. Esmaeilpour, J. Javidi, F. Dehghani, and F. Nowroozi Dodeji, "A green one-pot three-component synthesis of tetrahydrobenzo[b]pyran and 3,4-dihydropyrano[c]chromene derivatives using a Fe<sub>3</sub>O<sub>4</sub>@SiO<sub>2</sub>-imid-PMA magnetic nanocatalyst under ultrasonic irradiation or reflux conditions," RSC Adv., vol. 5, no. 34, pp. 26625–26633, 2015, doi: 10.1039/c5ra01021g.

70. J. Singh, T. Dutta, K. H. Kim, M. Rawat, P. Samddar, and P. Kumar, "'Green' synthesis of metals and their oxide nanoparticles: Applications for environmental remediation," J. Nanobiotechnology, vol. 16, no. 1, pp. 1–24, 2018, doi: 10.1186/s12951-018-0408-4.

71. E. K. Goharshadi, Y. Ding, M. N. Jorabchi, and P. Nancarrow, "Ultrasound-assisted green synthesis of nanocrystalline ZnO in the ionic liquid [hmim][NTf<sub>2</sub>]," Ultrason. Sonochem., vol. 16, no. 1, pp. 120–123, 2009, doi: 10.1016/j.ultsonch.2008.05.017.

72. P. Cerchier, M. Dabalà, and K. Brunelli, "Green synthesis of copper nanoparticles with ultrasound assistance," Green Process. Synth., vol. 6, no. 3, pp. 311–316, 2017, doi: 10.1515/gps-2016-0192.

73. S. Amaliyah, D. P. Pangesti, M. Masruri, A. Sabarudin, and S. B. Sumitro, "Green synthesis and characterization of copper nanoparticles using Piper retrofractum Vahl extract as bioreductor and capping agent," Heliyon, vol. 6, no. 8, p. e04636, 2020, doi: 10.1016/j.heliyon.2020.e04636.

74. Z. Hamami and V. Javanbakht, "Biosynthesis of copper oxide nanoparticles using biomass, peel, and extract polysaccharides of Solanum Tuberosum for ultrasound-assisted adsorption of azo direct red 80 contaminants," Ceram. Int., vol. 47, no. 17, pp. 24170–24181, 2021, doi: 10.1016/j.ceramint.2021.05.128.